Australian Government
Attorney-General's Department

REVIEW OF THE FIREFIGHTER PROVISIONS OF THE *SAFETY, REHABILITATION AND COMPENSATION ACT 1988*

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Terms of reference

The review will inquire into and report on whether the firefighter provisions of the *Safety, Rehabilitation and Compensation Act* 1988 (SRC Act) continue to be appropriate in light of developments in the scientific literature and any other new information, in particular whether:

- the qualifying periods for the current list of prescribed cancers should be reduced
- there are any further diseases that warrant inclusion in the list prescribed at subsection 7(8) of the SRC Act
- lung cancer in non-smokers should be included among the listed cancers and, if so, any appropriate qualifying conditions, and
- the presumption of liability for prescribed cancers should be expanded to include volunteer firefighters and, if so, any appropriate qualifying conditions.

The review will also consider if the determination process applied to claims by firefighters for the prescribed cancers continues to achieve the efficiencies intended by the firefighter provisions of the SRC Act.

Recommendations

No.	Recommendation
1	**The qualifying period for oesophageal cancer be reduced from 25 years to 15 years.**
2	**The current list of prescribed diseases at subsection 7(8) should be expanded to include malignant mesothelioma with a qualifying period of 15 years.**
3	**The Attorney-General's Department should continue to periodically examine the available scientific literature to ensure the list of prescribed diseases remains consistent with current science, with a particular focus on female reproductive cancers, malignant melanoma and lung cancer in non-smoking firefighters.**
4	**Lung cancer (whether in smokers or non-smokers) should not be included in the list of prescribed diseases.**
5	**The firefighter provisions of the SRC Act be extended to persons taken to be employed by the Australian Capital Territory by operation of a declaration made under subsection 5(15) of the SRC Act (volunteer firefighters).**
6	**Comcare should continue to investigate measures that provide more timely access to compensation for claimants under the firefighter provisions.**

The implementation of recommendations 1 and 5 require legislative amendment to the SRC Act. Recommendation 2 could be given effect to either by amendment to the SRC Act or the SRC Regulations.

Introduction

The *Safety, Rehabilitation and Compensation Amendment (Fair Protection for Firefighters) Act 2011* (the Firefighters Act) amended the disease provisions of the *Safety, Rehabilitation and Compensation Act 1988* (SRC Act) to streamline access to compensation for firefighters who contract any of the 12 prescribed diseases. The provisions apply to firefighters employed by the ACT Government, Airservices Australia and the Department of Environment and Energy. The provisions do not currently apply to volunteer firefighters in the ACT.

These provisions introduced a rebuttable presumption that the employment connection test was satisfied for firefighters suffering from a prescribed disease, sustained on or after 4 July 2011, and who meet certain qualifying requirements. If a firefighter or former firefighter meets these requirements, their employment is taken to have contributed, to a significant degree, to the contraction of the disease, unless the contrary is established. The list of prescribed diseases and their corresponding qualifying periods have not been amended since their commencement.

The purpose of this review (the review) was to examine the scientific evidence to determine if additional diseases should be included on the list of prescribed diseases, whether the qualifying periods remain appropriate or should be reduced and if the firefighter provisions should be extended to include volunteer firefighters. A further purpose of the review was to determine if the claims process for firefighters using the prescribed diseases provisions is operating as intended.

The firefighter provisions outline the qualifying periods an individual must be employed as a firefighter for that employment to be taken to have contributed, to a significant degree, to the individual suffering a disease listed in the provisions. The firefighter provisions do not require exposure to a particular substance, however they do require exposure to the hazards of a fire scene during the qualifying period. The qualifying periods under the firefighter provisions do not restrict a firefighter from making a disease claim in relation to a prescribed or non-prescribed disease in the ordinary way, including under subsections 7(1) using the specified diseases and employment instrument and 7(2) of the SRC Act. For example, it remains possible for a firefighter suffering from a prescribed disease who has not met the specified qualifying period to establish, on the balance of probabilities, that their condition was contributed to, to a significant degree, by their employment with the Commonwealth or a licensed corporation.

A previous review of the firefighters provisions of the SRC Act was undertaken by Ms Raelene Sharp and finalised on 24 December 2013 (2013 Review). This review aimed to assess whether the amendments were operating as intended and if the Firefighters Act had streamlined the determination of claims for firefighters seeking compensation for the prescribed diseases.

The 2013 Review made eight recommendations which the Government accepted in full and the current review fulfils the Government’s commitment to hold a further review after five years.

Review process

The Attorney-General’s Department (the department) has conducted the review relying on the Report of Dr Tim Driscoll (MBBS BSc(Med) MOHS PhD FAFOEM FAFPHM) (see Appendix A) and submissions received from stakeholders. Dr Driscoll is an independent consultant in epidemiology, occupational health and public health, a specialist in occupational medicine and public health medicine and a fellow of the Australasian Faculty of Occupational and Environmental Medicine and the Australasian Faculty of Public Health. Submissions to the review were received from:

- ACT Government
- ACT Volunteer Brigades Association
- Airservices Australia
- Anonymous
- Comcare
- Department of Veterans’ Affairs
- Hall Volunteer Rural Fire Brigade
- Liberal Members of the ACT Legislative Assembly
- United Firefighters Union of Australia

The Department of Enviroment and Energy was consulted and provided input to the review but did not provide a written submission.

The department offered to meet with stakeholders to discuss their submissions. No meetings were requested, although the department subsequently met with both Comcare and the ACT Government to discuss relevant findings and recommendations of the department’s draft report.

Dr Driscoll reviewed the current scientific literature, including studies cited by stakeholders, assessed the underlying methodology of relevant studies and provided a qualitative synthesis. Dr Driscoll has reported to the department on his findings in relation to the review’s first four terms of reference, whether:

- the qualifying periods for the current list of prescribed diseases should be reduced
- there are any further diseases that warrant inclusion in the list prescribed at subsection 7(8) of the SRC Act
- lung cancer in non-smokers should be included among the prescribed diseases and, if so, any appropriate qualifying conditions, and
- the scientific literature supports the presumption of liability for prescribed diseases under the SRC Act being extended to volunteer firefighters and, if so, any appropriate qualifying conditions.

Dr Driscoll’s report is provided in full at Appendix A. The department accepts the report’s findings and its recommendations.

The review also considers whether claims by firefighters for the prescribed diseases continues to achieve the efficiencies intended by the firefighter provisions of the SRC Act. The assessment of this matter is based on claims management data provided by Comcare.

The department acknowledges and thanks Dr Driscoll for his independent and rigorous report and all stakeholders for their participation and valuable contributions. The department has provided the report to the Hon Christian Porter MP, Attorney-General and Minister for Industrial Relations, for his consideration.

Structure of report

Each of the report's five terms of reference are considered separately in the body of the report with a short introduction or explanation where necessary.

'Stakeholder views' summarises the stakeholder submissions against the relevant term of reference to provide an understanding of their issues, concerns and expertise.

'Findings' refers to Dr Driscoll's findings and is a synthesis of his analysis taking stakeholder submissions into consideration. In two instances reference is made in this section to the department's findings and where this is the case, it has been clearly indicated.

Recommendations are made against the relevant term of reference, as well as summarised at the front of the report for ease of reference.

Qualifying periods

The review terms of reference asked whether the qualifying periods for the current list of prescribed diseases should be reduced. Qualifying periods for the purpose of subsection 7(8) of the SRC Act refer to the minimum period a firefighter must have been employed for before the prescribed disease was sustained.

The Safety, Rehabilitation and Compensation Amendment (Fair Protection for Firefighters) Bill 2011 (the original Bill) proposing the qualifying period provisions was introduced to Parliament by the Australian Greens Party. The basis for how the minimum qualifying periods were determined is unclear for the majority of the diseases included, however, provisions appear to be modelled on similar Canadian legislation that was in operation at the time.[1]

The Education, Employment and Workplace Relations Legislation Committee's review of the original Bill in 2011 resulted in several other cancers being added to the prescribed list in the Bill. These appear to be more closely based on the Canadian legislation. Other than possibly being based on the Canadian legislation, the scientific basis for these qualifying periods remains unclear.

As noted previously, it remains open for a firefighter suffering from a prescribed disease who has not met the specified qualifying period to establish, on the balance of probabilities, that their condition was contributed to in a significant degree by their employment. That is, the firefighter provisions do not remove or change the capacity for an employee to make a 'disease' claim in the ordinary way under the SRC Act.

Stakeholder views

Most stakeholders did not state a view on whether the qualifying periods should be reduced.

The Department of Veterans' Affairs (DVA) did not state a specific position on this issue but provided a range of studies and literature reviews it had previously commissioned, relevant to the review.[2]

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[1]Parliament, The Senate, *Safety, Rehabilitation and Compensation Amendment (Fair Protection for Firefighters) Bill 2011*, Senate Standing Committee on Education, Employment and Workplace relations, pp 5-6.
[2] Department of Veterans' Affairs, *Review of the Firefighter Provisions of the Safety, Rehabilitation Act 1988* (SRC Act), Department of Veterans' Affairs Submission, 2019.

Comcare noted that any proposed changes to current qualifying periods should be evidence-based. [3]

Findings

In his report, Dr Driscoll stated that 'there is very limited information in the published literature that provides guidance as to what a minimum exposure qualifying period should be and why this would vary between cancers' and 'there is no published evidence that provides useful guidance as to what the minimum qualifying periods should be for any of the cancers'.[4]

While Dr Driscoll found no evidence to support the specific length of the qualifying period prescribed for each disease, he also could not find any reason to justify why the qualifying period for oesophageal cancer should not be consistent with the other prescribed diseases. The qualifying period for oesophageal cancer is at least 10 years longer than for all other prescribed diseases. Accordingly, Dr Driscoll recommended that consideration be given to reducing the qualifying period for oesophageal cancer from 25 years to 15 years.[5]

Recommendation

1. **The qualifying period for oesophageal cancer be reduced from 25 years to 15 years.**

Additional diseases (excluding lung cancer)

The review terms of reference asked whether any further diseases warrant inclusion in the list prescribed at subsection 7(8) of the SRC Act, consistent with the 2013 Review recommendation to ensure the firefighter provisions reflect best practice globally. The inclusion of lung cancer is considered separately.

Stakeholder views

Most stakeholders did not state a view on whether additional diseases should be included in the list prescribed at subsection 7(8) of the SRC Act.

The United Firefighters Union of Australia (UFUA) submission argued that a number of diseases should be added to the current list of prescribed diseases, namely: stomach cancer, all skin cancers and melanoma.[6]

The UFUA submission further recommended that consideration be given to including female reproductive (ovarian and cervical) cancers on the list of prescribed diseases, on the basis that female career firefighters should not be disadvantaged by the lack of data that currently exists about the risks

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[3] Comcare, *Review of the firefighter provisions of the Safety, Rehabilitation and compensation Act 1988*, Comcare Submission, 2019.
[4] Driscoll, T., *op.cit.*, pp. 27-8.
[5] Ibid, p.28.
[6] Marshall, P.J., *United Firefighters Union of Australia Submission to the 2019 Review of the Safety, Rehabilitation and Compensation Amendment (Fair Protection for Firefighters) Act 2011*, United Firefighters Union of Australia Submission, 2019, p.2.

given there are too few female firefighters worldwide for conclusive scientific research to be conducted.[7]

Comcare stated that any change should be supported by evidence.[8]

Findings

Dr Driscoll found sufficient scientific literature to support the inclusion of malignant mesothelioma on the list of prescribed diseases.

Dr Driscoll noted that a number of studies identified an increased risk of contracting the disease compared to the comparison population, with the average increase being about 60%. Additionally, firefighters are known to have an increased level of exposure to asbestos, which is responsible for almost all cases of mesothelioma.[9] Dr Driscoll therefore recommended expanding the list of prescribed diseases to include malignant mesothelioma.[10]

Dr Driscoll was not asked to and did not recommend an appropriate qualifying period. Noting Dr Driscoll's finding above in relation to lack of evidence to support specific qualifying periods, and that a qualifying period is required for each prescribed disease, the department recommends that the qualifying period should be 15 years, consistent with that for most of the existing prescribed diseases.

Dr Driscoll also recommended consideration be given to the inclusion of malignant melanoma on the list of prescribed diseases, noting that, based on 11 incidence studies, firefighters were estimated to have a 21% increased risk of developing malignant melanoma compared to the comparison population.

Dr Driscoll noted that people are often screened for melanoma and firefighters may be more frequently screened than the general population, possibly leading to existing melanoma being more likely to be identified than in the general population, rather than reflecting a higher incidence rate in firefighters. He also noted that there is not enough evidence to suggest that firefighters are exposed to higher levels of ultra-violet radiation due to their work.[11] While recommending consideration being given to prescribing malignant melanoma, Dr Driscoll concluded that *'…..the lack of control of confounding by non-work-related solar-UV exposure, and the possible influence of greater levels of screening in firefighters, suggests the overall evidence for inclusion is not strong.'* On the basis of these observations, the department does not recommend including malignant melanoma on the list of prescribed diseases, however, recommends that the disease continues to be monitored for developments in the scientific literature.

Dr Driscoll determined that the scientific literature was not conclusive enough to support inclusion of additional cancers on the prescribed list. In relation to female reproductive cancers, the difficulty of securing an adequate evidence base to support inclusion of female reproductive cancers on the prescribed diseases list is acknowledged.

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[7] Ibid.
[8] Comcare, *op.cit*.
[9] Driscoll, T., *op.cit*., p.33.
[10] Ibid, p.33.
[11] Ibid, p.33.

The department considers that scientific literature should continue to be monitored to ensure the list of prescribed diseases remains current with scientific literature, including in relation to female reproductive cancers, malignant melanoma and lung cancer in non-smoking firefighters (findings in relation to lung cancer are discussed in the next section below). The department notes the Government announcement of 15 January 2020 which states it will provide $3 million in grant funding for research into the physiological impacts of prolonged bushfire smoke exposure[12], and considers this research, once completed, would form part of the scientific literature.

Recommendations

2. **The current list of prescribed diseases at subsection 7(8) should be expanded to include malignant mesothelioma with a qualifying period of 15 years.**
3. **The Attorney-General's Department should continue to periodically examine the available scientific literature to ensure the list of prescribed diseases remains consistent with current science, with a particular focus on female reproductive cancers, malignant melanoma and lung cancer in non-smoking firefighters.**

Lung cancer

The review terms of reference asked whether lung cancer in non-smokers should be included among the prescribed diseases and, if so, any appropriate qualifying conditions. The 2013 Review stated that research over coming years may support the inclusion of lung cancer for non-smokers on the prescribed list which, if included, would assist to continue streamlining the claims determination process for affected firefighters.

Stakeholder views

Most stakeholders did not state a view on whether lung cancer for non-smokers should be included in the list prescribed at subsection 7(8) of the SRC Act.

The UFUA supported the inclusion of lung cancer for non-smokers and suggested the department commence a process for defining the term 'non-smoker' for the purpose of lung cancer as a matter of urgency.[13]

The Hall Volunteer Rural Fire Brigade submission supported adding lung cancer to the list of prescribed diseases citing a recent American study on the mutagenicity and lung toxicity of wildland fires.[14]

Airservices Australia, although not advocating a position on whether lung cancer in non-smokers should be added to the list of prescribed diseases, considered that a 'non-smoker' definition should be included that takes into account passive smoking. Airservices Australia also suggested that the review

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[12] Hunt, G. (Minister for Health), *$5 million for bushfire related health research*. media release, Department of Health, Canberra, 15 January 2020, viewed 16 January 2020, https://www.health.gov.au/ministers/the-hon-greg-hunt-mp/media/5-million-for-bushfire-related-health-research.

[13] Marshall, *op.cit*., p.2.

[14] Kim, Y.H., et al., *Mutagenicity and Lung Toxicity of Smoldering vs Flaming Emissions from various Biomass Fuels: Implications for Health Effects from Wildland Fires*, Journal of Environmental Health Perspectives, 26 January 2018.

consider qualifying conditions that take into account that other factors can contribute to lung cancer, including exposure to carcinogens outside of work.[15]

Comcare considered any decision to add lung cancer for non-smokers to the list of prescribed diseases should be supported by evidence.[16]

Findings

Dr Driscoll reviewed current scientific literature and concluded that the evidence did not support that working as a firefighter increased the risk of developing lung cancer, in either smokers or non-smokers.[17]

In considering the study cited by the Hall Volunteer Rural Fire Brigade, which identified that burning wood, including eucalyptus wood, had mutagenic properties and could be harmful to people, Dr Driscoll concluded that the epidemiological evidence did not indicate that firefighters had an increased risk of contracting lung cancer.[18]

Dr Driscoll therefore recommended that lung cancer (whether in smokers or non-smokers) should not be included in the list of prescribed diseases.[19] The department accepts Dr Driscoll's recommendation. The inclusion of lung cancer in non-smoking firefighters should not be included on the list of prescribed diseases in the absence of evidence of an increased risk. The department therefore recommends that the scientific literature continue to be monitored for emerging evidence on the link between firefighting and the contraction of lung cancer in non-smokers

Recommendations

4. **Lung cancer (whether in smokers or non-smokers) should not be included in the list of prescribed diseases.**

Volunteer firefighters

The review terms of reference asked whether the presumption of liability for prescribed diseases should be expanded to include volunteer firefighters and, if so, any appropriate qualifying conditions.

The firefighter provisions of the SRC Act currently apply to all employees covered by the SRC Act, other than persons who are deemed to be employees of the Australian Capital Territory by operation of a declaration made under subsection 5(15) of the SRC Act. In practice, this means the presumption of liability for prescribed diseases for firefighters do not apply to volunteer firefighters of the Australian Capital Territory (ACT).

The SRC Act firefighter provisions were the first firefighter provisions to be legislated in Australia and similar provisions were subsequently adopted by all states and territories. However, unlike the SRC Act, the provisions adopted by states and the Northern Territory do apply to volunteer firefighters.

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[15] Harfield, J., *Submission to the Review of the firefighter provisions in the Safety, Rehabilitation and Compensation Act, 1988*, Airservices Australia, 29 April 2019.
[16] Comcare, *op.cit*.
[17] Ibid, p. 37.
[18] Ibid, p. 52.
[19] Driscoll, T., op.cit., pp.36-7.

Stakeholder views

Most stakeholders who expressed a view supported extending the presumption of liability for prescribed diseases to include volunteer firefighters. They were the Department of Environment and Energy, Hall Volunteer Rural Fire Brigade, ACT Volunteer Brigades Association (ACTVBA), ACT Government, Liberal Members of the ACT Legislative Assembly and a confidential submission.

The ACT, which is a self-insurer under Part VIII of the SRC Act, would be responsible for any additional cost associated with extending the workers' compensation firefighter provisions to the approximately 400 volunteer firefighters deemed to be employed by the ACT. The Act Government's submission stated that 'volunteer firefighters should have the opportunity to access the same workers' compensation cover provisions as their career counterparts...'.[20]

No stakeholders cited scientific studies to support their view, arguing instead on the basis that the anomaly for volunteer firefighters in the ACT is unfair. The ACTVBA stated that:

> Under the ACT Emergencies Act 2004 the main function of the Rural Fire Services is to protect and preserve life, property and the environment in rural areas. But the Act confers additional responsibilities on the Rural Fire Services for undertaking assistance operations to other services in rural areas, and the Service may be called upon to respond to fires in built up areas.[21]

The ACTVBA also identified that the volunteer brigade has a range of specialist equipment, including a Heavy Tanker and Compressed Air Foam vehicle, which have application across a range of incidents in urban areas from vehicle to industrial fires.[22]

The Hall Volunteer Rural Fire Brigade supported providing ACT volunteer firefighters with the same protections as volunteer firefighters in other jurisdictions or afforded to paid firefighters within the ACT. Furthermore, this provision should have retrospective application.

Airservices Australia noted that, as many paid firefighters are also volunteers, if the firefighter provisions included volunteers, they should also indicate how liability would be apportioned between paid and volunteer work.[23]

The UFUA considered that, if the provisions were extended to include volunteer firefighters, consideration be given to a tiered model for access to compensation, to preserve the integrity of the legislation, including establishing an independent review panel or committee to determine liability for the claim.[24]

Comcare noted that the standard SRC Act provisions cover volunteers.[25]

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[20] Stephen-Smith, R, *Review of the firefighter provisions of the Safety, Rehabilitation and compensation Act 1988*, ACT Government Submission, 2019.
[21] Pacey, B., *ACT volunteer Brigades Association submission to the review of the firefighter provisions of the Safety, Rehabilitation and Compensation Act 1988*, ACT Volunteer Brigades Association, 2019.
B, Henderson, T, Hazelton, *Hall Volunteer Rural Fire Brigade submission to the review of the firefighter provisions of the Safety, Rehabilitation and Compensation Act 1988*, Hall Volunteer Rural Fire Brigade, 2019.
[22] Ibid*.*
[23] Harfield, J., *op.cit.*
[24] Marshall, P.J., *op.cit.*, p.2.
[25] Comcare, *op.cit.*

Findings

Dr Driscoll's review of the available scientific literature found little research specifically relating to volunteer firefighters.

The evidence showed that few cancers had a higher incidence rate in volunteer firefighters compared to the general population. However, Dr Driscoll noted that volunteers can have some similar fire-related exposures as paid firefighters and may attend fires alongside paid firefighters. Dr Driscoll also noted the anomaly that the ACT volunteer firefighters are the only firefighters in Australia not covered by specific firefighter provisions.

While recognising the limited scientific evidence available in relation to diseases suffered by volunteer firefighters, the department notes that the SRC Act has the only firefighter-specific provisions in Australia that excludes coverage for a subset of volunteers (being ACT volunteer firefighters). In addition, the ACT supports extending the provisions to ACT volunteers. Given these factors, the department recommends that the provisions are extended to cover ACT volunteer firefighters.

Recommendation

5. **The firefighter provisions of the SRC Act be extended to persons taken to be employed by the Australian Capital Territory by operation of a declaration made under subsection 5(15) of the SRC Act (volunteer firefighters).**

Claims determination process

The terms of reference ask whether the claims determination process for claims by firefighters for the prescribed diseases continues to achieve the efficiencies intended by the Firefighters Act.

Stakeholder views

Most stakeholders did not express an opinion on whether the prescribed diseases are continuing to achieve the efficiencies intended by the Firefighters Act.

Comcare submitted that it had streamlined their claims determination process since the 2013 Review, which has resulted in a reduction in the average time taken to determine a claim by a firefighter for a prescribed cancer from 82 days in 2013 to 49 days (or 41 days if two outlier claims are excluded). Despite the 49 day average claim determination time comparing favourably with the 62 day average for all disease claims or the 119 day average for all cancers, Comcare acknowledged more work in this area could lead to a further reductions to timeframes for determinations and reconsiderations.[26]

The information provided by Comcare in relation to timeframes for claims determination shows that the provisions have had the desired effect of reducing the processing time of claims made by firefighters. However, Comcare acknowledged that additional work can be done to implement the 2013 Review recommendations to reduce claims determination timeframes further, and the department supports this view.

The UFUA did not identify inefficiencies in the claims determination process but considered that an information campaign would improve the awareness and understanding for a claimant and their family on how the scheme can be accessed, which is particularly important for terminal patients with a

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[26] Comcare, *op.cit*.

short life expectancy.[27] This review has not sought to measure the visibility of the firefighter provisions, however, the department agrees that employers and unions should take steps to ensure that firefighters are aware of the provisions.

Recommendation

6. **Comcare should continue to investigate measures that provide more timely access to compensation for claimants under the firefighter provisions.**

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[27] Marshall, P.J., *op.cit.*, p.13.

FIREFIGHTERS AND CANCER – REVIEW OF THE FIREFIGHTER PROVISIONS OF THE SAFETY, REHABILITATION AND COMPENSATION ACT 1988 (SRC ACT)

REPORT FOR THE ATTORNEY-GENERAL'S DEPARTMENT

TIM DRISCOLL

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BACKGROUND OF THE AUTHOR

This report was prepared by Dr Tim Driscoll (MBBS BSc(Med) MOHS PhD FAFOEM FAFPHM). Dr Driscoll is an independent consultant in epidemiology, occupational health and public health, and a specialist in occupational medicine and public health medicine who is a fellow of the Australasian Faculty of Occupational and Environmental Medicine and the Australasian Faculty of Public Health Medicine.

GLOSSARY

DVA	Department of Veterans' Affairs
HR	Hazard Ratio
IARC	International Agency for Research on Cancer
NHL	Non-Hodgkin's Lymphoma
OR	Odds Ratio
RR	International Agency for Research on Cancer
SIR	Standardised Incidence Ratio
SMOR	Summary Morbidity Odds Ratio
SMR	Standardised Mortality Ratio
sRE	Summary Risk Estimate

EXECUTIVE SUMMARY

Background

This report considers information in the peer-reviewed literature and which is relevant to an assessment of the risk of cancer arising from work as a firefighter, and formal external submissions to the review, to provide answers to four specific questions relevant to subsection 7(8) of the *Safety, Rehabilitation and Compensation Act 1988* (SRC Act):

a) whether the qualifying periods for the current list of prescribed cancers should be reduced;

b) whether there are any further diseases that warrant inclusion in the list prescribed at subsection 7(8) of the SRC Act;

c) whether lung cancer in non-smokers should be included among the listed cancers and, if so, any appropriate qualifying conditions;

d) whether the scientific literature supports the presumption of liability for prescribed cancers under the SRC Act being extended to volunteer firefighters and, if so, any appropriate qualifying conditions.

Approach

Relevant studies were identified through a comprehensive search of the published literature. The studies were critically appraised and the quality of each study assessed. The findings were summarized and their relevance to the Australian context considered but there was no formal attempt to synthesize the results. The key methodological issues and challenges in the studies were also considered. The four questions of interest were answered and responses prepared in regards to the four formal external submissions.

Findings

In terms of qualifying periods, there is no evidence that would support reducing the qualifying period for cancers. However, **it is recommended that consideration be given to simplifying the qualifying periods by decreasing the period for oesophageal cancer from 25 years to 15 years.** No other changes to the qualifying periods are proposed.

In terms of further diseases that warrant inclusion in the list, it is considered that malignant mesothelioma meets the requirements to be listed as a prescribed disease under the Act and that malignant melanoma should be considered for inclusion but probably does not meet the requirements of the Act because of the possible role of confounding and screening behaviour. **It is recommended that malignant mesothelioma be included in the list of prescribed cancers and that malignant melanoma be considered for inclusion.** Based on available information, no other cancers are considered to warrant inclusion in the list.

In terms of lung cancer in non-smokers, the most recent meta-risk estimates for lung cancer in firefighters were not raised, the confidence intervals were narrow and there was little evidence to examine whether risk might have changed with level of exposure (such as number of fires attended). Methodological shortcomings of many of the studies mean that the lack of an identified relationship should not be considered as definitive evidence of the lack of a true, underlying increased risk. However, the published evidence available currently does not suggest that work as a firefighter involves an increased risk of developing lung cancer in either smokers or non-smokers. **It is recommended that lung cancer (whether in smokers or non-smokers) not be included in the list.**

In terms of the presumption of liability for prescribed cancers under the SRC Act being extended to volunteer firefighters, the published evidence provides little support for volunteer firefighters to be included under the prescribed cancers section of the Act. However, it is noted that volunteer firefighters can be expected to have many of the same fire-related exposures as paid firefighters and might attend fires alongside paid firefighters covered by the prescribed cancers section of the Act, and that volunteer firefighters from many other jurisdictions are covered by an equivalent to the prescribed cancers section of the Act. **It is recommended that consideration be given to including volunteer firefighters under the prescribed cancers section of the Act. It is further recommended that if volunteer firefighters are included under the prescribed cancers section of the Act, consideration be given to using the same qualifying periods as used for paid firefighters.**

Conclusion

The findings of the report should support the overall review of the firefighter-related parts of the Act and evidence-based consideration of approaches to assessing the relationship between paid and volunteer work as a firefighter and the risk of developing cancer.

1. INTRODUCTION

The following information comes from the Terms of Reference for the review which is supported by the current report.

"On 7 December 2011, the *Safety, Rehabilitation and Compensation Amendment (Fair Protection for Firefighters) Act 2011* (the Firefighters Act) amended the disease provisions contained in section 7 of the Safety, Rehabilitation and Compensation Act 1988 (SRC Act). The SRC Act covers firefighters for the ACT Government, Airservices Australia and the Department of Environment.

The amendments introduced a presumption of liability for 12 prescribed cancers suffered by firefighters diagnosed on or after 4 July 2011, who meet certain qualifying requirements. The link between these cancers and firefighting was pivotal to the development of the legislation. The presumption of liability does not apply to volunteer firefighters, which reflected the state of scientific knowledge at the time the Firefighters Act was passed.

The Australian Government commissioned a review of the amendments made by the Firefighters Act that was undertaken by Raelene Sharp and finalised on 24 December 2013 (the 2013 Review[1]). The 2013 Review found that, based on the evidence available at the time, the list of prescribed cancers remained appropriate. However, it noted that the evidence was continuing to evolve, and recommended that the Government conduct a further review of the firefighter provisions in five years, to consider any further developments in the scientific literature.

The 2013 Review also recommended that the further review consider whether lung cancer in non-smokers should be included in the list of prescribed cancers and if the determination process for the prescribed cancers is achieving the efficiencies intended by the Firefighters Act.

The Government accepted these recommendations."

The project which is covered by this report required the reviewer to:

"…inquire into and report on whether the provisions of the SRC Act introduced by the Firefighters Act continue to be appropriate in light of developments in the scientific literature and any other new information, in particular whether:

a) the qualifying periods for the current list of prescribed cancers should be reduced;

b) there are any further diseases that warrant inclusion in the list prescribed at subsection 7(8) of the SRC Act;

c) lung cancer in non-smokers should be included among the listed cancers and, if so, any appropriate qualifying conditions;

d) the scientific literature supports the presumption of liability for prescribed cancers under the SRC Act being extended to volunteer firefighters and, if so, any appropriate qualifying conditions.

This report addresses these requirements. It provides an updated review of the epidemiological literature regarding the occurrence of and occupational risk factors for cancer in firefighters, with a focus on the relevance of these findings for Australian firefighters, and also addresses the specific requirements in regards to lung cancer in non-smokers and in terms of volunteer firefighters.

This report consists of eight chapters:

- Chapter 1 provides a brief Introduction
- Chapter 2 outlines the methods used
- Chapter 3 presents a review of relevant literature
- Chapter 4 presents consideration of the four questions of interest
- Chapter 5 presents a consideration of the four formal submissions made to the review
- Chapter 6 provides a consideration of the methods used in the project and their implications
- Chapter 7 provides a brief conclusion
- Chapter 8 contains the references cited in the document.

There are also three appendices:

- Appendix 1 provides some additional detail on the search for relevant publications;
- Appendix 2 provides a table which summarises the results from included studies;
- Appendix 3 provides a brief critical appraisal of each study included in the report.

2. METHODS

INTRODUCTION

This section summarises the methods used in this study. Additional information on the search strategy and its output are provided in Appendix 1.

INCLUDED DATABASES

Searches were undertaken of Medline (via Ovid), Web of Science, Scopus and EMBASE. No comprehensive search was undertaken of the grey literature.

SEARCH STRATEGY

Separate search strategies were developed for each database but they all used the same general approach. The approach was to identify all publications that contained information on firefighters and all publications that contained information on neoplasms. These two searches were combined to identify all studies that appeared in both searches. The search strategy was then refined to include only publications from 2006 onwards and only studies of humans. Originally a cut-off of 2013 was going to be used, to cover literature published after the 2013 review by Ms Sharp[1]. Using a cut-off of 2006 was chosen because a comprehensive systematic review published in 2006[2] covered all relevant literature published in prior years and some of the literature published from 2006 onwards was relevant to at least some of the specific review questions. The final searches were conducted in May 2019.

In addition to the database search, the reference list of each included paper was reviewed to identify any possibly relevant papers not identified by the database searches. Also, papers published prior to 2006 were included if considered of particular relevance.

Inclusion and exclusion criteria

The main inclusion criteria were full publications of peer-reviewed studies that examined cancer risk in firefighters relative to an unexposed population or a differently exposed population. Studies which compared firefighters with different levels of exposure were also included. Systematic reviews were also included as long as they provided some sort of numeric or semi-quantitative results.

There were a number of potentially relevant papers that arose from the World Trade Centre attacks in New York. These were excluded because the potential exposures involved were not likely to be typical of firefighters, either in the United States or in Australia. This exclusion was undertaken at the title review stage, not in the initial searches.

Excluded were:

- Studies that did not provide separate results for cancer
- Studies that did not provide separate results for firefighters
- Studies of 9/11 firefighters
- Studies without a clear comparison group
- Narrative reviews
- Opinion articles
- Studies published before 2006
- Studies that did not focus on humans
- Laboratory-based studies
- Proceedings of conferences.

Review process

Studies identified through searching any of the included databases were combined into a single Endnote file. All studies were reviewed by title and, if necessary, abstract. The full text version of studies that appeared to meet inclusion criteria, or for which there was some uncertainty, was examined and a final decision then made on inclusion or exclusion. For studies identified through review of reference lists, the full text version was also examined and a final decision made regarding inclusion or exclusion. While obtaining the full text of one identified article, two additional studies that appeared to meet the selection criteria, and both by the same author, were identified. These two publications were added to the search output and the full text versions of the papers considered. One of these studies was included and the other was not.

One person (the author) undertook all the searching and made the decisions regarding inclusion and exclusion.

Data extraction, critical appraisal and synthesis

The author critically appraised all included studies. For each study, a summary was prepared of the study aims, methodology and key results. This summary also described the identified key strengths and limitations of the methodology and the potential effect of the identified limitations on the study findings. The quality was rated Weak, Fair, Moderate or Strong, based on the critical appraisal, using the following as guidance in assigning the rating:

Weak: Clear major weakness in at least one of selection, measurement, control of confounding or analysis likely to lead to important bias.

Fair: Risk of major weakness in at least one of selection, measurement, control of confounding or analysis that could lead to important bias.

Moderate: Major weakness unlikely, but potential important weakness in one or more of selection, measurement, control of confounding or analysis that could lead to non-trivial bias.

Strong: No important areas of weakness; non-trivial bias unlikely.

The results from the included studies were then synthesized qualitatively. Separate synthesis was undertaken by cancer type and for cancers overall. The common strengths and limitations of the included studies were also considered and described.

3. RESULTS

INTRODUCTION

This chapter provides an overview of the mechanistic aspects of the literature search and then provides a consideration of the relevant data from the included papers. Information is presented for all cancers combined and then for individual cancers, with a focus on cancer types that are currently covered in Australia by firefighter presumptive legislation and other cancer types that were covered in many of the papers.

OUTCOME OF THE LITERATURE SEARCH

Seven hundred and ninety-four titles were identified in the combined searchers. Three hundred and eight of these were excluded as they were duplicates, leaving 486 unique titles. Another three studies were identified through review of reference lists (one) and by chance when searching for paper in Pubmed (two), resulting in 489 titles for review. Of these, 243 were clearly not relevant as they didn't involve firefighters; 78 didn't have an appropriate comparison group or have cancer as a measureable outcome (including one which was a narrative review article without useful numeric or other summary data); 64 only examined exposures; 32 focused on the aftermath of the 9/11 attacks on the World Trade Centre; 21 did not have cancer as an outcome; and 18 were not peer-reviewed journal articles (see Figure 1 in Appendix 1). That left 33 relevant papers – 19 cohort studies[3-21], six case-control studies[22-27] (one of these was a pooled study), one case-comparison study[28], six systematic reviews with meta-analyses[2, 29-33], and one systematic review without a meta-analysis[34].

GENERAL ASPECTS

Most of the identified studies were cohort studies, usually comparing a firefighter group to an external population using standardised methods. Some of these examined cancer mortality and most examined cancer incidence. Other study types were systematic reviews, mainly with an associated meta-analysis; case-control studies; and a case-comparison study.

Eight countries were covered by individual studies (Australia, Canada, Denmark, France, South Korea, Scotland, Sweden and the United States), one study covered the five Nordic countries[20] and the review studies covered a number of countries. Three studies were based in Australia – one in Queensland[9], one in Victoria[8] and three in Australia overall[10-12]. The earliest year covered was 1950[6, 7] and the most recent was 2019[12, 31]. Fourteen studies were of live cases[4, 9, 13, 15-18, 20-23, 25-27], four just of mortality[3, 5, 19, 28], and the remainder covered both morbidity and mortality. Most of the studies covered many cancer outcomes but some studies focussed on only one cancer type – lung cancer[23], prostate cancer[25, 26] and testicular cancer[34].

None of the studies was rated of high methodological quality, primarily due to concerns regarding bias arising from selection bias and/or confounding and the length of follow-up. Nineteen studies were rated as being of moderate quality[2, 5-7, 10-13, 16, 18-21, 23-25, 29-34], three as fair quality[3, 4, 22] and eight as weak quality[8, 9, 14, 15, 17, 26-28]. For each cancer type, the analysis presented in this chapter presents information on all studies regardless of quality and then focuses on studies of moderate quality. The numbers presented are point estimates, using whatever outcome measure(s) was used in the relevant study or studies.

ALL CANCERS

Twenty-one studies provided measures of all-cancer risk. Six of these identified a significantly increased risk, with estimates ranging from 1.04 to 1.19[7, 10, 19, 20, 28, 33]. Another six studies identified a significantly decreased risk, with estimates ranging from 0.40 to 0.86[3, 8, 11, 14, 16, 17]. For the remaining nine studies, the confidence interval of each risk estimate crossed one[2, 4-6, 9, 12, 13, 18, 31]. The studies were conducted in many different countries. Three were meta-analyses[2, 31, 33] and all but one of the remainder were cohort studies.

Including only studies of moderate quality, there were five studies (including one study of Australian firefighters[10]) that identified a significantly increased risk (ranging from 1.04 to 1.12)[7, 10, 19, 20, 33]; two studies (including one study of Australian firefighters[11]) that found a significantly decreased risk (0.81 and 0.86[11, 16]); and six studies (including one study of Australian firefighters[12])in which the confidence intervals crossed one[2, 5, 6, 12, 13, 18, 31].

Bladder cancer

Twenty-one studies provided measures of the risk of bladder cancer. Six of these identified a significantly increased risk, with estimates ranging from 1.12 to 1.68[4, 7, 17, 29, 31, 33]. One study, of Australian male volunteers, identified a significantly decreased risk, with an estimate of 0.86[11]. The remaining 14 studies did not identify a significantly increased or decreased risk of bladder cancer, with the confidence interval of each risk estimate crossing one[2, 5, 6, 9, 10, 12-15, 18-20, 22, 27]. The studies were conducted in a range of countries. Four were meta-analyses[2, 29, 31, 33], two were case-control studies[22, 27] and the remainder were cohort studies.

Including only studies of moderate quality, there was only a single cohort study (SIR=1.12)[7] and three meta-analyses[29, 31, 33] (summary estimates ranged from 1.12 to 1.68) that identified a significantly increased risk. There was also one study (an Australian study) that identified a significantly decreased risk (SIR=0.60)[11]. Nine of the studies that did not identify a significantly increased or decreased risk were of moderate quality[2, 5, 6, 10, 12, 13, 18-20]. This included two studies of Australian firefighters[10, 12].

Brain cancer

Seventeen studies provided measures of the risk of brain cancer. Five of these identified a significantly increased risk, with estimates ranging from 1.32 to 1.90[2, 15, 22, 27, 28]. For the remaining 11 studies, the confidence interval of each risk estimate crossed one[4, 7, 9-14, 17, 18, 20]. The studies were conducted in many different countries. Two of the studies were meta-analyses[2, 31], two were case-control studies[22, 27], one was a case-comparison study[28] and the remainder were cohort studies.

Including only studies of moderate quality, there were no primary studies that identified a significantly increased risk, just one meta-analysis[2]. Eight of the studies that did not identify a significantly increased or decreased risk were of moderate quality[7, 10-13, 18, 20]. This included three studies of Australian firefighters[10-12].

Breast cancer

Ten studies provided measures of the risk of breast cancer[5, 7, 10-13, 15, 17, 28, 31]. None of these identified significantly increased or decreased risk. One was a meta-analysis[31], one was a case-comparison study[28] and the remainder were cohort studies. Seven of the studies were of moderate quality[5, 7, 10-13, 31] (three were Australian-based[10-12]) and the remaining three were rated as weak.

Colorectal cancer

Eighteen studies provided measures of the risk of colorectal cancer. The results presented here under the heading 'colorectal cancer' cover the outcomes colon cancer, rectal cancer, colorectal cancer and other sites of bowel cancer, with different studies including one or more of these or a combination of them. Five studies identified a significantly increased risk, with estimates ranging from 1.14 to 1.36[2, 4, 7, 15, 31]. Two studies found a significantly decreased risk (0.63 and 0.85)[6, 11]. For the remaining 14 studies, the confidence interval of each risk estimate crossed one[4, 5, 9, 10, 12-14, 16-20, 22, 27]. The studies were conducted in many different countries. Two of the studies were meta-analyses[2, 31], two were case-control studies[5, 27] and the remainder were cohort studies.

Including only studies of moderate quality, there was one cohort study (SIR=1.31)[7] and two meta-analyses[2, 31] that identified a significantly increased risk; two studies (including one study of Australian firefighters[11]) that found a significantly decreased risk (0.63 and 0.85)[6, 11]; and eight studies (including two studies of Australian firefighters[10, 12]) in which the confidence intervals crossed one[5, 10, 12, 13, 16, 18-20].

Kidney cancer

Twenty studies provided measures of the risk of kidney cancer. Six of these identified a significantly increased risk, with estimates ranging from 1.27 to 2.07[4, 7, 14, 27, 28, 33]. For the remaining 14 studies, the confidence interval of each risk estimate crossed one[2, 5, 9-13, 15-18, 20, 22, 31]. The studies were conducted in many different countries. Three of the studies were meta-analyses[2, 31, 33], two were case-control studies[22, 27], one was a case-comparison study[28] and the remainder were cohort studies.

Including only studies of moderate quality, there was one cohort study (SIR=1.27)[7] and one meta-analysis[33] that identified a significantly increased risk and ten studies (including three studies of Australian firefighters[10-12]) in which the confidence intervals crossed one[2, 5, 10-13, 16, 18, 20, 31]. In one of the Australian studies[10], an internal analysis found an increased risk in persons who had worked ten or more years compared to firefighters who had worked less than ten years.

LEUKAEMIA

Eighteen studies provided measures of the risk of leukaemia. Two of these identified a significantly increased risk (1.45 and 1.32)[6, 27]. For the remaining 16 studies, the confidence interval of each risk estimate crossed one[2-4, 7, 9-13, 15-18, 20, 22, 31]. The studies were conducted in many different countries. Two of the studies were meta-analyses[2, 31], two were case-control studies[22, 27] and the remainder were cohort studies.

Including only studies of moderate quality, there was one study that identified a significantly increased risk (HR=1.45)[6] and ten studies (including three studies of Australian firefighters[10-12]) in which the confidence intervals crossed one[2, 7, 10-13, 16, 18, 20, 31].

MULTIPLE MYELOMA

Fourteen studies provided measures of the risk of multiple myeloma. Two of these identified a significantly increased risk (1.35 and 1.53)[2, 27]; one identified a significantly decreased risk (0.75)[11]; and for the remaining 11 studies the confidence interval of each risk estimate crossed one[7, 9, 10, 12, 13, 15, 16, 18, 20, 30, 31]. The studies were conducted in many different countries. Three of the studies were meta-analyses[2, 30, 31], one was a case-control study[27] and the remainder were cohort studies.

Including only studies of moderate quality, there was one study (a meta-analysis) that identified a significantly increased risk (sRE=1.53)[2]; one study (a study of Australian firefighters) that identified a significantly decreased risk (0.75)[11]; and nine studies (including two studies of Australian firefighters[10, 12]) in which the confidence intervals crossed one[7, 10, 12, 13, 16, 18, 20, 30, 31].

Non-Hodgkin's Lymphoma

Nineteen studies provided measures of the risk of Non-Hodgkin's Lymphoma cancer. Five of these identified a significantly increased risk, with estimates ranging from 1.21 to 1.69[2, 4, 30, 31, 33]. One study identified a significantly decreased risk (0.83)[11]. For the remaining 13 studies, the confidence interval of each risk estimate crossed one[6, 7, 9-13, 15-18, 20, 22, 27]. The studies were conducted in many different countries. Four of the studies were meta-analyses[2, 30, 31, 33], two were case-control studies[22, 27] and the remainder were cohort studies.

Including only studies of moderate quality, there were four studies that identified a significantly increased risk – all were meta-analyses (the summary risks estimates (sREs) ranged from 1.21 to 1.51)[2, 30, 31, 33]. One study (a study of Australian firefighters[11]) identified a significantly decreased risk (0.83). In the remaining eight studies (two of which were studies of Australian firefighters[10, 12]) the confidence intervals crossed one[6, 7, 10, 12, 13, 16, 18, 20]. One of the Australian studies included an internal analysis which found an increased risk in persons who had worked for a longer period of time, with the risk in firefighters who had worked for 20 or more years about three times that of firefighters who had worked for less than 10 years[10].

Oesophageal cancer

Eighteen studies provided measures of the risk of oesophageal cancer. Three of these identified a significantly increased risk, with estimates ranging from 1.48 to 1.85[7, 22, 27]. One study identified a significantly decreased risk (0.65)[11]. For the remaining 14 studies, the confidence interval of each risk estimate crossed one[2, 4-6, 9, 10, 12, 13, 15-18, 20, 31]. The studies were conducted in many different countries. Two of the studies were meta-analyses[2, 31], two were case-control studies[22, 27] and the remainder were cohort studies.

Including only studies of moderate quality, there was one study that identified a significantly increased risk (SIR=1.62)[7]. One study (a study of Australian firefighters[11]) identified a significantly decreased risk (0.83) and ten studies (including two studies of Australian firefighters[10, 12]) in which the confidence intervals crossed one[2, 5, 6, 10, 12, 13, 16, 18, 20, 31].

Prostate cancer

Twenty-four studies provided measures of the risk of prostate cancer. Twelve of these identified a significantly increased risk, with estimates ranging from 1.08 to 1.67[2, 10, 11, 13, 20-22, 26, 27, 30-32]. Four studies identified a significantly decreased risk, with estimates ranging from 0.54 to 0.68[5, 6, 16, 19]. For the remaining eight studies, the confidence interval of each risk estimate crossed one[4, 7, 9, 10, 15, 17, 18, 25]. The studies were conducted in many different countries. Four of the studies were meta-analyses[2, 30-32], four were case-control studies[22, 25-27] and the remainder were cohort studies.

Including only studies of moderate quality, there were nine studies (including two studies of Australian firefighters[10, 11]) that identified a significantly increased risk (ranging from 1.08 to 1.31)[2, 10, 11, 13, 20, 21, 30, 32]; four studies that found a significantly decreased risk (ranging from 0.54 to 0.68)[5, 6, 16, 19] and three studies in which the confidence intervals crossed one[7, 18, 25].

Testicular cancer

Eighteen studies provided measures of the risk of testicular cancer. Five of these identified a significantly increased risk, with estimates ranging from 1.38 to 2.02[2, 17, 22, 30, 31]. One study found a decreased risk (SIR=0.51)[20] and for the remaining 12 studies, the confidence interval of each risk estimate crossed one[7-11, 13-16, 18, 27, 28]. The studies were conducted in many different countries. Three of the studies were meta-analyses[2, 30, 31], two were case-control studies[22, 27], one was a case-comparison study[28] and the remainder were cohort studies.

Including only studies of moderate quality, there were three studies, all meta-analyses, that identified a significantly increased risk (1.38 to 2.02)[2, 30, 31]; one study that found a significantly decreased risk (SIR=0.51)[20] and six studies (including two studies of Australian firefighters[10, 11]) in which the confidence intervals crossed one[7, 10, 13, 16, 18].

Ureteric cancer

None of the identified studies examined the risk of ureteric cancer.

Hodgkin's lymphoma

Ten studies provided measures of the risk of Hodgkin's Lymphoma. One of these identified a significantly increased risk (HR=2.89)[13]. For the remaining nine studies, the confidence interval of each risk estimate crossed one[2, 10-12, 16-18, 27, 31]. The studies were conducted in many different countries. Two were meta-analyses[2, 31], one was a case-control study[27] and the remainder were cohort studies.

Including only studies of moderate quality, there was one study that identified a significantly increased risk (HR=2.89)[13] and seven studies (including three studies of Australian firefighters[10-12]) in which the confidence intervals crossed one[2, 10-12, 16, 18, 31].

Lung cancer

Twenty-two studies provided measures of the risk of lung cancer. Four of these identified a significantly increased risk, with estimates ranging from 1.12 to 2.01[6, 7, 20, 27]. Another five studies identified significantly decreased risk, with estimates ranging from 0.48 to 0.86[3, 5, 10, 11, 17]. For the remaining 13 studies, the confidence interval of each risk estimate crossed one[2, 4, 9, 12-16, 18, 19, 22, 23, 31]. The studies were conducted in many different countries. Two of the studies were meta-analyses[2, 31], three were case-control studies[22, 23, 27] and the remainder were cohort studies.

Including only studies of moderate quality, there were three studies that identified a significantly increased risk (ranging from 1.12 to 1.39)[6, 7, 20], three studies (including two studies of Australian firefighters[10, 11]) that found a significantly decreased risk (0.48 to 0.86)[5, 10, 11] and eight studies in which the confidence intervals crossed one[2, 12, 13, 16, 18, 19, 23, 31].

Malignant melanoma

Fifteen studies provided measures of the risk of malignant melanoma. Nine of these identified a significantly increased risk, with estimates ranging from 1.21 to 1.75[2, 10, 12-14, 20, 22, 27, 31]. Two studies identified a significantly decreased risk (0.30 to 0.65)[15, 16] and for the remaining three studies the confidence interval of each risk estimate crossed one[8, 9, 18]. The studies were conducted in many different countries. Two of the studies were meta-analyses[2, 31], two were case-control studies[27] and the remainder were cohort studies.

Including only studies of moderate quality, there were six studies (including two studies of Australian firefighters[10, 12]) that identified a significantly increased risk (ranging from 1.21 to 1.67)[2, 10, 12, 13, 20, 31]; one study that found a significantly decreased risk (SIR=0.30)[16]; and two studies (including one study of Australian firefighters[11]) in which the confidence interval crossed one[11, 18].

Malignant mesothelioma

Ten studies provided measures of the risk of malignant mesothelioma. Two of these identified a significantly increased risk (1.60 and 2.29)[7, 31]. One study identified a significantly decreased risk (0.64)[11]. For the remaining seven studies, the confidence interval of each risk estimate crossed one[10, 12, 13, 16, 18, 20, 27]. The studies were conducted in many different countries. One study was a meta-analysis[31], one was a case-control study[27] and the remainder were cohort studies.

Including only studies of moderate quality, there was one study that identified a significantly increased risk (SIR=2.29)[7]; one study (a study of Australian firefighters) that identified a significantly decreased risk (0.64)[11]; and six studies (including two studies of Australian firefighters[10, 12]) in which the confidence intervals crossed one[10, 12, 13, 16, 18, 20].

Stomach cancer

Nineteen studies provided measures of the risk of stomach cancer. Three of these identified a significantly increased risk, with estimates ranging from 1.22 to 1.96[2, 16, 19]. Two studies identified a significantly decreased risk (0.50 and 0.69)[11, 17]. For the remaining 14 studies, the confidence interval of each risk estimate crossed one[3-5, 7, 9, 10, 12, 13, 15, 18, 20, 22, 27, 31]. The studies were conducted in many different countries. Two of the studies were meta-analyses[2, 31], two were case-control studies[22, 27] and the remainder were cohort studies.

Including only studies of moderate quality, there were three studies (one of which was a meta-analysis[2]) that identified a significantly increased risk (ranging from 1.22 to 1.96)[2, 16, 19]; one study (a study of Australian firefighters) that identified a significantly decreased risk (0.69)[11]; and eight studies (including two studies of Australian firefighters[10, 12]) in which the confidence intervals crossed one[5, 7, 10, 12, 13, 18, 20].

NON-MELANOMA SKIN CANCER

Seven studies provided measures of the risk of non-melanoma skin cancer. Two of these identified a significantly increased risk (1.33 and 1.39)[2, 20]. For the remaining five studies, the confidence interval of each risk estimate crossed one[5, 14, 17, 18, 31]. The studies were conducted in many different countries. Two of the studies were meta-analyses[2, 31] and the remainder were cohort studies.

Including only studies of moderate quality, there were two studies (one of which was a meta-analysis[2]) that identified a significantly increased risk (1.33 and 1.39)[2, 20] and three studies in which the confidence intervals crossed one[5, 18, 31].

THYROID CANCER

Thirteen studies provided measures of the risk of thyroid cancer. Two of these identified a significantly increased risk (1.22 and 1.77)[17, 31]. For the remaining 11 studies, the confidence interval of each risk estimate crossed one[4, 8, 10-13, 15, 18, 20, 22, 27]. The studies were conducted in many different countries. One of the studies was a meta-analysis[31], two were case-control studies[22, 27] and the remainder were cohort studies.

Seven of the studies were of moderate quality. One, a meta-analysis, identified a significantly increased risk (1.22)[31]. The remaining six (three of which were studies of

Australian firefighters[10-12]), had estimates of effect in which the confidence intervals crossed one[10-13, 18, 20].

All lymphopoeitic cancer

Ten studies provided measures of the risk of all lymphopoeitic cancer. None identified a significantly increased risk. Two identified significantly decreased risk (0.68 and 0.81)[11, 17]. For the remaining eight studies, the confidence interval of each risk estimate crossed one[3-5, 10, 12, 16, 19, 28]. The studies were conducted in many different countries. One of the studies was a case-comparison study[28] and the remainder were cohort studies.

Six of the studies were of moderate quality. One study of Australian firefighters identified a significantly decreased estimate (0.81)[11]. The remaining five (two of which were studies of Australian firefighters[10, 11]), had estimates of effect in which the confidence intervals crossed one[5, 10, 11, 16, 19].

Other cancers

Measures of risk for several other cancer types were provided by one or a small number of studies for each cancer type (18 studies in total)[2, 7, 10-20, 22, 24, 27, 28, 31]. These are not documented in detail here.

Strengths and limitations of included studies

Cohort studies comparing to external populations

Most of the cohort studies were limited by problems with the comparison group and an inability to control for potentially important confounding factors.

As mentioned, most of the identified studies were cohort studies and nearly all of these used a standardised approach, comparing a firefighter cohort to an external population using standardised methods. Some of these examined cancer mortality and most examined cancer incidence. Standardised studies have several important potential weaknesses. The first concerns selection bias. Selection bias refers to errors in the study results due to the way people are selected into the study or leave the study prior to analysis. In the firefighter studies, the main selection issue is the group to which firefighters were compared. In most studies the comparison was the general community. The general community can be expected to be less healthy than firefighters, because firefighters need a high level of fitness to be considered able to undertake their duties. This means that for many conditions, firefighters would be expected to have a lower rate than the general community apart from any influence of firefighting. This is the well-known ‘healthy worker effect’. A better comparison group for firefighters would be workers undertaking jobs requiring a similar level of fitness but which don’t involve the same exposures as firefighters. Unfortunately, the available studies did not have such a comparison group. A result of the healthy worker effect is that an increased risk of a condition (such as cancer) might be masked if the risk is increased compared to the risk firefighters would have had if they weren’t exposed to work as a firefighter, but not increased enough to appear different to the risk in the general community.

In addition, firefighters might well have had a lower exposure than people in the comparison group to important lifestyle and other factors (known as ‘potential confounding factors’) that are known to increase the risk of cancer. This would tend to lead to an underestimate of the risk of cancer associated with exposure arising from work as a firefighter. Alternatively, firefighters could have worked in other occupations with exposure to carcinogens, or might have more common or higher exposure to some important lifestyle factors than the general population. This would tend to lead to an overestimate of the risk of cancer associated with exposure arising from work as a firefighter.

Control of confounding

Confounding describes the situation where an exposure that increases (or decreases) the risk of developing the outcome is more common in one exposure group than another. This results in the measure of the effect of the exposure (which in the firefighter studies is usually the relative risk or equivalent) being biased; that is, being lower or higher than it really it is. This confounding effect can be controlled for in several ways but sometimes is not possible or is not done.

The standardised approach described above doesn't allow differences in potential confounding factors to be taken account, with the exception of a few factors such as age, gender and calendar period. Depending on the distribution of the factors between the firefighters and the general population, this could lead to an overestimate or an underestimate, of the risk of cancer associated with exposure arising from work as a firefighter. Many potentially important confounding factors, such as smoking, alcohol use, other lifestyle factors and previous occupation, typically cannot be measured and controlled for in such studies. Some such factors were included in a small number of studies, usually those using a case-control design.

Gender

Nearly all of the studies included only male firefighters or presented results only for male firefighters. This was usually because of the low number of female firefighters and the low number of female firefighters with cancer, which made the analysis of risks for females too imprecise to be useful. The main exception was the study of female volunteer firefighters[12], but this study was hampered by a relatively short period of follow-up.

Power and sample size

In an epidemiological study, power refers to the ability of a study to identify a true effect if that effect exists. Specifically in terms of cancer in firefighters, power refers to the likelihood that a true increase (or decrease) in the risk of cancer in firefighters would be able to be identified. The power of a study is determined by the sample size of the study (i.e. the number of participants included in the study) and the proportion of people who develop the outcome. Power increases with bigger sample sizes and higher proportions of the subjects developing the outcome of interest. The power of the study is indicated by the width of the confidence intervals. The confidence interval is essentially the range in which the true value probably lies. Usually the confidence interval is a 95% confidence interval, which essentially means it is the range in which the true value probably lies, with 95% confidence (i.e. the true value could be higher or lower than the interval five per cent of the time). If this confidence interval does not include one (that is, if it is entirely above or below one), this implies that the exposure of interest (in this instance firefighting) truly does increase (or decrease) the risk of developing the outcome (in this instance lung cancer). In this situation the estimate is described as being "statistically significant". Studies with a low number of subjects or low number of cases will have low power and poor precision. This is reflected in wide confidence intervals around the study estimate of effect and a poor ability to accurately identify the true risk of cancer in the firefighter group in relation to a comparison group. In such studies, a failure to identify an increased (or decreased) risk might reflect the small sample size and the low number of cases rather than an absence of an increased (or decreased) risk.

A considerable number of the available studies on firefighters and cancer risk were limited by having low power due to a limited number of subjects and/or a low number of subjects with cancer.

Follow-up time and latency

Several of the studies were limited because of a limited follow-up and/or the young age of subjects.

Most cancers have a long period of time between when someone is first exposed and when they are diagnosed with a cancer that arises due to that exposure. This is known as the latency. For solid cancers (such as brain cancer or lung cancer), the latency is generally considered to be at least five years and more commonly 15 to 20 years or more. For haematological cancers, the latency is probably shorter, but of the order of several years as a minimum and more commonly at least 10 to 15 years or more. Therefore, to identify cancers that might arise as a result of exposures related to firefighting, it is necessary to follow the firefighters for several decades, and the longer the better. Shorter periods of follow-up are likely to result in an underestimate of any increased risk associated with firefighting.

Age

Related to the latency issue is the age of the subjects. Cancer in adults (with a few exceptions) becomes more common with age, the incidence increasing considerably after about the age of 60 years. Higher underlying cancer rates make it easier to identify true differences between the exposed and comparison populations. Therefore, studies that include subjects in their 60s, 70s and 80s are more useful for identifying or excluding differences in cancer rates than are studies that only or mainly include young people.

Measures of exposure

All of the studies were limited by a lack of direct exposure measures and only a few had even indirect measures of exposure.

It is not known what aspect of firefighting is the cause of any increased cancer risk in firefighters, if such an increased risk exists. However, exposures associated with direct firefighting (such as smoke and fumes) are thought to be the most likely relevant hazards. Any increased risk is likely to be greater with greater exposure. So, cumulative exposure is usually presumed to be the most relevant measure of exposure. None of the identified studies had single or cumulative measures of smoke, fume or associated hazards present at a fire. Duration of service was a general measure used as a proxy of cumulative exposure in some studies. One study used three better, but still indirect, measures – "the number of days worked in a job or location that had a potential for occupational exposure"; attendance at fires; and a measure considered equivalent to time spent at a fire and so assumed to be the best measure of cumulative exposure to fire-related carcinogens[6].

Cumulative exposure

Most of the studies probably had the vast majority of subjects with sufficient duration of employment as a firefighter, and thus sufficient cumulative exposure, to be able to be usefully included in a study of cancer risk related to firefighting.

As mentioned, risk is likely to increase with greater total (cumulative) exposure. Cumulative exposure is likely to be directly proportional to the duration of employment as a firefighter and the amount of fire-related activity while employed. There is likely to be a minimum exposure below which any increased risk of cancer, if it was associated with the exposure, would be too small to be identified. With no direct measure of exposure, and no data available for most studies about level of fire-related activity, nearly all studies relied on measures of duration of employment. Therefore, it is appropriate to have a minimum threshold for duration of employment as a firefighter before subjects are included in a study.

Unfortunately, what that minimum exposure should be is not known. Some studies did not use a minimum, some used a minimum of three months and some used a minimum of one year. Most studies provided information on duration of exposure of the subjects. Based on this information it appears likely the vast majority of subjects had considerably more than one year of service as a firefighter.

Measures of outcome

Nearly all studies had good measures of the outcome (cancer), with the proviso about screening, mentioned in the next section.

Nearly all studies obtained information on the presence and type of cancer from cancer registries and/or death registries or their equivalent. This information in terms of the presence and type of cancer is likely to have been accurate, given the high coverage of the government agencies that supplied the data and the high quality of their data.

Screening

A concern for many studies was the issue of screening, particularly for prostate cancer and melanoma. Both types of cancer have been the subject of widespread screening behaviour in the last one to two decades. If one population undertakes more screening than another, an observed higher incidence may be due to increased detection through screening in that population rather than to a true increased incidence resulting from a particular exposure.

The authors of papers where screening might have been an issue generally argued that screening for prostate cancer or melanoma was not a routine part of firefighter medical care and was not recommended to them and that therefore increased screening should not have been a cause of an apparent increased incidence. However, that doesn't exclude the possibility that firefighters organised their own screening or that their doctors proposed such screening. This is especially the case if either the firefighters or their doctors were aware of results from previous studies that suggested an increase in risk of prostate cancer and melanoma. This issue is a concern for all studies that identified an increased risk of prostate cancer or melanoma in firefighters compared to an external population. It should be less of a concern for internal analyses, where all subjects were firefighters and the comparison was between firefighters with different levels of exposure. However, such internal analyses were not common in the included studies.

Measures of potential confounders

The measurement of potential confounders that were typically included in studies of firefighters and cancer (age, gender and year) is likely to have been accurate because they are unambiguous. So, little error in the studies is expected to have arisen from this aspect.

As mentioned earlier, most studies did not include many of the important potential confounders. Important potential confounders such as smoking, alcohol use, other lifestyle factors and previous occupation were included in a small number of studies. The information about these typically came from self-report and so were subject to inaccuracies, either related to the presence of the outcome or just through difficulty for the subject to accurately recall and/or report. The extent and effect of any such error in measurement is hard to determine and is only relevant to the studies that included these types of variables in the analysis, which typically was the case-control studies.

Morbidity versus mortality

Most of the included studies focussed on just incident cases of cancer or both incident and fatal cases. A small number included only fatal cases. In general, cancer is better studied using incident cases rather than just fatal cases, because many people develop cancer but do not die from it. Focussing on fatal cases therefore limits the number of cases that will be identified. It might also produce a misleading or incomplete understanding of the exposure-cancer risk relationship if the exposures or associated factors resulting in fatal cases of cancer are different to those that result in non-fatal cancer.

Professional versus volunteer firefighters

Some of the included studies had volunteers among their subjects but most did not. Where volunteers were included, they typically only comprised a small proportion of the subjects and/or results comprising only the professional firefighters were presented in the papers and were used in the current report. Only two papers focussed on volunteer firefighters. Both were Australian studies, one of male volunteer firefighters[11] and one of female firefighters[12], with volunteer firefighters comprising the vast majority of the cohort and only the results for volunteer firefighters presented in this report. None of the results presented in this report from other studies were based on significant proportions of volunteers and most did not include any volunteer firefighters.

Relevance to the Australian context

The reviewed studies were based on firefighters from a number of different countries. All were developed countries and the studies primarily included urban firefighters. None of the studies had measures of the specific exposures of concern but all stated or strongly implied that the relevant exposures were those that occurred when attending fires, during the fire or the clean-up or both. No information was presented to allow a detailed assessment of which specific exposures were covered by the measure of exposure, which was nearly always just work as a firefighter. Since the included firefighters were mostly urban firefighters working in developed, modern industrial countries, it seems reasonable to consider that the main results, if valid, would be relevant to the Australian urban firefighter context. Whether they are relevant to firefighters in rural areas is not clear. However, as the type of fire-related exposures are likely to differ considerably between urban and rural firefighters, it seems prudent to be cautious about extrapolating the results to the Australian rural context. The two Australian studies of volunteer firefighters[11, 12] probably primarily reflect exposures in rural areas.

Five of the included studies were based on Australian firefighters[8-12]. Two are not very useful to the current report, one because of limited power and short follow-up[9] and the other because it focussed on exposures at a firefighting training facility rather than on exposures received during typical firefighting work[8].

The other three studies do seem useful and relevant to the Australian context. The study of paid firefighters is probably the most directly relevant study of the 33 published since 2005 in terms of the Australian context[10]. The study aimed to cover all male professional Australian firefighters. Information that is more detailed is available in Appendix 3 but, in brief, this was a cancer incidence and mortality study of a cohort of male Australian paid firefighters. The commencement dates varied from 1976 to 2003. Subjects had worked as firefighters for at least three months. Information was available on the number and type of fire incidents attended by each subjects. The main findings were increased cancer incidence for all-cancers combined, melanoma and prostate cancer; decreased risk for all-cancer mortality and decreased incidence for liver cancer and lung cancer; and no strong evidence either way for a large number of other cancers. This lack of strong evidence either way included for all cancers covered by Australian presumptive legislation except prostate cancer (for which an increased risk was found) and ureteric cancer (which wasn't included in the study). There was evidence of increased risk with length of employment for kidney cancer and non-Hodgkin's lymphoma; and increased risk with number of fire incidents attended for prostate cancer. As mentioned earlier, findings of increased risk of prostate cancer or melanoma in firefighters in comparison to an external group are a concern because of the possible influence of different screening rates. That concern is valid for this study. However, the findings of an internal analysis, comparing firefighters in different exposure groups, of an increased risk of prostate cancer related to the number of fire incidents attended should be less subject to the possibility of differential screening.

The other two Australian studies were of volunteer firefighters – only volunteers for the study of males[11] and mainly volunteers for the study of females[12]. These studies are described in detail in Appendix 3. In brief, both were cancer incidence and mortality studies. The study of male volunteer firefighters identified a small increase in the incidence of prostate cancer (SIR=1.12, 95% CI 1.08 to 1.16). This risk increased with years of service but not with the number of fires attended. The risk of kidney cancer was decreased, but risk appeared to increase with attendance at fires, particularly structural fires. Risks appeared to be decreased for many cancer types. The study of female firefighters found a raised risk of melanoma (SIR=1.25, 95% CI 1.05 to 1.46), but no increased or decreased risk in other cancer types.

4 SPECIFIC QUESTIONS OF INTEREST

INTRODUCTION

This chapter considers each of the four key questions of interest, using the literature summarised and considered in the previous chapter.

QUALIFYING PERIODS

The first requirement for the report was to examine "*whether the qualifying periods for the current list of prescribed cancers should be reduced*".

Qualifying periods have been assigned for each prescribed cancer. These are shown in Table 1. These qualifying periods are the minimum period of service required for a firefighter to be eligible to make a claim under the Act in terms of one of the prescribed cancers. Note the qualifying period is not a minimum latency, which is the minimum period between first exposure and diagnosis of the cancer to accept that the exposure could reasonably have resulted in the cancer.

Table 1: Prescribed cancers and their minimum qualifying periods of service

Disease	Qualifying Period
Primary site brain cancer	5 years
Primary site bladder cancer	15 years
Primary site kidney cancer	15 years
Primary non-Hodgkin's lymphoma	15 years
Primary leukaemia	5 years
Primary site breast cancer	10 years
Primary site testicular cancer	10 years
Multiple myeloma	15 years
Primary site prostate cancer	15 years
Primary site ureter cancer	15 years
Primary site colorectal cancer	15 years
Primary site oesophageal cancer	25 years

The justification for having a minimum exposure period was presumably that cancer risk increases with increasing total (or cumulative) exposure, and a certain minimum cumulative exposure would need to be reached before the risk would increase enough to be distinguishable from the background risk. This seems a sensible approach.

This minimum exposure ideally would be based on quantitative measures of exposure but that would not be possible for most (perhaps all) firefighting jurisdictions because such measurements are not available. There are thousands of potentially relevant substances that would need to be measured during the fire, during clean-up of the fire area and at other times when the firefighter could be exposed. Exposure measures would need to cover skin absorption as well as respiratory exposure. Therefore, this sort of detailed quantitative measure of exposure is not realistic, at least with current technology.

A next-best measure would be the number of fires attended, the length of time at the fire and the type of fire, which should be provide a reasonable proxy measure of the overall absolute exposure. However, it seems this information is not readily available for many firefighters and certainly not in regards to firefighting undertaken in previous decades.

Therefore, the length of service appears to be the best feasible measure of exposure. Presuming that a firefighter is likely to attend a certain minimum number of fires in a given period (week, month or year), length of service as an active firefighter should provide a moderately appropriate estimate of the total exposure of the firefighter.

I have been unable to find the explicit reasoning for the qualifying periods assigned to each prescribed cancer under the Act. I have reviewed the Hansard for 2nd September 2011 when the relevant Senate Committee (Education, Employment and Workplace Relations Legislation Committee) sat. However, the only relevant mention of qualifying periods I can find is by one of the Canadian witnesses, and it appears the discussion is about latency period rather than qualifying period. The witness noted that the five-year "qualifying period" for leukaemia used in one Canadian jurisdiction was because the scientific evidence was that risk of leukaemia doubled after this length of time:

“*We struggle with that in Canada but we wanted to build the strongest legislation possible. That is why leukaemia has such a strong connection. Within five years you see a doubling of risk and the doubling of risk of the general population is the general standard throughout Canada. Once a cancer reaches a doubling of risk, that is when you see legislation being in place. You see the doubling of risk only after a certain time frame as a firefighter. What we are concerned with, by not having latencies, is that if a firefighter were to contract cancer within one year of being hired, the presumption would be that he would be covered, but that would weaken the legislation because the chances are he did not get that cancer from his job. We are not trying to get anything more than what we deserve. We want to have this legislation. We want to err on the side of caution because that is where the strength of this legislation has come through*” (Hansard, 2 September 2011).

There is very limited information in the published literature that provides guidance as to what a minimum exposure qualifying period should be and why this would vary between cancers. Some studies provide information about cancer rates after different periods of service, but those periods differ between studies and the lower number of cases in the required sub-analyses means the point estimates of effect (such as the RR) are commonly imprecise.

An English academic, Professor Fear, who conducted some relevant research for the Department of Veterans' Affairs (this is considered in more detail in Chapter 5) considered the available information relevant to establishing appropriate qualifying periods for individual cancer types. The report concluded that there was little evidence in regards to qualifying periods and little evidence that they were of use: “*…there was little evidence to suggest that employment length or number of runs (number of attended firefighting events) predicted risk for any of the 13 cancers, and believe that these exposure metrics have limited value in contributing to a 'qualifying period'.*”[35]. I agree with this conclusion.

The short qualifying periods for leukaemia and brain cancer in the Act, in comparison to most of the other cancers, are more consistent with latency than with a required minimum cumulative exposure. There seems no obvious reason why the qualifying periods for testicular cancer and breast cancer should be shorter than for the remaining cancers. Similarly, there does not seem a strong reason for the qualifying period for oesophageal cancer to be much longer than for the other included cancers.

In summary, there is no published evidence that provides useful guidance as to what the minimum qualifying periods should be for any of the cancers but it seems anomalous that the qualifying period for oesophageal cancer is at least 10 years longer than for other prescribed cancers.

The first requirement asked not what the qualifying periods should be but whether any should be reduced. On the basis of the above, it is recommended that consideration be given to simplifying the qualifying periods by decreasing the period for oesophageal cancer from 25 years to 15 years. No other changes to the qualifying periods are proposed.

ADDITIONAL DISEASE WARRANTING INCLUSION

The second requirement for the report was to examine "*whether there are any further diseases that warrant inclusion in the list prescribed at subsection 7(8) of the SRC Act.".* The list of cancers prescribed under the act is shown in Table 1.

Key aspects of the identified studies considered in Chapter 3 are summarised in Table 2 for cancers APART FROM the 12 prescribed cancers currently covered by the SRC Act. (Information from the literature relevant to the 12 cancers that are covered by the Act is included in Table 3 in Appendix 2). In Table 2, after the all-cancer results, the columns of the table present information for any cancers included in at least one study but not currently covered by the Act. The estimates summarised are based primarily on incident cases where such estimates were available. Where the confidence interval for the incident estimate crossed one, but the confidence interval for the corresponding mortality estimate did not cross one, the mortality estimate was used in the table. In the table, the green cells show the cancer types (and relevant point estimate) for which the point estimate was above one and the confidence interval excluded one (i.e. firefighters had a significantly increased risk of the relevant cancer compared to the comparison exposure group). The orange cells show the cancer types (and relevant point estimate) for which the point estimate was below one and the confidence interval excluded one (i.e. firefighters had a significantly decreased risk of the relevant cancer compared to the comparison exposure group). The grey cells (with a full-stop included) show cancer types examined in the relevant paper but for which the confidence interval included one. For these, the point estimate for the relevant cancer might have been above or below one but the evidence of an increased or decreased risk in firefighters compared to the comparison exposure group was weak because the 95% confidence interval included one. Summaries of the individual studies are presented in alphabetical order in Appendix 3.

Criteria to guide recommendations on inclusion of cancers

The criteria used to guide recommendation on inclusion of cancers to prescribed list were:

- Consistency of evidence as identified in meta-analyses
- Evidence of, or probability of, exposure to firefighters of the relevant carcinogens

- Likelihood that evidence of increased risk could be due to bias, confounding or chance.

Table 2: Summary of results from included studies – by study quality*

Author	Year	Type[1]	Location[2]	Mort/Morb[3]	Measure[4]	Quality[5]	Hodgkin's	Lung	Melanoma[6]	Mesothelioma
Amadeo	2015	Cohort	France	Mort	SMR	M		0.86		
Béranger	2013	Rev	All	Both	None	M				
Bigert	2016	CC	All	Morb	OR	M		.		
Cumberbatch	2015	M-A	All	Both	sRE	M				
Daniels	2014	Cohort	U.S.	Both	SMR/SIR	M		1.12		2.29
Daniels	2015	Cohort	U.S.	Both	HR	M		1.39		
Glass_a	2016	Cohort	Australia	Both	SMR/SIR	M	.	0.71	1.44	.
Glass	2017	Cohort	Australia	Both	SMR/SIR	M	.	0.48	.	0.64
Glass	2019	Cohort	Australia	Both	SMR/SIR	M	.	.	1.25	.
Harris	2018	Cohort	Canada	Morb	HR	M	2.89	.	1.67	.
IARC	2010	M-A	All	Both	sRE	M				
Jalilian	2019	M-A	All	Both	sRE	M	.	.	1.21	1.60
Kullberg	2018	Cohort	Sweden	Morb	SIR	M	.	.	0.30	.
LeMasters	2006	M-A	All	Both	sRE	M	.	.	1.32	
Paget-Bailly	2013	CC	France	Both	OR	M				
Petersen_a	2018	Cohort	Denmark	Mort	SMR	M		.		

Petersen_b	2018	Cohort	Denmark	Morb	SIR	M	.	.	.	.
Pukkala	2014	Cohort	Nordic	Morb	SIR	M		1.29	1.25	.
Sauve	2016	CC	Canada	Morb	OR	M				
Sritharan_a	2017	M-A	All	Both	sRE	M				
Sritharan	2018	Cohort	Canada	Morb	HR	M				
Youakim	2006	M-A	All	Both	sRE	M				
Ahn	2015	Cohort	Korea	Mort	SMR	F		0.58		
Bates	2007	CC	U.S.	Morb	OR	F		.	1.50	
Glass	2012	Coh	Qld	Morb	SIR	W		.	.	
Glass_b	2016	Cohort	Vic	Both	SMR/SIR	W			.	
Ide	2014	Cohort	Scot	Both	SMR/SIR	W		.	1.68	
Kang	2008	Coh	U.S.	Morb	SMOR	W		.	0.65	
Ma	2006	Coh	U.S.	Morb	SIR	W	.	0.65		
Muegge	2018	CCom	U.S.	Mort	OR	W				
Sritharan_b	2017	CC	Canada	Morb	OR	W				
Tsai	2015	CC	U.S.	Morb	OR	W	.	2.01	1.75	.

*: The green cells show the cancer types for which the point estimate was above one and the confidence intervals excluded one. The orange cells show the cancer types for which the point estimate was below one and the confidence intervals excluded one. The grey cells show cancers types examined but for which the confidence interval included one.

1: Study type (CC=case-control; CCom-Case-comparison; M-A=meta-analysis; Rev=systematic review)

5: Quality (F=fair; M=moderate; W=weak)

2: Location (Qld=Queensland; Scot=Scotland; Vic=Victoria; U.S.=United States

6.: # in a cell means there was evidence of dose-response

3: Mortality or morbidity (mort=mortality; morb=morbidity)   4: HR=hazard ratio; OR=odds ratio; SIR=Standardised Incidence Ratio; SMR=Standardised Incidence Ratio; sRE=summary risk estimate

Table 2: Summary of results from included studies – by study quality (continued)*

Author	Year	Type[1]	Location[2]	Mort/Morb[3]	Measure[4]	Quality[5]	Stomach	Skin	Thyroid	ALL LH	Others
Amadeo	2015	Coh	France	Mort	SMR	M	.	.		.	
Béranger	2013	Rev	All	Both	None	M					
Bigert	2016	CC	All	Morb	OR	M					
Cumberbatch	2015	M-A	All	Both	sRE	M					
Daniels	2014	Coh	U.S.	Both	SMR/SIR	M	.				.
Daniels	2015	Coh	U.S.	Both	HR	M					
Glass_a	2016	Coh	Australia	Both	SMR/SIR	M	.		.	.	.
Glass	2017	Cohort	Australia	Both	SMR/SIR	M	0.69		.	0.81	.
Glass	2019	Cohort	Australia	Both	SMR/SIR	M	.		.	.	.
Harris	2018	Coh	Canada	Morb	HR	M	.		.		.
IARC	2010	M-A	All	Both	sRE	M					
Jalilian	2019	M-A	All	Both	sRE	M	.	.	1.22		.
Kullberg	2018	Coh	Sweden	Morb	SIR	M	1.89			.	.
LeMasters	2006	M-A	All	Both	sRE	M	1.22	1.39			.
Paget-Bailly	2013	CC	France	Both	OR	M					#
Petersen_a	2018	Coh	Denmark	Mort	SMR	M	1.96			.	.
Petersen_b	2018	Coh	Denmark	Morb	SIR	M	.	.	.		#

Pukkala	2014	Coh	Nordic	Morb	SIR	M	.	1.33	.		.
Sauve	2016	CC	Canada	Morb	OR	M					
Sritharan_a	2017	M-A	All	Both	sRE	M					
Sritharan	2018	Coh	Canada	Morb	HR	M					
Youakim	2006	M-A	All	Both	sRE	M					
Ahn	2012	Coh	Korea	Morb	SIR	F	.		.	.	
Ahn	2015	Coh	Korea	Mort	SMR	F	.			.	
Bates	2007	CC	U.S.	Morb	OR	F	.		.		.
Glass	2012	Coh	Qld	Morb	SIR	W	.				
Glass_b	2016	Coh	Vic	Both	SMR/SIR	W			.		
Ide	2014	Coh	Scot	Both	SMR/SIR	W		.			.
Kang	2008	Coh	U.S.	Morb	SMOR	W	.		.		.
Ma	2006	Coh	U.S.	Morb	SIR	W	0.50	.	1.77	0.68	#
Muegge	2018	CCom	U.S.	Mort	OR	W				.	.
Sritharan_b	2017	CC	Canada	Morb	OR	W					
Tsai	2015	CC	U.S.	Morb	OR	W	.		.		#

*: The green cells show the cancer types for which the point estimate was above one and the confidence intervals excluded one. The orange cells show the cancer types for which the point estimate was below one and the confidence intervals excluded one. The grey cells show cancers types examined but for which the confidence interval included one.

1: Study type (CC=case-control; CCom-Case-comparison; Coh=Cohort; M-A=meta-analysis; Rev=systematic review)

2: Location (Qld=Queensland; Scot=Scotland; Vic=Victoria; U.S.=United States

5: Quality (F=fair; M=moderate; W=weak)

6.: # in a cell means there was evidence of dose-response

3: Mortality or morbidity (mort=mortality; morb=morbidity)   4: HR=hazard ratio; OR=odds ratio; SIR=Standardised Incidence Ratio; SMR=Standardised Incidence Ratio; sRE=summary risk estimate

The most recent meta-analysis covering the literature regarding firefighter work and cancer risk[36] is considered at least equal in quality to the earlier systematic reviews. Being the most recent (published in May 2019) and containing studies published to January 2018, it covered all the relevant studies identified in the literature search for the current report, with the exception of the two papers focussing on volunteer firefighters in Australia.

This meta-analysis found significantly increased risk estimates for several cancers not currently covered by the Act. These were malignant melanoma, malignant mesothelioma and thyroid cancer. The authors applied two criteria, based on those used in the main previous meta-analysis[2], to make an assessment as to whether the identified associations might reasonably considered causal. These criteria were the pattern of meta-relative risks and consistency in results between relevant studies. On the basis of these criteria, the authors considered malignant mesothelioma and thyroid cancer were likely to have an increased incidence in firefighters and malignant melanoma to possibly have an increased risk. These three conditions are considered in detail here.

Malignant melanoma

Malignant melanoma was estimated to have a 21% increased risk in firefighters compared to the comparison population (meta-risk estimate=1.21, 95% CI 1.02-1.45) , based on 11 incidence studies[36]. Only one other meta-analysis examined the risk of malignant melanoma and that also found a raised risk (RR=1.32, 95% CI 1.10-1.57), based on eight studies[2]. As mentioned earlier, including only studies of moderate quality, there were six studies that identified a significantly increased risk of melanoma in firefighters (ranging from 1.21 to 1.67)[2, 10, 12, 13, 20, 31]; one study that found a significantly decreased risk (SIR=0.30)[16]; and two studies in which the confidence interval crossed one[11, 18]. The 2017 report by Fear, in which she reviewed relevant literature published to that point, found “limited” evidence of an increased risk of melanoma in firefighters[35].

Some of the hazardous substances to which firefighters are known or suspected of being exposed are associated with an increased risk of malignant melanoma. Firefighters might also be exposed to higher levels than the general public of ultraviolet radiation from the sun (solar-UV) in the course of their work, although there does not appear to be any specific evidence of this.

The strong relationship between exposure to solar-UV and the risk of melanoma makes a causal connection difficult to assess confidently. This is because firefighters might spend more time in the sun recreationally rather than connected to work, and this possibility has not been controlled for in the studies of firefighters included here.

Another potential problem with considering the evidence in regards to malignant melanoma is that melanoma is subject to screening tests and as a result a higher incidence may be due to increased detection through screening rather than to a true increased incidence. Where this has been identified as a potential issues in individual studies, the study authors have commonly argued the issue of screening was unlikely to be a problem because firefighters were not offered screening for melanoma as part of their employment. This a reasonable explanation but it doesn't exclude the possibility that firefighters organised their own screening or that their doctors proposed such screening. This is especially the case if either the firefighters or their doctors were aware of results from previous studies that suggested an increase in risk of melanoma associated with firefighting.

On the basis of this evidence, malignant melanoma is an appropriate condition to be considered for inclusion as a prescribed cancer under the Act. However, the lack of control of confounding by non-work-related solar-UV exposure, and the possible influence of greater levels of screening in firefighters, suggests the overall evidence for inclusion is not strong.

<u>Malignant mesothelioma</u>

Malignant mesothelioma was estimated to have a 60% increased risk in firefighters compared to the comparison population (RR=1.60, 95% CI 1.09-2.34), based on five incidence studies[36]. None of the other meta-analyses examined the risk of malignant mesothelioma in firefighters.

As mentioned earlier, including only studies of moderate quality, there was one study that identified a significantly increased risk (SIR=2.29)[7]; one study that identified a significantly decreased risk (0.64)[11]; and six studies in which the confidence intervals crossed one[10, 12, 13, 16, 18, 20].

Firefighters are known to be at increased risk of exposure to asbestos[30] and nearly all cases of mesothelioma are considered due to asbestos. Asbestos exposure external to work is possible, as is asbestos exposure in occupations other than firefighting if the firefighter held different jobs before or after their work as a firefighter[37], but such exposure is not likely and if present presumably could be a basis for an employer questioning the claim.

The most recent meta-analysis identified a considerable increased risk of mesothelioma in firefighters. Firefighters are certainly at risk of exposure to asbestos in the course of fighting fires. Selection bias and measurement bias are unlikely to have resulted in a bias upwards of the risk of malignant mesothelioma in firefighters. Finally, there are no important potential confounding factors (apart from age, which was controlled for in all, or virtually all, relevant studies) which might have biased the results. On the basis of that analysis, malignant mesothelioma is considered to meet the requirements to be listed as a prescribed disease under the Act.

Thyroid cancer

Thyroid cancer was estimated to have a 22% increased risk in firefighters compared to the comparison population (RR=1.22, 95% CI 1.01-1.48), based on 10 incidence studies[36]. However, only one of these individual studies found a significantly increased risk of thyroid cancer in firefighters and the quality of that study was considered (for the purposes of the current report) to be weak. None of the other meta-analyses examined the risk of thyroid cancer in firefighters. As mentioned earlier, including only studies of moderate quality, one study, the meta-analysis mentioned above, identified a significantly increased risk[31]. The remaining six studies had estimates of effect in which the confidence intervals crossed one[10-13, 18, 20].

The main occupational exposures that might increase the risk of cancer appear to be ionizing radiation and possibly pesticides exposure[38], neither of which are known or likely to be common exposure of firefighters. Gender is the only other well-established risk factor for thyroid cancer.

The most recent meta-analysis identified a moderately increased risk of thyroid cancer in firefighters. Firefighters are not likely to be exposed to either of the suspected occupational risk factors for thyroid cancer. Selection bias and measurement bias are unlikely to have resulted in a bias upwards of the risk of thyroid cancer in firefighters. Gender, the only known potential confounder, was controlled for in the relevant studies. On the basis of that analysis, thyroid cancer is not considered to meet the requirements to be listed as a prescribed disease under the Act.

Summary

In summary, it is considered that malignant mesothelioma meets the requirements to be listed as a prescribed disease under the Act and that malignant melanoma should be considered for inclusion but probably does not meet the requirements of the Act because of the possible role of confounding and screening behaviour. It is recommended that malignant mesothelioma be included in the list of prescribed cancers and that malignant melanoma be considered for inclusion. Based on currently available information, no other cancers are considered to warrant inclusion in the list.

Lung cancer in non-smokers

The third requirement for the report was to examine "*…whether lung cancer in non-smokers should be included among the listed cancers and, if so, any appropriate qualifying conditions.*".

The lung would be expected to be a target organ for firefighter exposures, with the respiratory system and the skin expected to be the main routes of entry of hazardous substances encountered during firefighting. Therefore, it is reasonable to expect that carcinogenic exposures encountered during firefighting work might affect the lung, resulting in lung cancer. Lung cancer was not included among the list of 12 carcinogens prescribed under the act. However, the 2013 review of the Act recommended that a consideration should be made after five years as to "*…whether lung cancer in non-smokers should be included in the list of prescribed cancers.*"[1]. Lung cancer presents a particular challenge when being considered for inclusion as a prescribed cancer because in people who smoke, smoking is likely to be the primary cause of the cancer. This makes lung cancer a less appropriate condition to include as prescribed cancer. The focus on non-smokers in the review recommendation was presumably because if a certain exposure does increase the risk of lung cancer, the proportion of lung cancer cases due to that exposure in people who are exposed will be much higher in non-smokers than smokers. This would make the condition more appropriate to be considered as a prescribed cancer.

The published literature does not provide strong evidence to suggest the risk of lung cancer is raised in firefighters, either in smokers or non-smokers. Since 2006, 22 studies have examined the incidence and or mortality rate of lung cancer in firefighters. Of these 22 studies, four found a significantly increased risk (RRs ranged from 1.12 to 2.01[6, 7, 20, 27]), five found a significantly decreased risk (RRs ranged 0.48 to 0.86[3, 5, 10, 11, 17]) and the remaining 13 found point estimates of the relative risk that were not considered different to one[2, 4, 9, 12-16, 18, 19, 22, 23, 31]. In the most recent systematic review[36], the results were not supportive of an increased risk of lung cancer in firefighters, with a meta-estimate of the RR of 0.94 (95% CI 0.84-1.06) in incidence studies and a meta-estimate of the RR of 1.00 (95% CI 0.92-1.09). These results suggest that, if the methodology of the studies did not result in important bias, it is unlikely that the risk of lung cancer in firefighters is raised as a result of their work.

These individual studies, including studies on which the meta-analysis was based, were not specifically of non-smokers. Also, there are several methodological issues to consider when evaluating the study results. These are considered in relation to various types of cancer in the previous chapter. Issues specifically relevant to lung cancer are considered here.

The healthy worker effect could have led to an underestimation of the risk of lung cancer due to firefighting. In addition, confounding due to smoking may have been an issue in some of the studies. When examining the risk of lung cancer from an exposure, the most important confounder to consider is usually tobacco smoking. Most of the identified studies that examined the risk of lung cancer in firefighters did not control for smoking. This means they could have been subject to confounding by smoking. If rates of smoking were higher in the comparison populations than they were in the firefighters, this could have resulted in an underestimate of the relative risk, potentially masking any harmful effect of firefighting. Finally, a considerable number of the included studies on lung cancer in firefighters did not have high power. That means that it is possible that there truly was a higher risk of lung cancer but that the study was not powerful to identify it. This is one of the advantages of a meta-analysis, as this allows the data from many studies to be combined, which greatly increases the power of the analysis. It is notable that in the recent meta-analysis, the precision of the meta-estimates of the relative risk was good (i.e. the confidence intervals were narrow).

In summary, the most recent meta-risk estimates were not raised, the confidence intervals were narrow and there was little evidence to examine whether risk might have changed with level of exposure (such as number of fires attended). Methodological shortcomings of many of the studies mean that the lack of an identified relationship should not be considered as definitive evidence of the lack of a true, underlying increased risk. However, the published evidence available currently does not suggest that work as a firefighter involves an increased risk of developing lung cancer in either smokers or non-smokers. It is recommended that lung cancer (whether in smokers or non-smokers) not be included in the list.

VOLUNTEER FIREFIGHTERS

The fourth requirement for the report was to examine "*…whether the scientific literature supports the presumption of liability for prescribed cancers under the SRC Act being extended to volunteers firefighters and, if so, any appropriate qualifying conditions.*".

Volunteer firefighters are not currently covered by the prescribed cancers section of the Act. There is a prima facie argument to include volunteer firefighters because they would be expected to have many of the same exposures as paid firefighters when attending fires and when involved in post-fire clean-ups. In fact, they could well be working on the same fires with paid firefighters yet not have the same level of access to compensation as the paid firefighters. However, volunteer firefighters would be expected to attend a lower number of fires overall, and a lower proportion of structural fires compared to paid firefighters. This could mean that their exposures to smoke in general, and smoke arising from burning synthetic material in particular, is probably much lower than it would be for paid firefighters.

The probable lower exposures per year in volunteer firefighters compared to paid firefighters suggests that if volunteer firefighters are to be included under the prescribed cancers section of the Act that the qualifying periods should be longer. However, the basis of the current qualifying periods is not clear and very likely have a large uncertainty. Given that, it would be simpler to use the same qualifying periods for volunteer firefighters as are used for paid firefighters.

Many jurisdictions in Australia already include volunteer firefighters under the provisions that are equivalent to the prescribed diseases aspect of the Act. This means volunteer firefighters engaged in places covered by parts of the Act but not the prescribed cancers section (such as the Australian Capital Territory) might be working alongside volunteers from another jurisdiction but not receive equivalent levels of access to compensation arising from this work.

There is not a lot of published evidence about the risk of cancer specifically in volunteer firefighters but what information is available does not provide strong support for an increased risk of cancer. The largest and most relevant study was contacted by Monash

University[39]. The results have been published separately for male volunteers[11] and female volunteers[40].

This first study was a cancer incidence and mortality study of a cohort of male Australian volunteer firefighters who had ever had an active volunteer firefighting role[11]. Firefighters who had ever worked in a paid capacity were excluded. The main outcome measures were the Standardised Incidence Ratio (SIR) and the Standardised Mortality Ratio (SMR), calculated using the Australia male population as the reference and taking into account age and calendar year. In addition to the overall analysis, internal analyses were conducted based on duration of service and number and type of fire incidents attended. Analyses were undertaken for all deaths, all cancers and for some major cancer types. The main findings of relevance were:

- All-cancer SMR was decreased (0.59, 95% CI 0.57 to 0.62)
- All-cancer SIR was decreased (0.86, 95% CI 0.84 to 0.88)
- Prostate cancer SIR was increased (1.08, 95% CI 1.04 to 1.12) and the risk increased with years of service but not with number of fires attended
- Kidney cancer SIR was decreased, but risk appeared to increase with attendance at fires, particularly structural fires
- Decreased SIRs were seen for many types of cancer, including many of the cancer types prescribed in the Act (lip, oral cavity and pharynx; oesophagus; stomach; colon; liver; larynx; lung; mesothelioma; kidney; bladder; non-Hodgkin's lymphoma; and myeloma) and for many the risk decreased with years of service.

The study appears to have used appropriate methods and analysis. It appears only volunteer firefighters were included in the cohort. Some did not attend any fires but the results were similar when these participants were excluded. The follow-up time was moderate and should have been adequate to provide reasonable quality information on cancers due to service in volunteer firefighting, but longer follow-up would provide more definitive information. Similarly, the cohort members were fairly young, which meant their underlying risk of cancer was low, making it less likely an increased risk of cancer would have been identified. The identification of cancer should have been essentially complete, given the high quality of the NDI and ACD in Australia. As with most SMR studies, the major potential weaknesses were selection bias that can result if the comparison group used was not appropriate; and the limited control of potential confounding, with only age, calendar time and gender (by exclusion of females) able to be controlled for. Another potential problem was that prostate cancer is often the subject of screening and as a result a higher incidence may be due to increased detection through screening rather than to a true increased incidence.

The second study was a cancer incidence and mortality study of a cohort of female Australian firefighters[40]. It included paid and volunteer firefighters but most members of the cohort were volunteers. Subjects had served as firefighters for at least three months. The main outcome measures were the Standardised Incidence Ratio (SIR) and the Standardised Mortality Ratio (SMR), calculated using the Australia female population as the reference and taking into account age and calendar year. In addition to the overall analysis, internal analyses were conducted based on duration of service and number and type of fire incidents attended. This was only possible for the volunteer firefighters because of the low number of paid firefighters. Analyses were undertaken for all deaths, all cancers and for some major cancer types. The main findings of relevance were:

- All-cancer SMR was decreased (0.75, 95% CI 0.66 to 0.84)
- All-cancer SIR was similar (0.97, 95% CI 0.91 to 1.03)
- Melanoma SIR was increased (1.25, 95% CI 1.05 to 1.46)
- Some evidence of increased risk of death from cancer overall with increased attendance at all fires and at landscape fires

The strengths and weaknesses of the study were similar to those for the male volunteer firefighters study. It was considered the higher risk of melanoma in firefighters compared to the general public might well reflect greater exposure to UV radiation from sunlight in the rural firefighters (not necessarily due to work) compared with the general public. In addition, there was the possibility of some uncontrolled confounding from other important potential confounders, such as alcohol and other occupations, which could result in bias in either direction. Another potential problem was that melanoma is often the subject of screening and as a result a higher incidence may be due to increased detection through screening rather than to a true increased incidence. It is not known if screening for melanoma was offered to firefighters as part of their engagement. This could plausibly have occurred, especially if either the firefighters or their doctors were aware of results from previous studies that suggested an increase in risk of and melanoma.

A Danish study of a cohort of firefighters included volunteer firefighters, combining them with part-time paid firefighters for the analysis. Half the participants were full-time professionals and half were part-time professionals or volunteers. Incidence[18] and mortality[19] analyses were conducted. The outcome measures were the Standardised Incidence Ratio (SIR) and Standardised Mortality Ratio (SMR), calculated using several reference populations. In addition to the overall analysis, internal analyses were conducted, adjusting for age and calendar year.

The main findings of relevance in part-time paid and volunteer firefighters combined were:

- All cancer SMR was not increased (0.93, 95% CI 0.77–1.10)
- Prostate cancer SMR was increased in the part time/volunteer group (1.89, 95% CI 1.22–2.93) and seemed to increase with employment duration
- Hodgkin's lymphoma SIR was significantly increased for part-time/volunteer firefighters (2.29, 95% CI 1.15 to 4.58)

In summary, the published evidence provides little support for volunteer firefighters to be included under the prescribed cancers section of the Act. Few cancers have been found to have a higher rate in volunteer firefighters than the general population in the small number of relevant studies and the evidence in male Australian volunteer firefighters was that their rate of cancer was much lower than in the general population. Volunteer firefighters would also be expected to attend less fires per year than paid firefighters. This means their exposure in terms of years involved as a firefighter would be less than for paid firefighters. However, it is noted that volunteer firefighters can be expected to have many of the same fire-related exposures as paid firefighters and might attend fires alongside paid firefighters covered by the prescribed cancers section of the Act, and that volunteer firefighters from many other jurisdictions are covered by an equivalent to the prescribed cancers section of the Act. If volunteer firefighters are included under the prescribed cancers section of the Act, it would be simpler to use the same qualifying periods as used for paid firefighters.

5 COMMENTS ON SUBMISSIONS BY INTERESTED PARTIES

INTRODUCTION

This chapter provides comment on the scientific evidence cited in formal submissions by various parties to the review of the firefighter provisions of the SRC Act.

SUBMISSION BY THE UNITED FIREFIGHTERS UNION OF AUSTRALIA

The United Firefighters Union of Australia (UFUA) made four recommendations:

- Recommendation 1: "*Consider the inclusion of stomach cancer, and all skin cancers and melanoma in the list of prescribed cancers…*"
- Recommendation 2: "*…consider the inclusion of female reproductive (ovarian and cervical) cancers in the list of prescribed cancers…*"
- Recommendation 3: "*…commence a process for defining the term 'non-smoker' for the purposes of lung cancer…*"
- Recommendation 4: "*…consider a tiered model for access to compensation, inclusive of an independent review panel or committee…*"

Recommendation 1

The UFUA argued that the available scientific evidence supports the inclusion of stomach cancer, all skin cancers and melanoma in the list of prescribed cancers. They provided background information on the exposure of firefighters to hazardous substances, including carcinogens, in an introductory section, and then cited published evidence in regards to each of the three cancer types proposed for inclusion.

<u>Stomach cancer</u>

In regards to stomach cancer, the UFUA submission noted an increased SIR for stomach cancer in several studies – the studies by Lemasters and co-workers[2], Monash University[10, 39] and a Korean study by Ahn and co-workers[4].

The LeMasters study, published in 2006[2], identified a meta-risk estimate of 1.22 (95% CI 1.04-1.44). The UFUA submission cited the meta-SIR from the paper, which was 1.58 (95% CI 1.12-2.16). In general, risk estimates based on incidence are more reliable than risk estimates based on mortality, but the approach taken in this study was to focus on the combined risks from all study types and all outcomes. Also, for cancer types where the meta-estimate was significantly elevated, the authors made an assessment of the "*likelihood of cancer risk*", with the assessment based on the "*…'pattern of meta-relative risk association', 'study type', and 'consistency' among studies.*". The evidence was rated as "probable", "possible", or "not likely". On the basis of these criteria, the authors concluded there was a "possible" relationship between firefighting and an increased risk of stomach cancer. The UFUA argue that since the estimated meta-risk was higher for stomach cancer than it was for prostate cancer, and because two of the cancers identified in the study (prostate and testicular) had raised SIRs and were included in the prescribed list, that stomach cancer should also be included. Prostate cancer had a lower meta-risk estimate than stomach cancer but the authors rated the level of evidence as supporting a "probable" relationship with firefighting. The level of evidence in regards to testicular cancer was rated as supporting a "possible" relationship but the estimated meta-risk estimate was much higher (meta-RR=2.02, 95% CI 130-3.13) than for stomach cancer (meta-RR=1.22, 95% CI 1.04-1.44). (Note that the submission states that the comparison group for the study was "non-career firefighters", by which I presume they mean the general population, as the general population was the comparison group for nearly all the studies included in the LeMasters and co-workers' meta-analysis[2].)

The Monash University study did not find a raised risk for stomach cancer overall (RR=0.99, 95% CI 0.68-1.39). It did find a (two-fold) raised risk for firefighters who worked before 1985 but not for those who were employed after 1985. In regards to stomach cancer, the Monash report concluded "*When compared to the Australian population, stomach cancer was not increased but it was significantly raised for those firefighters who worked before 1985 but not for those employed after this date. There was no relationship with employment duration or number or type of incidents attended in internal analyses.*". The UFUA argued that this raised risk estimate in those employed before 1985, and a raised risk estimate for all cancers combined in those employed for more than 20 years (SIR=1.09, 95% CI 1.02 to 1.16), was enough evidence for stomach cancer to be included on the prescribed list.

The submission also mentions a Korean study published in 2012 which the UFUA stated "*identified a non-significant increase in SIR*"[4]. This was an incidence study of a cohort of male Korean professional emergency responders, 88% of whom were firefighters. The relative risk for firefighters employed for at least 20 years was in fact very close to one (RR=1.03, 95% CI 0.44-2.44) and well below one for firefighters employed for a shorter period (RR=0.63, 95% CI 0.27-1.50).

The UFUA argued that the combined weight of evidence regarding stomach cancer is enough to warrant its inclusion on the prescribed list.

The evidence cited by the UFUA does not seem enough to justify the inclusion of stomach cancer. LeMasters and co-workers rated the evidence they summarised as only suggesting a possible link. The Monash study evidence was very limited, with no increase overall and no evidence of a dose-response. The Korean study provides no support for an increased risk. The most recent meta-analysis, which covers the papers included by the LeMasters and co-workers study and all papers published since, including the Monash study, found an SIR of 1.04 (95% CI 0.90-1.20). So, it does not provide evidence supporting the inclusion of stomach cancer on the prescribed list.

<u>Melanoma</u>

In regards to melanoma, the UFUA submission referred to results from the studies by Lemasters and co-workers[2], by Monash University[10, 39] and from a Nordic study[20].

The LeMasters and co-workers study identified a meta-risk estimate of 1.32 (95% CI 1.10-1.57). The authors concluded there was a "possible" relationship between firefighting and an increased risk of melanoma. The UFUA noted that the estimated meta-risk estimate for melanoma was higher than it was for prostate cancer.

The Monash University study round a raised risk for melanoma (RR=1.44, 95% CI 1.28-1.62) and a relationship with length of service compared to the general population but not in the internal analysis compared only to firefighters. In regards to melanoma, the Monash report concluded "*The risk of melanoma was significantly increased for career full-time firefighters, and for both of the employment duration groups who were employed for more than 10 years. It was not related to duration of service or number or type of incidents attended in internal analyses however. Melanoma was significantly increased for all eras of first employment (pre-1970, 1970-1994, 1995 and later)….*".

The submission also mentioned a Nordic study, citing an all-occupation study from 2009 and the fire-fighter focussed follow-up study published in 2014[20]. This later study was a cancer incidence study of the whole population of male firefighters aged 30 to 64 years from five Nordic countries. The study identified an SIR for melanoma of 1.25 (95% CI 1.03–1.51), with an increased risk primarily in younger firefighters and in persons employed prior to 1991.

The UFUA argued that the combined weight of evidence regarding melanoma is enough to warrant its inclusion on the prescribed list. As mentioned in the previous chapter, there does appear to be moderately consistent evidence of an increased risk of melanoma in firefighters compared to the general public. However, the authors of both relevant meta-analyses rated the causal connection only as possible and there is no evidence of an increased risk with increased exposure. Also, the possibility of the findings being due to confounding from non-occupational exposure to sunlight makes a causal connection difficult to assess confidently.

Non-melanoma skin cancer

In regards to non-melanoma skin, the UFUA submission referred to results from the studies by Lemasters and co-workers[2] and the Nordic study[20] mentioned in the section on melanoma.

The LeMasters and co-workers study identified a meta-risk estimate of 1.39 (95% CI 1.10-1.73). The authors concluded there was a "possible" relationship between firefighting and an increased risk of non-melanoma skin cancer, the lack of certainty particularly because the increased meta-risk estimate relied importantly on results from proportional mortality studies, which provide weak epidemiological evidence. The UFUA noted that the estimated meta-risk estimate for non-melanoma skin cancer was higher than it was for prostate cancer.

The Nordic study identified an SIR for non-melanoma skin cancer of 1.33 (95% CI 1.10–1.59), with an increased risk primarily in firefighters employed more recently.

The Monash University study was unable to provide estimates of the risk of non-melanoma skin cancer because there is no reliable register of non-melanoma skin cancer in Australia.

The UFUA argued that the combined weight of evidence regarding non-melanoma skin cancer is enough to warrant its inclusion on the prescribed list. Based on the summary presented in Chapter 3, there does not appear to be not strong evidence in the published literature of an increased risk of non-melanoma skin cancer. LeMasters and co-workers rated the causal connection only as “possible” and the only other meta-analysis to consider non-melanoma skin cancer did not find strong evidence of an increased risk[36]. In addition, as with malignant melanoma, the main cause of non-melanoma skin cancer is sun exposure, and the possibility of the findings being due to confounding from non-occupational exposure to sunlight makes a causal connection difficult to assess confidently.

Recommendation 2

The UFUA argued that there was very limited information available about risks in female firefighters and that this meant female firefighters were disadvantaged. Female firefighters are allowed to use the prescribed cancers list in the same way as males, but prostate cancer is obviously not relevant to female firefighters and no female-specific cancer is included in the prescribed list (although breast cancer is included). The UFUA submission argued that consideration should be made of including female reproductive (ovarian and cervical) cancers in the list of prescribed cancers. The submission did not cite any specific findings in support of this proposal, apart from a “*…study of Florida career firefighters…*”.

This Florida study was almost certainly the study by Ma and co-workers[17], which was a cancer incidence study of a cohort of United States (Florida) professional firefighters. Amongst other findings, this study identified an increased SIR for cervical cancer in female firefighters (SIR=5.24, 95% CI 2.93–8.65). The Monash University study had too few cases to be able to provide useful information. No other identified published studies have considered the risk of cervical or ovarian cancer in female firefighters. Reproductive organ cancers are included in the equivalent of a prescribed list of cancers for firefighters in some Canadian provinces, but the scientific basis for this is not clear. The major meta-analyses did not include estimates for cervical or ovarian cancers.

The limited information on cervical and ovarian cancer risks in firefighters makes it difficult to make a confident assessment of those risks. This in turn means it is difficult to mount a strong argument that these cancers should be listed as prescribed disease.

Recommendation 3

The UFUA argued that the process to define "non-smoker" should commence urgently, with the implication that once this definition was developed then lung cancer in non-smokers could be included on the prescribed list. The UFUA noted that "*The scientific link between lung cancer and firefighter exposure was accepted by the Senate Committee in the 2011 Senate Inquiry.*".

The basis for this acceptance by the Senate Committee is not addressed here. There in fact is little published evidence to support a conclusion that firefighter exposures increase the risk of lung cancer. Both major meta-analyses did not find evidence of an increased risk, finding meta risk estimates of 0.94 (0.84-1.06)[36] and 1.03 (0.97-1.08). The issue of lung cancer in non-smokers is considered in Chapter 4. As summarised there, it is difficult to mount a strong argument that lung cancer should be listed as prescribed disease. However, if it is to be included on the list but only for non-smokers, a definition of non-smoker is clearly required.

Recommendation 4

The UFUA recommended a tiered model for access to compensation if volunteer firefighters were to be included under the provision of the Act for the purposes of the prescribed diseases. The relevant arguments in regards to this proposal are not primarily epidemiological. Therefore, the merits or otherwise of the proposal are not addressed here.

The UFUA also noted there was not strong evidence of an increased risk of cancer amongst volunteer firefighters, an issue considered in Chapter 4.

Submission by the Department of Veterans' Affairs

The Department of Veterans' Affairs (DVA) made a short submission that primarily provided a brief description of each of seven studies that the DVA had commissioned and that were considered relevant to the review of the Act. The reports of these seven studies were reviewed for the purposes of the current report.

1) Peel case review: This was a 2013 review of the compensation cases of 71 former firefighters who had served at RAAF Base Amberley. It does not provide any substantive epidemiological evidence of use for the current report.

2) Literature review by Professor Tee Guidotti: This was systematic review completed in early 2014 of the literature on health disorders related to firefighting, both civilian and military. It also included consideration of aspects of exposure specific to chemical exposure at Point Cook. The purpose of the report was to examine "*… the current evidence for risk, and to provide a summary of the current literature addressing the risk, of health outcomes associated with the occupation of firefighting.*".

The report identified a number of cancers (and other conditions) that Professor Guidotti described as "*Conditions demonstrating elevated risk among firefighters, weight of evidence sufficient to make a recommendation on general causation*". These cancers were bladder cancer; kidney cancer; testicular cancer; lymphoma ("*Diffuse large B-cell lymphoma and follicular cell lymphoma; others unclear and require individual analysis*"); leukaemia (acute myeloid leukaemia); brain cancers; lung cancer in a firefighter with little or no smoking history; mesothelioma ; cancer of the lip and breast cancer among males. Some of these cancers are already on the prescribed list. The exceptions are some of the lymphomas, lung cancer, mesothelioma and cancer of the lip.

The report also mentioned other cancers under the heading "*Conditions for which elevated risk of firefighters is suggested by the current weight of evidence: but which require qualification in a recommendation on general causation*". These were colon cancer ("for individuals with a low a priori risk"); melanoma ("*taking into account sun protection,* *lifestyle, and location*"); myeloma; parotid gland tumours ("*suggest case-by-case evaluation*"); and nasal sinus cancer ("*in the absence of other exposures*").

A third category was "*Conditions for which evidence of elevated risk of firefighters is not sufficient to make a provisional recommendation on general causation – individual evaluation is recommended*". The cancers mentioned were thyroid cancer, oesophageal cancer, basal and squamous cell carcinomas "(*taking into account sun protection, lifestyle, and location*"); laryngeal cancer; and prostate cancer in men below the age of 60.

The fourth and final category was "*Conditions for which evidence of elevated risk of firefighters is not sufficient to make a provisional recommendation on general causation but association is unlikely – individual evaluation is recommended*". The only cancer mentioned was prostate cancer in men above the age of 60.

The report does not provide any additional evidence with regard to cancer in firefighters to that considered earlier in this report, or in the most recent meta-analysis of firefighter exposures and cancer[36].

3) Fourth Mortality and Incidence – firefighter subcohort

The DVA submission rightly notes that the cohort was too small to provide definitive conclusions. This report does not provide additional useful evidence in regards to cancer in firefighters.

4) Kings College London literature review of eight studies

This was the first of three reports produced by Professor Nicola Fear in 2016 and 2017 that examined various health outcomes, including cancer, in defence firefighters. The first report had two conclusions of relevance to the current report and review:

- "*To class melanoma as having convincing evidence for a causal association with the occupational hazards of being a firefighter*
- *To consider melanoma for inclusion in the Safety, Rehabilitation and Compensation policies for firefighter, including Defence firefighters*".

This report was based only on studies referred to Professor Fear for specific review. The conclusions in regards to melanoma are of relevance to the considerations in Chapter 4 of this report.

5) Kings College London (KCL) Occupational Health Research Studies Review Examining the Occupational Health of Firefighters, Phase 1 and Phase 2

Professor Fear then conducted additional work to examine the level of evidence regarding the 12 cancers prescribed under the Act and melanoma. This work was conducted in two phases. In this review the strength of evidence was graded from "*…grade 1 (convincing evidence for a causal association) to grade 5 (inadequate or suggests no causal association).*". The report found "limited" evidence for cancer of the bladder (examined combined with cancer of the ureter) and melanoma; "very limited evidence" for cancer of the brain, colon and rectum combined, kidney, oesophagus and prostate; and inadequate evidence for cancer of the breast cancer, testicular cancer, leukaemia (and all subtypes of leukaemia), lymphoma (and all subtypes of lymphoma) and multiple myeloma.

The report also considered the available information relevant to establishing appropriate qualifying periods for individual cancer types (as considered in Chapter 4). The report concluded that there was little evidence in regards to qualifying periods and little evidence that they were of use: "*…there was little evidence to suggest that employment length or number of runs (number of attended firefighting events) predicted risk for any of the 13 cancers, and believe that these exposure metrics have limited value in contributing to a 'qualifying period'.*".

These reports provides interesting insights into the level of evidence regarding the cancers prescribed under the Act, but this aspect is not relevant to the current review. They identified evidence of an increased incidence of melanoma in firefighters, which is of relevance to the considerations in Chapter 4 of this report. They also considered information on qualifying periods, which is also of relevance to the considerations in Chapter 4 of this report.

6) Firefighter chemical review

This was a review (conducted in 2018) of chemical contaminants and associated health effects at RAAF Base Point Cook. The main conclusion of relevance was: "*There were several well conducted large-scale studies that supported the view that, on the balance of probabilities, exposures experienced by firefighters contributed materially to the subsequent development of cancers in general, and to some specific malignancies: cancers of the bladder, brain, colon, kidney, lung, prostate, and testes; and leukaemia, multiple myeloma, and non-Hodgkin's lymphoma.*".

The report proposed that the following cancers should be linked to firefighting and included under the Statement of Principles: acute myeloid leukaemia; malignant neoplasm of the bladder; malignant neoplasm of the brain; malignant neoplasm of the colorectum; malignant neoplasm of the liver; malignant neoplasm of the lung; malignant neoplasm of the prostate; malignant neoplasm of the renal pelvis and ureter; malignant neoplasm of the testis; mesothelioma; myelodysplastic syndrome; myeloma; Non-Hodgkin's lymphoma; and non-melanotic malignant neoplasm of the skin. Many of these are already prescribed under the Act, but some (cancer of the liver, cancer of the lung, myelodysplastic syndrome and non-melanotic malignant neoplasm of the skin) are not.

The report does not provide any additional evidence in regards to cancer in firefighters to that considered earlier in this report or in the most recent meta-analysis of firefighter exposures and cancer[36]. However, as a result of this work, and the work of Professor Fear described earlier, the submission states the DVA is considering including firefighting under the State of Principles in relation to mesothelioma, and the Repatriation Medical Authority will consider whether melanoma in relation to firefighting should be included under the Statement of Principles. Both of these considerations are of relevance to the considerations in Chapter 4 but do not provide any additional evidence in regards to them.

7) Firefighter chemical review – extension to review additional substances – ARP1701

This report (submitted in early 2019) reviewed additional chemicals to those reviewed in the first report. It does not add anything material that is of relevance to the current report.

SUBMISSION BY THE HALL VOLUNTEER RURAL FIRE BRIGADE (HVRFB)

The HVRFB made a submission in regards to volunteer firefighters being included under the presumptive provisions of the Act relating to firefighters and in regards to lung cancer being included under these same provisions.

The HVRFB argued, or implied, that volunteer firefighters face similar risks (or perhaps higher risks because of limited access to breathing protection equipment and decontamination facilities) to paid firefighters and so it is logical and fair that both should receive the same rights in terms of compensation. They also noted that some jurisdictions do cover volunteer firefighters and stated it was unfair that firefighters in the Australian Capital Territory were not covered by the presumptive provisions of the Act relating to firefighters.

The HVRFB argument in relation to lung cancer was based on the findings of a paper they cited that examined the mutagenicity and lung toxicity in smoke emanating from various types of wood-based fires[41]. The cited study focussed on a comparison of the different levels of mutagenicity and lung toxicity in various types of burning wood, including eucalyptus. It provides evidence that smoke from burning wood, including burning eucalyptus wood, has mutagenic properties and can be toxic to the lung. This information about the general effects of wood smoke is relevant to a consideration about lung cancer in firefighters because it suggests a mechanism by which work as a firefighter might result in an increased risk of lung cancer. This confirms information that is already well known. However, the study did not provide any substantive epidemiological evidence that indicated an increase rate of lung cancer in firefighters that could be used in the current report.

The HVRFB also argued that volunteer firefighters from the Australian Capital Territory often travel interstate to fight fires and work alongside volunteer firefighters who have access to presumptive firefighter provisions similar to those provided by the Act whereas the volunteer firefighters from the Australian Capital Territory do not. The submission argues this anomaly is not appropriate.

6 DISCUSSION

INTRODUCTION

This chapter consider some aspects of the methodology used in the study and the implications that has for the study results.

IDENTIFICATION OF RELEVANT LITERATURE

It is likely that all relevant publications were identified.

A comprehensive search of the published literature was undertaken. This involved all the main databases likely to have relevant publications. The search strings used were designed to be sensitive and should not have excluded relevant papers. A conclusion that the approach was effective is supported by the fact that only one relevant report was found in the reference list of other studies. This report was a study of all occupational exposures that might contribute to the occurrence of prostate cancer and which happened to include firefighters as one of the many occupations examined, rather than being focussed on firefighting.

The review of potentially relevant publications by title and abstract was potentially limited by only being undertaken by one person. However, the inclusion and exclusion criteria were clear and the decision to exclude was straightforward for the vast majority of publications, even just by title. Abstract and full text were used for each publication where there was any doubt as to whether a paper should be included.

EXCLUSION OF WORLD TRADE CENTRE FIREFIGHTERS

Studies covering firefighters exposed at the World Trade Centre disaster were excluded because the potential exposures involved were not likely to be typical of firefighters, either in the United States or in Australia. They therefore are considered not likely to be relevant to the Australian context and possibly to provide misleading results. In addition, the maximum follow-up of affected firefighters would be less than 20 years, which is a short time to provide useful information on a change in cancer incidence resulting from exposure.

Assessment of study quality

The assessment of study quality necessarily has a considerable subjective component and necessarily contains a qualitative component. Numeric systems that add points for various sections to produce an overall score suffer from the implication that a major weakness in one area can be made up for by strength in another area. This is not the case in epidemiological studies, where a fatal flaw in one important area undermines the usefulness of the study regardless of how good the rest of the study might be. Therefore, this report allocated each study to one of four categories based on overall study quality, which was in turn based on an assessment of specific aspects of the methodology, focussing on selection, measurement, confounding and analysis. The assessment was only undertaken by one person, which means the final decisions contain a subjective element that will reflect the skills and biases of the assessor. Nevertheless, the assessment was undertaken by a very experienced epidemiologist with particular strength in critical appraisal of epidemiological studies and the assessment was able to be undertaken consistently. Therefore, it is reasonable to consider the quality assessment to have been undertaken thoroughly and to have produced robust results, while accepting that another assessor might have resulted in minor differences in the overall quality assessments.

None of the studies was judged to be of high quality because of one or more areas of weakness in the methodology. This does not mean the investigators had been careless in the way they conducted the study. Usually it meant that the methodology used had some inherent limitations regardless of how well the methodology was applied. In the absence of studies judged as high quality, the report focussed on studies that were judged to be of "moderate" quality. These were studies in which major weakness was unlikely, but there was potential for important weakness in one or more of selection, measurement, control of confounding or analysis that could lead to non-trivial bias. Usually the problem in the moderate quality studies was with the comparison population in studies that used standardisation methods, in the incomplete control of confounding, and/or in the period of follow-up. These limitations mean that while the information provided by the studies can still be useful, the results from individual studies should be considered with caution.

Interpretation and analysis

An explicit description of the main strengths and limitations of each study and the likely implications of these for the study results are provided in Appendix 3. In many instances, it was not possible to be confident in which direction and to what extent a particular result might have been biased. This reinforces the importance of not making conclusions based on the results from a single study. Care must also be taken in assuming that if several studies find a similar result, this means the result is probably reflecting the truth. It may do so, but if the studies use similar methodology then the similarity of results might instead reflect similar biases arising from similar methodological weaknesses.

Relevance to the Australian context

Only three of the studies[10-12] were considered directly relevant to the Australian context. These studies were based on Australian firefighters. All of the other studies were based on firefighters in other countries. However, as argued earlier, it seems likely that the results would be applicable to Australian firefighters, at least those working in an urban environment, because the studies were conducted in developed countries like Australia and the exposures involved are likely to be similar to those experienced by urban firefighters in Australia.

7. CONCLUSIONS

This report provides a review of recent literature addressing the relationship between paid and volunteer work as a firefighter and the risk of cancer. It answers four specific questions in relation to the prescribed cancers aspect of the Act, and provides comment on submissions to the review by the four interested parties who made such submissions. Thirty-three directly relevant papers were identified, summarised and critically appraised (and some other papers considered where relevant to a specific issue). The studies investigated many different types of cancer, some of which appeared to have an increased incidence, some to have decreased incidence and some to have a similar incidence to the relevant comparison populations. Many of the results were not consistent between studies and no formal attempt was made to synthesise the findings. No specific exposures were investigated or identified in any of the papers. The key methodological issues and challenges in the studies have also been considered. The findings of the report should support the review of the Act and evidence-based consideration of approaches to assessing the relationship between paid and volunteer work as a firefighter and the risk of developing cancer.

8. REFERENCES

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APPENDIX 1 – DETAILS OF SEARCH METHODOLOGY

Medline

1 exp Fires/ (9250)

2 Firefighters/ (862)

3 firefighter*.tw. (1971)

4 "fire fighter*".tw. (361)

5 1 or 2 or 3 or 4 (10886)

6 cancer*.mp. (1664418)

7 neoplasm*.mp. (2680582)

8 tumo?r*.tw. (1578932)

9 malignan*.tw. (536396)

10 6 or 7 or 8 or 9 (3626838)

11 5 and 10 (283)

12 limit 11 to humans (243)

13 limit 12 to yr="2006 -Current" (129)

Scopus

(TITLE-ABS-KEY (firefight* OR "fire fight*" OR "fire-fight*") AND TITLE-ABS-KEY (cancer OR neoplasm* AND tumo?r OR malignan*)) AND PUBYEAR > 2005

Web of Science

(firefight* OR "fire fight*" OR "fire-fight*") AND TOPIC: (cancer* OR neoplasm* OR tumo?r* OR malignan*); Timespan: 2006-2019

EMBASE

1 exp Fires/ (12793)

2 Firefighters/ (2536)

3 firefighter*.tw. (2383)

4 "fire fighter*".tw. (485)

5 1 or 2 or 3 or 4 (15680)

6 cancer*.mp. (3364080)

7 neoplasm*.mp. (749624)

8 tumo?r*.tw. (2191314)

9 malignan*.tw. (781973)

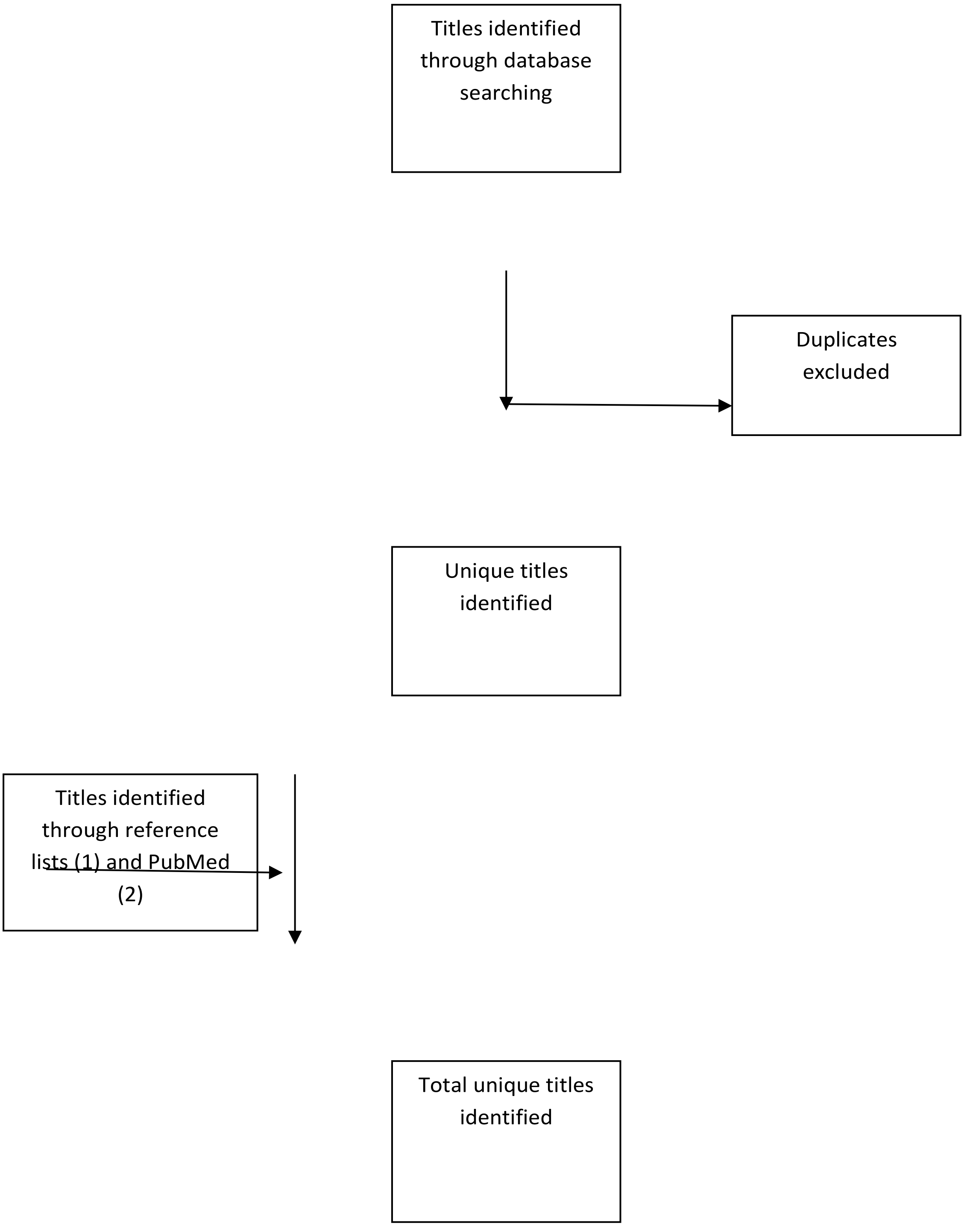
10 6 or 7 or 8 or 9 (4524698)

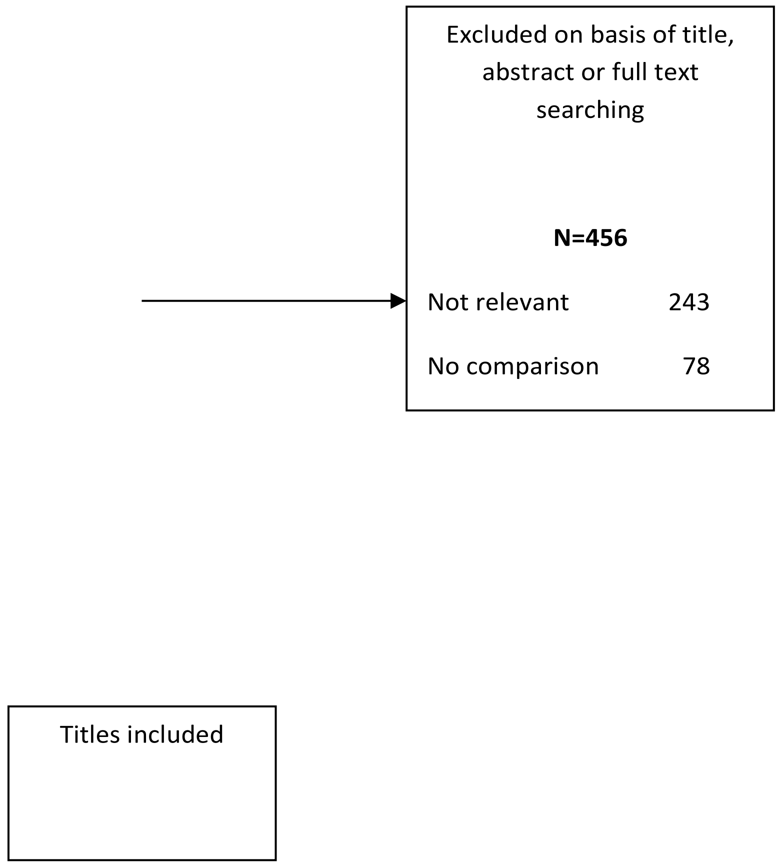
11 5 and 10 (604)

12 limit 11 to human (470)

13 limit 12 to yr="2006 -Current" (361)

Figure 1: Flow chart of study identification and selection




Excluded on basis of title, abstract or full text searching
N=456
Not relevant 243
No comparison 78
Titles included

APPENDIX 2 – SUMMARY OF RESULTS FROM INCLUDED STUDIES

Summary of results from included studies – by study quality*

Author	Year	Type[1]	Location[2]	Mort/Morb[3]	Measure[4]	Quality[5]	All[6]	Bladder	Brain	Breast	Colorectal	Kidney	Leukaemia	Myeloma
Amadeo	2015	Cohort	France	Mort	SMR	M	.	.		.	.	.		
Béranger	2013	Rev	All	Both	None	M								
Bigert	2016	CC	All	Morb	OR	M								
Cumberbatch	2015	M-A	All	Both	sRE	M		1.68						
Daniels	2014	Cohort	U.S.	Both	SMR/SIR	M	1.09	1.12	.	.	1.31	1.27	.	.
Daniels	2015	Cohort	U.S.	Both	HR	M	.	.			0.63		1.45	
Glass_a	2016	Cohort	Australia	Both	SMR/SIR	M	1.09	.	.	.	.	#	.	.
Glass	2017	Cohort	Australia	Both	SMR/SIR	M	0.86	0.60	.	.	0.85	.	.	0.75
Glass	2019	Cohort	Australia	Both	SMR/SIR	M	.	.	.	.	.	.	.	.
Harris	2018	Cohort	Canada	Morb	HR	M	.	.	.	.	.	.	.	.
IARC	2010	M-A	All	Both	sRE	M								.
Jalilian	2019	M-A	All	Both	sRE	M	.	1.12	.	.	1.12	.	.	.
Kullberg	2018	Cohort	Sweden	Morb	SIR	M	0.81				.	.	.	.
LeMasters	2006	M-A	All	Both	sRE	M	.	.	1.32		1.29	.	.	1.53
Paget-Bailly	2013	CC	France	Both	OR	M								
Petersen_a	2018	Cohort	Denmark	Mort	SMR	M	1.12	.			.			
Petersen_b	2018	Cohort	Denmark	Morb	SIR	M	.	.	.		.	.	.	.

Pukkala	2014	Cohort	Nordic	Morb	SIR	M	1.06	.	.		.	.	.	.
Sauve	2016	CC	Canada	Morb	OR	M								
Sritharan_a	2017	M-A	All	Both	sRE	M								
Sritharan	2018	Cohort	Canada	Morb	HR	M								
Youakim	2006	M-A	All	Both	sRE	M	1.04	1.36				1.22		
Ahn	2012	Cohort	Korea	Morb	SIR	F	.	1.60	.		1.27	1.56	.	
Ahn	2015	Cohort	Korea	Mort	SMR	F	0.58				.		.	
Bates	2007	CC	U.S.	Morb	OR	F		.	1.35		.	.	.	
Glass	2012	Cohort	Qld	Morb	SIR	W	.	.	.		.	.	.	.
Glass_b	2016	Cohort	Vic	Both	SMR/SIR	W	0.40							
Ide	2014	Cohort	Scot	Both	SMR/SIR	W	0.70	.	.		.	2.07		
Kang	2008	Cohort	U.S.	Morb	SMOR	W		.	1.90	.	1.36	.	.	.
Ma	2006	Cohort	U.S.	Morb	SIR	W	0.84	1.29	.	.	.	.	.	
Muegge	2018	CCom	U.S.	Mort	OR	W	1.19		1.98	.		1.84		
Sritharan_b	2017	CC	Canada	Morb	OR	W								
Tsai	2015	CC	U.S.	Morb	OR	W		.	1.54		.	1.27	1.32	1.35

*: The green cells show the cancer types for which the point estimate was above one and the confidence intervals excluded one. The orange cells show the cancer types for which the point estimate was below one and the confidence intervals excluded one. The grey cells show cancers types examined but for which the confidence interval included one.

1: Study type (CC=case-control; CCom-Case-comparison; M-A=meta-analysis; Rev=systematic review)

2: Location (Qld=Queensland; Scot=Scotland; Vic=Victoria; U.S.=United States

5: Quality (F=fair; M=moderate; W=weak)

6.: # in a cell means there was evidence of dose-response

3: Mortality or morbidity (mort=mortality; morb=morbidity)   4: HR=hazard ratio; OR=odds ratio; SIR=Standardised Incidence Ratio; SMR=Standardised Incidence Ratio; sRE=summary risk estimate

Summary of results from included studies – by study quality (continued)*

Author	Year	Type[1]	Location[2]	Mort/Morb[3]	Measure[4]	Quality[5]	NHL[6]	Oesophagus	Prostate	Testis	Ureter	Hodgkin's	Lung
Amadeo	2015	Cohort	France	Mort	SMR	M		.	0.54				0.86
Béranger	2013	Rev	All	Both	None	M							
Bigert	2016	CC	All	Morb	OR	M							.
Cumberbatch	2015	M-A	All	Both	sRE	M							
Daniels	2014	Cohort	U.S.	Both	SMR/SIR	M	.	1.62	.	.			1.12
Daniels	2015	Cohort	U.S.	Both	HR	M	.	.	0.61				1.39
Glass_a	2016	Cohort	Australia	Both	SMR/SIR	M	#	.	1.31	.		.	0.71
Glass	2017	Cohort	Australia	Both	SMR/SIR	M	0.83	0.65	1.08	.		.	0.48
Glass	2019	Cohort	Australia	Both	SMR/SIR	M	.	.				.	.
Harris	2018	Cohort	Canada	Morb	HR	M	.	.	1.18	.		2.89	.
IARC	2010	M-A	All	Both	sRE	M	1.21		1.30	1.47			
Jalilian	2019	M-A	All	Both	sRE	M	1.42	.	1.15	1.38		.	.
Kullberg	2018	Cohort	Sweden	Morb	SIR	M	.	.	0.68	.		.	.
LeMasters	2006	M-A	All	Both	sRE	M	1.51	.	1.28	2.02		.	.
Paget-Bailly	2013	CC	France	Both	OR	M							
Petersen_a	2018	Cohort	Denmark	Mort	SMR	M			0.66				.
Petersen_b	2018	Cohort	Denmark	Morb	SIR	M	.	.	.	.		.	.

Pukkala	2014	Cohort	Nordic	Morb	SIR	M	.	.	1.13	0.51			1.29
Sauve	2016	CC	Canada	Morb	OR	M			.				
Sritharan_a	2017	M-A	All	Both	sRE	M			1.17				
Sritharan	2018	Cohort	Canada	Morb	HR	M			1.17				
Youakim	2006	M-A	All	Both	sRE	M	1.40						
Ahn	2012	Cohort	Korea	Morb	SIR	F	1.69	.	.				.
Ahn	2015	Cohort	Korea	Mort	SMR	F							0.58
Bates	2007	CC	U.S.	Morb	OR	F	.	1.48	1.22	1.54			.
Glass	2012	Cohort	Qld	Morb	SIR	W	.	.	.	.			.
Glass_b	2016	Cohort	Vic	Both	SMR/SIR	W			.	.			
Ide	2014	Cohort	Scot	Both	SMR/SIR	W				.			.
Kang	2008	Cohort	U.S.	Morb	SMOR	W	.	.	.	.			.
Ma	2006	Cohort	U.S.	Morb	SIR	W	.	.	.	1.60		.	0.65
Muegge	2018	CCom	U.S.	Mort	OR	W				.			
Sritharan_b	2017	CC	Canada	Morb	OR	W			1.67				
Tsai	2015	CC	U.S.	Morb	OR	W	.	1.85	1.45	.		.	2.01

*: The green cells show the cancer types for which the point estimate was above one and the confidence intervals excluded one. The orange cells show the cancer types for which the point estimate was below one and the confidence intervals excluded one. The grey cells show cancers types examined but for which the confidence interval included one.

1: Study type (CC=case-control; CCom-Case-comparison; M-A=meta-analysis; Rev=systematic review)

5: Quality (F=fair; M=moderate; W=weak)

2: Location (Qld=Queensland; Scot=Scotland; Vic=Victoria; U.S.=United States)

6.: # in a cell means there was evidence of dose-response

3: Mortality or morbidity (mort=mortality; morb=morbidity)   4: HR=hazard ratio; OR=odds ratio; SIR=Standardised Incidence Ratio; SMR=Standardised Incidence Ratio; sRE=summary risk estimate

Summary of results from included studies – by study quality (continued)*

Author	Year	Type[1]	Location[2]	Mort/Morb[3]	Measure[4]	Quality[5]	Melanoma[6]	Mesothelioma	Stomach	Skin	Thyroid	ALL LH	Others
Amadeo	2015	Coh	France	Mort	SMR	M			.	.		.	
Béranger	2013	Rev	All	Both	None	M							
Bigert	2016	CC	All	Morb	OR	M							
Cumberbatch	2015	M-A	All	Both	sRE	M							
Daniels	2014	Coh	U.S.	Both	SMR/SIR	M		2.29	.				.
Daniels	2015	Coh	U.S.	Both	HR	M							
Glass_a	2016	Coh	Australia	Both	SMR/SIR	M	1.44	.	.		.	.	.
Glass	2017	Cohort	Australia	Both	SMR/SIR	M	.	0.64	0.69		.	0.81	.
Glass	2019	Cohort	Australia	Both	SMR/SIR	M	1.25	.	.		.	.	.
Harris	2018	Coh	Canada	Morb	HR	M	1.67	.	.		.		.

IARC	2010	M-A	All	Both	sRE	M							
Jalilian	2019	M-A	All	Both	sRE	M	1.21	1.60	.	.	1.22		.
Kullberg	2018	Coh	Sweden	Morb	SIR	M	0.30	.	1.89			.	.
LeMasters	2006	M-A	All	Both	sRE	M	1.32		1.22	1.39			.
Paget-Bailly	2013	CC	France	Both	OR	M							#
Petersen_a	2018	Coh	Denmark	Mort	SMR	M			1.96			.	.
Petersen_b	2018	Coh	Denmark	Morb	SIR	M	.	.	.	.	.		#
Pukkala	2014	Coh	Nordic	Morb	SIR	M	1.25	.	.	1.33	.		.
Sauve	2016	CC	Canada	Morb	OR	M							
Sritharan_a	2017	M-A	All	Both	sRE	M							
Sritharan	2018	Coh	Canada	Morb	HR	M							
Youakim	2006	M-A	All	Both	sRE	M							

Ahn	2012	Coh	Korea	Morb	SIR	F			.		.	.	
Ahn	2015	Coh	Korea	Mort	SMR	F			.			.	
Bates	2007	CC	U.S.	Morb	OR	F	1.50		.		.		.
Glass	2012	Coh	Qld	Morb	SIR	W	.		.				
Glass_b	2016	Coh	Vic	Both	SMR/SIR	W	.				.		
Ide	2014	Coh	Scot	Both	SMR/SIR	W	1.68			.			.
Kang	2008	Coh	U.S.	Morb	SMOR	W	0.65		.		.		.
Ma	2006	Coh	U.S.	Morb	SIR	W			0.50	.	1.77	0.68	#
Muegge	2018	CCom	U.S.	Mort	OR	W						.	.
Sritharan_b	2017	CC	Canada	Morb	OR	W							
Tsai	2015	CC	U.S.	Morb	OR	W	1.75	.	.		.		#

*: The green cells show the cancer types for which the point estimate was above one and the confidence intervals excluded one. The orange cells show the cancer types for which the point estimate was below one and the confidence intervals excluded one. The grey cells show cancers types examined but for which the confidence interval included one.

1: Study type (CC=case-control; CCom-Case-comparison; Coh=Cohort; M-A=meta-analysis; Rev=systematic review)

5: Quality (F=fair; M=moderate; W=weak)

2: Location (Qld=Queensland; Scot=Scotland; Vic=Victoria; U.S.=United States

6.: # in a cell means there was evidence of dose-response

3: Mortality or morbidity (mort=mortality; morb=morbidity) 4: HR=hazard ratio; OR=odds ratio; SIR=Standardised Incidence Ratio; SMR=Standardised Incidence Ratio; sRE=summary risk estimate

APPENDIX 3 – REVIEW OF RELEVANT PAPERS

[In the following descriptions, the reported results in brackets are the point estimate of the relevant measure, followed by the 95% confidence interval.]

Ahn et al, 2012: Cancer morbidity of professional emergency responders in Korea[4]

This was an incidence study of a cohort of male Korean professional emergency responders, 88% of whom were firefighters, employed for at least one month between 1980 and 2007 and followed up between 1996 and 2007 inclusive (the information presented here is just for firefighters). The cohort was assembled from administrative records. Employment information was linked to national death registry information to determine vital status. Mean age at the end of follow up was 42 years. Mean employment duration was 12 years. Twenty cancer outcomes were examined. The main outcome measure was the Standardised Incidence Ratio (SIR), calculated using the Korean male population as the reference population and taking into account age and calendar year, with a one-year lag. In addition, relative risks were calculated comparing firefighters to non-firefighter emergency responders within the cohort.

The main findings of relevance were:

- Colon and rectum cancer SIR was increased (1.27, 1.01–1.59)
- Kidney cancer SIR was increased (1.56, 1.01–2.41)
- Bladder cancer SIR was increased (1.60, 1.01–2.56)
- Non-Hodgkin's lymphoma SIR was increased (1.69, 1.01–2.67)
- For other cancer types, there was no strong evidence of increased risk.

The study had several strengths. It appears to have used appropriate methods and analysis and only professional firefighters were included in the cohort. The measurement of the presence and type of cancer, and of the included confounders, would be expected to be good, given the sources and nature of the information.

As with most SIR studies, the major potential weaknesses were selection bias that can result if the comparison group used was not appropriate; and the limited control of potential confounding, with only gender, age, race and calendar year controlled for. This is a concern in regards to these issues in this study, with firefighters expected to have been healthier than the general population and they might well have had a lower exposure to important lifestyle and other factors that are known to increase the risk of cancer, with smoking a key example of this. This would have the tendency to under-estimate any increased risk that might be associated with exposure arising from work as a firefighter. Alternatively, firefighters could have worked in other occupations with exposure to carcinogens and the authors suggested firefighters might drink more than the general population. These factors would have the tendency to over-estimate any increased risk that might be associated with exposure arising from work as a firefighter. The number of cases was not large, leading to potential problems with a lack of precision for all but the most common cancer types. In addition, the follow-up time was reasonably short and the cohort members were fairly young, which might have led to an underestimation of any risk associated with firefighting. There was no direct measure of exposure.

The quality of this study was assessed as Fair.

Ahn and Jeong, 2015: Mortality due to malignant and non-malignant diseases in Korean professional emergency responders[3]

This was a mortality study of a cohort of male Korean professional emergency responders, 88% of whom were firefighters, employed for at least one month between 1980 and 2007 and followed up between 1992 and 2007 inclusive (the information presented here is just for firefighters). The cohort was assembled from administrative records. Employment information was linked to national death registry information to determine vital status. Mean age at the end of follow up was 42 years. Mean employment duration was 16 years. Seven cancer outcomes were examined. The main outcome measure was the Standardised Mortality Ratio (SMR), calculated using the Korean male population as the reference population and taking into account age and calendar year, with a one-year lag. In addition, relative risks were calculated comparing firefighters with lengthy employment to firefighters with less than 10 years of employment and non-firefighters within the cohort.

The main findings of relevance were:

- All-cancer SMR was considerably decreased (0.58, 0.50–0.68)
- Liver and intrahepatic bile duct cancer SMR was decreased (0.55, 0.41–0.73)
- Lung cancer SMR was decreased (0.58, 0.38–0.84)
- For other cancer types, there was no strong evidence of increased risk.
- Compared to firefighters with less than 10 years of employment and non-firefighters within the cohort, firefighters with 20 more years experience had:
    - Higher All-cancer risk (1.54, 1.02–2.31)
    - Higher leukaemia risk, but based on only two cases
    - No increased risk in other individual cancer types

The study had several strengths. It appears to have used appropriate methods and analysis and only professional firefighters were included in the cohort. The measurement of the presence and type of cancer, and of the included confounders, would be expected to be good, given the sources and nature of the information.

As with most SMR studies, the major potential weaknesses were selection bias that can result if the comparison group used was not appropriate; and the limited control of potential confounding, with only gender, age, race and calendar year controlled for. This is a concern in regards to these issues in this study, with firefighters expected to have been healthier than the general population and they might well have had a lower exposure to important lifestyle and other factors that are known to increase the risk of cancer, with smoking a key example of this. This would have the tendency to under-estimate any increased risk that might be associated with exposure arising from work as a firefighter. Alternatively, firefighters could have worked in other occupations with exposure to carcinogens and the authors suggested firefighters might drink more than the general population. These factors would have the tendency to over-estimate any increased risk that might be associated with exposure arising from work as a firefighter. The number of cases was not large, leading to potential problems with a lack of precision for all but the most common cancer types. In addition, the follow-up time was reasonably short and the cohort members were fairly young, which might have led to an underestimation of any risk associated with firefighting. There was no direct measure of exposure.

The quality of this study was assessed as Fair.

Amadeo et al, 2015: French firefighter mortality: analysis over a 30-year period[5]

This was a cancer mortality study of a cohort of male French professional firefighters (no minimum period of service was mentioned), covering the years 1979 to 2008 inclusive, and comprised of firefighters employed in 1979. The cohort was assembled from administrative records. Personal information was linked to national statistics to determine vital status. Mean employment duration was 29 years. Sixteen cancer outcomes were examined. The outcome measure was the Standardised Mortality Ratio (SMR), calculated using the French male population as the reference population and taking into account age and calendar year.

The main findings of relevance were:

- All-cancer SMR was not increased (0.95, 0.88–1.02)
- Lung cancer SMR was decreased (0.86, 0.74–0.99)
- Prostate cancer SMR was decreased (0.54, 0.31–0.86)
- For other cancers, there was no strong evidence of increased risk.

The study had several strengths. It appears to have used appropriate methods and analysis and only professional firefighters were included in the cohort. The measurement of the presence and type of cancer, and of the included confounders, would be expected to be good, given the sources and nature of the information. The follow-up time and the age of the cohort members should have been adequate to provide reasonable quality information on cancers due to employment in firefighting. The large number of subjects and cases allowed reasonable precision with most of the measures.

As with most SMR studies, the major potential weaknesses were selection bias that can result if the comparison group used was not appropriate; and the limited control of potential confounding, with only age, calendar time and gender (by exclusion of females) able to be controlled for. This is a concern in regards to these issues in this study, with firefighters expected to have been healthier than the general population and they might well have had a lower exposure to important lifestyle and other factors that are known to increase the risk of cancer, with smoking a key example of this. This would have the tendency to under-estimate any increase risk that might be associated with exposure arising from work as a firefighter. Alternatively, there was the possibility of some uncontrolled confounding from other important potential confounders, such as alcohol and other occupations, which result in bias in either direction. There was no direct measure of exposure.

The quality of this study was assessed as Moderate.

Bates, 2007: Registry-based case–control study of cancer in California firefighters[22]

This was a case-control study of cancers potentially related to male firefighters in the United States (California) (no minimum period of service was required), covering the years 1988 to 2003 inclusive. Cases were people with one of the cancers of a-priori interest or a cancer that occurred in more than 50 firefighters. They were identified from the state cancer registry. Controls were persons recorded on the registry with cancers others than those of a priori interest. The exposure was usual (the longest held) occupation, which was determined from text fields in the registry data. There was no information on employment duration. Sixteen cancer outcomes were examined. The outcome measure was the odds ratio, as a measure of risk. The potential confounders age, ethnicity and socioeconomic status were adjusted for in the analysis.

The main findings of relevance were:

- Oesophageal cancer risk was increased (1.48, 1.14-1.91)
- Melanoma risk was increased (1.50, 1.33-1.70)
- Prostate cancer risk was increased (1.22, 1.12-1.33)
- Testicular cancer risk was increased (1.54, 1.18-2.02)
- Brain cancer risk was increased (1.35, 1.06-2.72)
- For other cancers, there was no strong evidence of increased risk.

The study had several strengths. The general methods and analysis appeared appropriate. The large number of cases and controls provided reasonable precision. Participation proportion was good – occupation information was missing for 13% (although no information was provided on the excluded subjects). The coverage of cases would be expected to be almost complete and the recording of cancer type to be accurate.

The study had several limitations. The main one arises from the choice of controls from other cancer subjects, as they may not represent the exposure distribution (employment as a firefighter) of the study base from which the cases came. This could bias the results in either direction. There was also the possibility of inaccurate recording of occupation; and some subjects retiring and starting second jobs. The effect of these potential measurement issues is not clear. There was the possibility of some uncontrolled confounding from important potential confounders (e.g. smoking, alcohol, other occupations), which could result in bias in either direction. There was no direct measure of exposure.

The quality of this study was assessed as Fair.

Beranger et al, 2013: Occupational and environmental exposures associated with testicular germ cell tumours: systematic review of prenatal and life-long exposures[34]

This was a systematic review of risk of testicular germ cell tumour incidence arising from occupational and environmental exposures. Firefighters were one of a large number of occupational categories examined. Papers published from 1990 to 2012 inclusive were included. Study quality was formally assessed. No meta-analysis was conducted.

The study identified five studies that examined the relationship between work as a firefighter and the risk of testicular cancer. It reported that three studies found an excess risk, two (both smaller studies with low power) did not and all five did not consider relevant potential confounding factors. There was no numeric finding regarding the relationship between work as a firefighter and the risk of testicular cancer.

The study appears to have been conducted reasonably well, with appropriate methods and analysis. The search for studies was thorough. Study quality was assessed but there was little information supplied about the results beyond the numeric quality score.

The lack of a meta-analysis meant that the study has very limited relevance to the current report.

The quality of this study was assessed as Moderate.

Bigert et al, 2016: Lung cancer among firefighters: smoking-adjusted risk estimates in a pooled analysis of case-control studies[23]*

This study examined lung cancer risk in male firefighters. It involved a pooled analysis of data from 14 case control studies (from Europe, Canada, New Zealand and China) included in the larger SYNERGY study. The approach allowed information on smoking and lifetime work history to be taken into account in the analysis. About half the studies used controls obtained from the population and the other half used controls obtained from hospitals, with two studies using controls obtained from both sources. Information was obtained from self-report by the subject (or next of kin). Potential confounders considered in the analysis were age, smoking history and "having ever been employed in a job known to present an excess risk of lung cancer". Sub-analyses were conducted using strata of smoking, lung cancer cell type and firefighter type.

The main findings of relevance were:

- Overall lung cancer risk was not increased (0.95, 0.68–1.32)
- Lung cancer risk for specific cell types was not increased
- Lung cancer risk for different smoking categories was not increased
- Lung cancer risk for different duration of exposure was not increased
- Results did not change depending on firefighter type.

Strengths of the study include the large number of cases and controls (although the number of exposed cases and controls was not high, limiting the power). Participation proportion was reasonable – 84% for cases and 78% for controls. There appeared to be good control of the main potential confounding factors - age, smoking history and employment in an occupation associated with increased risk of lung cancer. However, the possibility of some uncontrolled confounding (e.g. from asbestos, inadequately controlled smoking or different firefighting type or era) remained a possibility.

The study had several limitations. In terms of selection, many of the controls were selected from hospitals rather than randomly from the study base, raising the possibility that the controls were not appropriate. Any resulting bias might under or over-estimate any harmful (or protective) effects of firefighting. However, the authors argued that this would be unlikely to have led to an underestimate of any harmful effect because those studies which used hospital controls had an overall estimate of effect of slightly more than 1.0. The lack of participation of some initially selected controls (and cases) meant that the included subjects might not appropriately represent all eligible subjects, which again could lead to an under or over-estimate of any harmful (or protective) effects of firefighting. Any effect from this is not expected to be important because the participation proportions were reasonable.

In terms of measurement, information on exposure (occupation) and on potential confounders such as smoking came from self-report (or report from next of kin) and so would have been susceptible to a bias in reporting, including classical recall bias. It is unlikely this would have been important in the current study in terms of occupation because there would have been no reason for subjects to preferentially report being a firefighter as opposed to having a different occupation, and information was collected on all occupations ever worked. Nevertheless, there may have been some general error in occupational assessment, which might be expected to lead to some underestimation of risk. Cases may have been more likely to report smoking than controls, because of the known connection to lung cancer. The extent of such reporting issues is difficult to gauge but it is considered not likely to have been important in this study. There was no direct measure of exposure.

The quality of this study was assessed as Moderate.

* A letter was written about this study in regards to its relevance in terms of providing information on the risk of lung cancer from firefighting in non-smokers. The study authors provided a written response to this letter:

Guidotti and Goldsmith, 2017: Lung Cancer Risk Among Non-Smoking Firefighters

- Bigert et al, 2017: Lung Cancer Risk Among Non-Smoking Firefighters.

Cumberbatch et al, 2015: Contemporary occupational carcinogen exposure and bladder cancer. A systematic review and meta-analysis[29#]

This was a systematic review of risk of bladder cancer incidence and mortality arising from occupational exposures. Firefighters was one of a large number of occupational categories examined. Papers published up to 2014 were included. A random-effects model was used to calculate the meta-analytic estimate of effect.

The main finding of relevance was:

- Bladder cancer incidence was not increased in firefighters (1.00, 0.90-1.12)
- Bladder cancer mortality was increased in firefighters (1.68, 1.16-2.45).

The study appears to have been conducted reasonably well, with appropriate methods and analysis. The search for studies was thorough.

The main potential limitations were apparently not assessing study quality; heterogeneity for some analyses (although that information wasn't presented for the firefighter analysis); possible relevant publication bias ((although that information wasn't presented for the firefighter analysis); and limitations in the methodology of some of the individual studies that were included. There was also no discussion of why the incidence and mortality analyses provided very different results. There was no direct measure of exposure.

The quality of this study was assessed as Moderate.

Cumberbatch et al, 2015 was found by accident when searching for another bladder cancer reference.

Cumberbatch et al, 2017 was found at the same time. It was excluded because it covered the same material as Cumberbatch et al, 2015 but only for the UK.

Daniels et al, 2014: Mortality and cancer incidence in a pooled cohort of US firefighters from San Francisco, Chicago and Philadelphia (1950–2009)[7]

This was a cancer mortality and incidence study of a cohort of male and female United States 'career' firefighters (from three city districts – Chicago, Philadelphia and San Francisco) who had worked for at least one year, covering the years 1950 to 2009 inclusive. The cohort was assembled from employment records and data from previous studies. Personal information was linked to 11 state cancer registries (the 11 states covered 95% of all deaths in three states from which the subjects were selected) and for mortality to a number of administrative and previous study records, including the National Death Index-Plus and social security information. Mean employment duration was 21 years, mean follow-up was 29 years and mean age at the end of follow-up was 60 years. Twenty cancer outcomes were examined. The outcome measures were the Standardised Mortality Ratio (SMR) and the Standardised Incidence Ratio (SIR), calculated using the United States population as the reference population and taking into account gender, age, race and calendar year. The SIR was calculated using two methods - all primary cancers and first primary cancers. There were also several sensitivity analyses undertaken.

The main findings of relevance were:

- All-cancer SMR was increased (1.14, 1.10–1.18)
- All-cancer SIR was increased (1.09, 1.06–1.12)
- Oesophageal cancer SMR (1.39, 1.14–1.67) and SIR (1.62, 1.31–2.00) were increased
- Large intestine cancer SMR (1.31, 1.16–1.48) and SIR (1.21, 1.09–1.34) were increased
- Lung cancer SMR (1.10, 1.04–1.17) and SIR (1.12, 1.04–1.21) were increased
- Kidney cancer SMR (1.29, 1.05–1.58) and SIR (1.27, 1.09–1.48) were increased
- Mesothelioma SMR (2.00, 1.03–3.49) and SIR (2.29, 1.60–3.19) were increased
- Bladder cancer SIR was increased (1.12, 1.00–1.25)
- Buccal cavity and pharynx cancer SMR (1.40, 1.13–1.72) and SIR (2.29, 1.60–3.19) were increased
- For other cancers, there was no strong evidence of increased risk.

The study had several strengths. It appears to have used appropriate methods and analysis and only professional firefighters were included in the cohort. The measurement of the presence and type of cancer, and of the included confounders, would be expected to be good, given the sources and nature of the information. The follow-up time and the age of the cohort members should have been adequate to provide reasonable quality information on cancers due to employment in firefighting. The large number of subjects and cases allowed reasonable precision with most of the measures.

As with most SMR studies, the major potential weaknesses were selection bias that can result if the comparison group used was not appropriate; and the limited control of potential confounding, with only age, calendar time and gender able to be controlled for. This is a concern in regards to these issues in this study, with firefighters expected to have been healthier than the general population and they might well have had a lower exposure to important lifestyle and other factors that are known to increase the risk of cancer, with smoking a key example of this. This would have the tendency to under-estimate any increase risk that might be associated with exposure arising from work as a firefighter. Alternatively, there was the possibility of some uncontrolled confounding from other important potential confounders, such as alcohol and other occupations, which could result in bias in either direction. There was no direct measure of exposure.

The quality of this study was assessed as Moderate.

Daniels et al, 2015: Exposure–response relationships for select cancer and non-cancer health outcomes in a cohort of US firefighters from San Francisco, Chicago and Philadelphia (1950–2009)[6]

This was a further analysis of a cancer mortality and incidence study of a cohort of male and female United States ‘career’ firefighters (from three city districts – Chicago, Philadelphia and San Francisco) who had worked for at least one year, covering the years 1950 to 2009 inclusive. The cohort was assembled from employment records and data from previous studies. Personal information was linked to 11 state cancer registries (the 11 states covered 95% of all deaths in three states from which the subjects were selected) and for mortality to a number of administrative and previous study records, including the National Death Index-Plus and social security information. Subjects who developed cancer were identified. For each of these ‘cases’, 200 subjects who had not developed cancer were selected from the cohort, using incidence density sampling with matching on age. Mean employment duration was 21 years. The study examined cancer incidence and mortality in relation to three measures of exposures – “the number of days worked in a job or location that had a potential for occupational exposure (exposed-days)”; attendance at fires (“fire runs”); and “deployment time”, which was considered equivalent to time spent at a fire and so assumed to be the best measure of cumulative exposure to fire-related carcinogens. Eight cancer outcomes were examined - all-cancers; bladder cancer, colorectal cancer, lung cancer, oesophageal cancer, prostate cancer, leukaemia and non-Hodgkin’s lymphoma. The analysis was undertaken using methods akin to Cox Proportional Hazards, with several specific models used. Comparisons were between subjects exposed at the 75th centile compared to subjects at the 25th centile of exposure. Potential confounders controlled for in the analysis were age, race, fire department and birth cohort. There were also several sensitivity analyses undertaken.

The main findings of relevance were:

- All-cancer mortality and incidence were not related to any exposure measure
- Lung cancer mortality (1.39, 1.12–1.73) and incidence (1.39, 1.10–1.74) were increased with increasing fire-hours and there was some evidence of a dose-response
- Leukaemia mortality was increased with increasing fire-runs (1.45, 1.00–2.35) and there was some evidence of a dose-response
- Colorectal cancer mortality decreased with all three exposure measures (0.63, Not calculable – 0.93 for fire-hours)
- Prostate cancer mortality decreased with fire runs (0.71, Not calculable – 0.90) and fire hours (0.61, Not calculable – 0.92)
- For other cancers, there was no strong evidence of increased risk with any exposure measure

The study had several strengths. It appears to have used appropriate methods and analysis and only professional firefighters were included in the cohort. The internal analyses should have overcome many of the concerns regarding inappropriate comparison populations that were common in other studies. The identification of cancer should have been essentially complete, given the high coverage and presumed quality of the included registries. Three quantitative measures of exposure were used, which should have improved the accuracy of risk measures to the extent any increased (or decreased) risk was related to exposures connected to attending fires. The exposure measures were assessed reasonably objectively. The measurement of the presence and type of cancer, and of the included confounders, would be expected to be good, given the sources and nature of the information. The follow-up time and the age of the cohort members should have been adequate to provide reasonable quality information on cancers due to employment in firefighting. The large number of subjects and cases allowed reasonable precision with most of the measures.

The main weakness was the lack of control of confounders apart from age, race, fire department and birth cohort. In particular, there was no control of the potential confounding effects of smoking, alcohol, diet, other relevant lifestyle-related exposures and occupational exposures. Any confounding effects could have led to an over or underestimation of increased (or decreased) risk.

The quality of this study was assessed as Moderate.

Glass et al, 2012: Cancer incidence in a cohort of active firefighters in Queensland[9]

This was a small cancer incidence study of a cohort of Australian (Queensland) paid firefighters. The included subjects were employed (full-time or part-time) at some time between 1995 and 2006. The cohort was assembled from firefighting agency employment information. Personal information was linked to the Queensland Cancer Registry. The main outcome measure was the Standardised Incidence Ratio (SIR), calculated using the Queensland population as the reference and taking into account age, with separate analyses for males and females. Analyses were undertaken for a range of cancer types.

The main findings of relevance were:

- No cancer type had a raised SIR with a confidence interval that didn't cross one.

The study appears to have used appropriate methods and analysis. It appears only professional firefighters were included in the cohort. The identification of cancer should have been essentially complete, given the high quality of the Queensland Cancer Registry.

As with most SIR studies, the major potential weaknesses were selection bias that can result if the comparison group used was not appropriate; and the limited control of potential confounding, with only age and gender (by exclusion of females) able to be controlled for. This is a concern in regards to these issues in this study, with firefighters expected to have been healthier than the general population and they might well have had a lower exposure to important lifestyle and other factors that are known to increase the risk of cancer, with smoking a key example of this. This would have the tendency to under-estimate any increased risk that might be associated with exposure arising from work as a firefighter. Alternatively, there was the possibility of some uncontrolled confounding from other important potential confounders, such as alcohol and other occupations, which could result in bias in either direction. There was no direct measure of exposure. The number of subjects was small and the period of follow-up short. So, the study had low power to identify any increased (or decreased) risk of cancer associated with firefighting. There was no direct measure of exposure.

The quality of this study was assessed as Weak.

Glass et al, 2016a: Mortality and cancer incidence in a cohort of male paid Australian firefighters[10]

This was a cancer incidence and mortality study of a cohort of male Australian paid firefighters. The commencement dates varied from 1976 to 2003. Information was available on the number and type of fire incidents attended by each subjects. Subjects had worked as firefighters for at least three months. The cohort was assembled from employment information provided by six of the eight Australian firefighting agencies. Personal information was linked to the Australian National Deaths Index (NDI) and the Australian Cancer Database (ACD). Follow-up for the NDI was from January 1980 to November 2011 and for the ACD was from January 1982 to December 2010. Mean employment duration was 17 years, mean follow-up was 16 years for the deaths analysis (mean follow-up for the incidence analysis was probably slightly less than this), mean age at employment was 34 years and mean age at end of follow-up was 50 years. The main outcome measures were the Standardised Incidence Ratio (SIR) and the Standardised Mortality Ratio (SMR), calculated using the Australia male population as the reference and taking into account age and calendar year. In addition to the overall analysis, internal analyses were conducted based on years of employment (in 10-year groups) and number of fire incidents attended, stratified by incident type. Analyses were undertaken for all deaths, all cancers and for some major cancer types.

The main findings of relevance were:

- All-cancer SMR was decreased (0.81, 0.74 to 0.89)
- All-cancer SIR was increased (1.09, 1.03 to 1.14)
- Melanoma SIR was increased (1.44, 1.28 to 1.62)
- Prostate cancer SIR was increased (1.31, 1.19 to 1.43)
- Liver cancer SIR was decreased (0.56, 0.29 to 0.97)
- Lung cancer SIR was decreased (0.71, 0.58 to 0.86)
- For other cancers, there was no strong evidence of increased risk
- Increased relative cancer incidence ratios with length of employment for kidney cancer and non-Hodgkin's lymphoma
- Increased relative cancer incidence ratios with number of vehicle fire incidents attended for cancer overall
- Increased relative cancer incidence ratios with number of fire incidents (overall and for the separate categories of fire type) attended for prostate cancer.

The study appears to have used appropriate methods and analysis. It appears only professional firefighters were included in the cohort. The follow-up time and the age of the cohort members should have been adequate to provide reasonable quality information on cancers due to employment in firefighting, but longer follow-up would provide more definitive information. The identification of cancer should have been essentially complete, given the high quality of the NDI and ACD in Australia.

As with most SMR studies, the major potential weaknesses were selection bias that can result if the comparison group used was not appropriate; and the limited control of potential confounding, with only age, calendar time and gender (by exclusion of females) able to be controlled for. This is a concern in regards to these issues in this study, with firefighters expected to have been healthier than the general population and they might well have had a lower exposure to important lifestyle and other factors that are known to increase the risk of cancer, with smoking a key example of this. This would have the tendency to under-estimate any increased risk that might be associated with exposure arising from work as a firefighter. Alternatively, there was the possibility of some uncontrolled confounding from other important potential confounders, such as alcohol and other occupations, which could result in bias in either direction. There was no direct measure of exposure.

Another potential problem was that both prostate cancer and melanoma are subject to screening tests and as a result a higher incidence may be due to increased detection through screening rather than to a true increased incidence. The authors argued the issue of screening was unlikely to be a problem in this study because firefighters were not offered screening for prostate cancer or melanoma as part of their employment. That sounds plausible but doesn't exclude the possibility that firefighters organised their own screening or that their doctors proposed such screening. This is especially the case if either the firefighters or their doctors were aware of results from previous studies that suggested an increase in risk of prostate cancer and melanoma.

The quality of this study was assessed as Moderate.

Glass et al, 2016b: Mortality and cancer incidence at a fire training college[8]

This was a cancer incidence and mortality study of a cohort of male Australian firefighters and firefighter trainers who had attended a firefighter training facility (at Fiskville) in Victoria (three females had initially been included but none died or developed cancer and so the analysis was based only on males). The cohort members were a mixture of paid firefighters receiving training and paid or volunteer trainers. The study wasn't really of firefighter work but of the potential effect of exposure to a range of hazardous substances present at the training facility. The employing authority (Country Fire Authority) allocated cohort members into one of three groups based on the assessed level of chronic exposure – "*high (practical areas for drills [PAD] operators and paid Fiskville instructors), medium (volunteer and paid regional staff instructors) or low (paid practical firefighting trainees)*". The analysis below focuses on the low exposure group because that consisted only of paid firefighters.

The earliest commencement dates for the cohort were 1980 for the deaths analysis and 1982 for the cancer incidence analysis, but subjects joined after this as they became eligible. The cohort was assembled from a variety of sources, including employment records, photographs, other documents and reports from other cohort members. Personal information was linked to the Australian National Deaths Index (NDI), the Australian Cancer Database (ACD) and the Victorian Cancer Registry (VCR). Follow-up for deaths in the NDI was from January 1980 to November 2011 and for cancers (NCD and VCR) was from January 1982 to December 2012. The mean age at entry to the cohort was 27 years and mean age at end of follow-up for mortality was 51 years. The main outcome measures were the Standardised Incidence Ratio (SIR) and the Standardised Mortality Ratio (SMR). The SIR was calculated using the Victorian male population as reference and the SMR was calculated using the Australia male population as the reference. In addition to the overall analysis, internal analyses were conducted comparing rates in the high and medium groups to rates in the low groups. All analyses appear to have taken into account age and calendar year. Analyses were undertaken for all deaths, all cancers and for some major cancer types.

The main findings of relevance were:

- All-cancer SMR for the low exposure group was not reliable as there was only one cancer death
- For the low exposure group, the all-cancer SIR was decreased (0.40, 0.15–0.87)
- For the low exposure group, the low number of incident cancers meant the confidence intervals were wide and the results too imprecise to be useful. The point estimate for melanoma was above 1.0 (1.43, 0.29–4.18), but with a wide confidence interval.
- *For the high exposure group, the all-cancer SIR was increased (1.85, 1.20–2.73)*
- *For the high exposure group, the SIR for melanoma was increased (4.59, 1.68–9.99)*
- *For the high exposure group, the SIR for testicular cancer was increased but was very imprecise (13.0, 1.58–47.1).*
- *The risk of cancer was raised in the high and medium exposure groups compared to the low exposure group.*

The study appears to have used appropriate methods and analysis. The main strengths were that the identification of cancer should have been essentially complete, given the high quality of the NDI and ACD in Australia.

As with most SMR studies, the major potential weaknesses were selection bias that can result if the comparison group used was not appropriate; and the limited control of potential confounding, with only age, calendar time and gender (by exclusion of females) able to be controlled for. This is a concern in regards to these issues in this study, with firefighters expected to have been healthier than the general population and they might well have had a lower exposure to important lifestyle and other factors that are known to increase the risk of cancer, with smoking a key example of this. This would have the tendency to under-estimate any increased risk that might be associated with exposure arising from the training facility. Alternatively, there was the possibility of some uncontrolled confounding from other important potential confounders, such as alcohol and other occupations, which could result in bias in either direction. There was no direct measure of exposure. The low number of subjects meant the power to detect an increased (or decreased) risk was low. A key issue in terms of the current project is that the study included a considerable number of subjects who were either volunteer firefighters or who were primarily involved in training rather than firefighting. The paid firefighters who were being trained, and presumably were receiving the sort of exposures they might receive in actual firefighting work, were classified as having the lowest exposures.

The quality of this study was assessed as Weak.

Glass et al, 2017: Mortality and cancer incidence among male volunteer Australian firefighters[11]

This was a cancer incidence and mortality study of a cohort of male Australian volunteer firefighters who had ever had an active volunteer firefighting role. Firefighters who had ever work in a paid capacity were excluded. Follow-up started some time between 1998 and 2000, depending on the agency, or at the commencement of employment if the person started work after follow-up commenced. Subjects who had served as firefighters for less than three months were excluded from some analyses. The cohort was assembled from information provided by five Australian firefighting agencies. Personal information was linked to the Australian National Deaths Index (NDI) and the Australian Cancer Database (ACD). Follow-up for the NDI was from January 1980 to November 2011 and for the ACD was from January 1982 to December 2010. Information was available on the number and type of fire incidents attended by each subjects. Mean duration of service was 15 years; mean follow-up was 9 years for the deaths analysis and 8 years for the incidence analysis; and mean age at the start of follow-up was 39 years and at the end of follow-up was 49 years. The main outcome measures were the Standardised Incidence Ratio (SIR) and the Standardised Mortality Ratio (SMR), calculated using the Australia male population as the reference and taking into account age and calendar year. In addition to the overall analysis, internal analyses were conducted based on duration of service and number and type of fire incidents attended. Analyses were undertaken for all deaths, all cancers and for some major cancer types.

The main findings of relevance were:

- All-cancer SMR was decreased (0.59, 0.57 to 0.62)
- All-cancer SIR was decreased (0.86, 0.84 to 0.88)
- Prostate cancer SIR was increased (1.08, 1.04 to 1.12) and the risk increased with years of service but not with number of fires attended
- Kidney cancer SIR was decreased, but risk appeared to increase with attendance at fires, particularly structural fires
- Decreased SIRs were seen for many types of cancer (lip, oral cavity and pharynx; oesophagus; stomach; colon; liver; larynx; lung; mesothelioma; kidney; bladder; non-Hodgkin's lymphoma; and myeloma) and for many the risk decreased with years of service.

The study appears to have used appropriate methods and analysis. It appears only volunteer firefighters were included in the cohort. Some did not attend any fires but the results were similar when these participants were excluded. The follow-up time was moderate and should have been adequate to provide reasonable quality information on cancers due to service in volunteer firefighting, but longer follow-up would provide more definitive information. Similarly, the cohort members were fairly young, which meant their underlying risk of cancer was low, making it less likely an increased risk of cancer would have been identified. The identification of cancer should have been essentially complete, given the high quality of the NDI and ACD in Australia.

As with most SMR studies, the major potential weaknesses were selection bias that can result if the comparison group used was not appropriate; and the limited control of potential confounding, with only age, calendar time and gender (by exclusion of females) able to be controlled for. This is a concern in regards to these issues in this study, with firefighters expected to have been healthier than the general population and they might well have had a lower exposure to important lifestyle and other factors that are known to increase the risk of cancer, with smoking a key example of this. This would have the tendency to under-estimate any increased risk that might be associated with exposure arising from work as a firefighter. Alternatively, there was the possibility of some uncontrolled confounding from other important potential confounders, such as alcohol and other occupations, which could result in bias in either direction. There was no direct measure of exposure.

Another potential problem was that prostate cancer is often the subject of screening and as a result a higher incidence may be due to increased detection through screening rather than to a true increased incidence. It is not known if prostate cancer screening was offered to firefighters as part of their engagement. This could plausibly have occurred, especially if either the firefighters or their doctors were aware of results from previous studies that suggested an increase in risk of and melanoma.

The quality of this study was assessed as Moderate.

Glass et al, 2019: Mortality and cancer incidence among female Australian firefighters[12]

This was a cancer incidence and mortality study of a cohort of female Australian firefighters. It included paid and volunteer firefighters but most members of the cohort were volunteers. Subjects had served as firefighters for at least three months. The cohort was assembled from information provided by nine Australian firefighting agencies covering all but two Australian States and Territories. Personal information was linked to the Australian National Deaths Index (NDI) and the Australian Cancer Database (ACD). Follow-up for the NDI was from January 1980 to November 2011 and for the ACD was from January 1982 to December 2010. Information was available on the number and type of fire incidents attended by each subjects. Mean duration of service was 6 years for full-time paid firefighters and 8 years for volunteer firefighters; mean follow-up was 16 years for the deaths analysis (mean follow-up for the incidence analysis was probably slightly less than this); and mean age at the start of follow-up was 32 years for full-time paid and 38 years for volunteers and at the end of follow-up was 40 years for full-time paid firefighters and 46 years for volunteers. The main outcome measures were the Standardised Incidence Ratio (SIR) and the Standardised Mortality Ratio (SMR), calculated using the Australia female population as the reference and taking into account age and calendar year. In addition to the overall analysis, internal analyses were conducted based on duration of service and number and type of fire incidents attended. This was only possible for the volunteer firefighters because of the low number of paid firefighters. Analyses were undertaken for all deaths, all cancers and for some major cancer types.

The main findings of relevance were:

- All-cancer SMR was decreased (0.75, 0.66 to 0.84)
- All-cancer SIR was similar (0.97, 0.91 to 1.03)
- Melanoma SIR was increased (1.25, 1.05 to 1.46)
- Some evidence of increased risk of death from cancer overall with increased attendance at all fires and at landscape fires

The study appears to have used appropriate methods and analysis. The cohort was mainly volunteer firefighters. The follow-up time was short and probably not long enough to provide a good estimate of risk of cancer due to work in firefighting - longer follow-up would provide more definitive information. The identification of cancer should have been essentially complete, given the high quality of the NDI and ACD in Australia.

As with most SMR studies, the major potential weaknesses were selection bias that can result if the comparison group used was not appropriate; and the limited control of potential confounding, with only age, calendar time and gender (by exclusion of females) able to be controlled for. This is a concern in regards to these issues in this study, with firefighters expected to have been healthier than the general population. This means they might well have had a lower exposure to important lifestyle and other factors that are known to increase the risk of cancer, although the authors cited evidence suggesting the rate of smoking in volunteer firefighters was higher than in the general population. Also, it was considered the higher risk of melanoma in firefighters compared to the general public might well reflect greater exposure to UV radiation from sunlight in the rural firefighters (not necessarily due to work) compared with the general public. In addition, there was the possibility of some uncontrolled confounding from other important potential confounders, such as alcohol and other occupations, which could result in bias in either direction. There was no direct measure of exposure.

Another potential problem was that melanoma is often the subject of screening and as a result a higher incidence may be due to increased detection through screening rather than to a true increased incidence. It is not known if screening for melanoma was offered to firefighters as part of their engagement. This could plausibly have occurred, especially if either the firefighters or their doctors were aware of results from previous studies that suggested an increase in risk of and melanoma.

The quality of this study was assessed as Moderate.

Harris et al, 2018: Surveillance of cancer risks for firefighters, police, and armed forces among men in a Canadian census cohort[13]

This study was a cancer incidence study based on a cohort of male workers identified by their occupation at the time of the 1991 Canadian Census and aged 25 to 74 years at that time. The study covered firefighters, police officers and members of the armed forces – only those aspects relevant to firefighters are considered here. Cohort members were linked to mortality and cancer incidence administrative databases using a probabilistic approach. Incident cancers were those which were diagnosed between the beginning of 1992 and the end of 2010, meaning the maximum follow-up was 19 years. Mean age at baseline was 41 years for firefighters. Mean follow-up time was 18 years for firefighters and 18 years for the entire cohort. Hazard ratios were calculated, with firefighters considered exposed and all other members of the cohort considered unexposed. The outcome measure was determined for cancer overall, 25 separate cancer types, and for prostate cancer under 50 years of age. Potential confounders considered were age, province and education level.

The main findings of relevance were:

- All-cancer risk was not increased (1.04, 0.96-1.14)
- Melanoma risk was increased SIR was increased (1.67, 1.17-2.37
- Hodgkin's lymphoma risk was increased (2.89, 1.29-6.46)
- Prostate cancer risk was increased (1.18, 1.01-1.37)
- For other cancers, there was no strong evidence of increased risk.

The study appears to have used appropriate methods and analysis. The identification of cancer should have been essentially complete, given the high quality of the death registry in Canada. The follow-up time and the age of the cohort members should have been adequate to provide reasonable quality information on cancers due to employment in firefighting, but longer follow-up would have provided more definitive information.

The study had several limitations. Information on occupation was only available at one time point. This meant there was no follow-up and no indication as to how long a subject remained in that occupation, meaning that identified firefighters might have spent most of their working life in a different occupation and that some people identified as not exposed actually worked as a firefighter at some stage. The effect of this exposure misclassification would be to underestimate any effect (harmful or protective) of being a firefighter (compared to working in a different occupation).

The comparison (unexposed) group was all workers and it is likely that firefighters are in general healthier than workers in many other occupations. This would also tend to underestimate any effect harmful effect and over-estimate any protective effect of being a firefighter (compared to working in a different occupation). The limitation in follow-up time would be expected to lead to an underestimate of any harmful effects of firefighting, especially for cancers with particularly long latencies.

There was limited information on, and thus limited control of, many potentially important confounders. This could be expected to lead to an overestimate or an underestimate of any harmful effect of work as a firefighter, depending on the particular cancer and the particular potential confounding factor. However, since firefighters are expected to have been healthier than the general working population, they might well have had a lower exposure to important lifestyle and other factors that are known to increase the risk of cancer, with smoking a key example of this. This would have the tendency to under-estimate any increase risk that might be associated with exposure arising from work as a firefighter. Alternatively, there was the possibility of some uncontrolled confounding from other important potential confounders, such as alcohol and other occupations, which could result in bias in either direction. There was no direct measure of exposure. There was no information on length of employment as a firefighter, meaning exposure-response analyses were not possible. The quality of this study was assessed as Moderate.

IARC, 2010: Monograph 98 – Painting, firefighting, and shiftwork[30]

In 2007, the International Agency for Research on Cancer (IARC) reviewed all relevant evidence in regards to the carcinogenicity of firefighting. As part of this review it considered all epidemiological evidence. Forty-two epidemiological studies were reviewed. The working group conducted a meta-analysis ('ever' vs 'never' working as a firefighter) for the four cancer sites with the most evidence suggestive of an increased risk (testicular cancer, prostate cancer, non-Hodgkin's lymphoma and multiple myeloma). This updated the analysis by LeMasters et al, 2006. Raised risk estimates with confidence intervals wholly above one were found for three of the four sites – testicular cancer (six studies - 1.47; 1.20-1.80), prostate cancer (16 studies - 1.30, 1.12-1.51) and non-Hodgkin's lymphoma (seven studies - 1.21, 1.08-1.36). However, there was evidence of a dose-response in only one study for each of these cancer types. The working group noted the difficulty with obtaining appropriate and accurate measures of exposure and the potential for this to bias the results. The working group classified firefighting as IARC Group 2b (Possibly carcinogenic to humans) on the basis of limited epidemiological evidence and no animal evidence.

Based on the limited information in the monograph, the study appears to have been conducted well, with appropriate methods and analysis. The search for studies appears to have been thorough.

The main potential limitations appear to have been apparently not assessing study quality; not providing analyses taking into account study quality; and limitations in the methodology of some of the individual studies that were included. There was no direct measure of exposure.

The quality of this study was assessed as Moderate.

Ide, 2014: Cancer incidence and mortality in serving wholetime Scottish firefighters 1984–2005[14]

This was a cancer incidence study of adult male professional firefighters in Scotland (no minimum period of service was mentioned), covering the years 1984 to 2005 inclusive. The cohort was assembled from employment records. Death certificates and information on cancer diagnoses were obtained from the employing agency. Mean employment duration was 19 years. Ten cancer outcomes were examined. The outcome measures were incidence rates and mortality rates, which were compared to the same rates calculated using the Scottish male population, and West of Scotland male population, aged 20 to 54, as the reference populations and taking into account age and calendar year. Essentially these were the equivalent of Standardised Mortality Ratio (SMR) and Standardised Incidence Ratio (SIR) analyses. The cohort was small, with only about 2,200 members, of whom 38 were diagnosed with cancer.

The main findings of relevance were:

- All-cancer SMR (0.38) and SIR (0.70) were decreased
- Kidney (RR=2.07) and melanoma (RR=1.68) incidence risk were increased, as was kidney cancer mortality (RR=3.61)
- For other cancer types, there was no strong evidence of increased risk in either incidence or mortality.

The study had some strengths. It appears to have used appropriate analysis and only professional firefighters were included in the cohort.

As with most SMR and SIR studies, the major potential weaknesses were selection bias that can result if the comparison group used was not appropriate; and the limited control of potential confounding, with only gender (by exclusion), age and calendar year controlled for. This is a concern in regards to these issues in this study, with firefighters expected to have been healthier than the general population and they might well have had a lower exposure to important lifestyle and other factors that are known to increase the risk of cancer, with smoking a key example of this. This would have the tendency to under-estimate any increased risk that might be associated with exposure arising from work as a firefighter. Alternatively, firefighters could have worked in other occupations with exposure to carcinogens. This would have the tendency to over-estimate any increased risk that might be associated with exposure arising from work as a firefighter. There was no direct information on exposure. Other important limitations included a low number of subjects, considerably decreasing precision; probable undercounting of some cancer cases due to problems obtaining the required information; small number of cases; only a moderate follow-up period; and some apparent uncertainty as to whether the age distribution of the reference population matched that of the firefighters.

The quality of this study was assessed as Weak.

Jalilian et al, 2019: Cancer incidence and mortality among firefighters[31]

This was a systematic review and meta-analysis of peer-reviewed studies published to January 2018 that provided information on the incidence and mortality of cancer in paid firefighters. Studies on volunteers or trainees were excluded. Fifty relevant studies were identified and included (27 with measures of incidence and 27 with measures of mortality); 48 of these were used in the meta-analyses. Twenty-nine cancer outcomes were examined (28 different cancers and one all-cancer measure). Random-effects models were used to calculate the meta-analytic estimates of effect. Separate analyses were conducted for incident cancers and deaths from cancer. Analyses combined estimates from different study types, although the vast majority of studies were cohort studies. Study quality was formally assessed using the Newcastle-Ottowa Scale but this assessment was not taken into account in conducting the meta-analyses. The strength of evidence was assessed using a modified version of the approach used by LeMasters and co-workers[2]. This took into account consistency of estimates between studies and the meta-analytic summary estimates of incidence and mortality.

The main findings of relevance were:

- Non-Hodgkin's lymphoma mortality risk was increased (1.42, 1.05-1.90) and considered to possibly be related to fire fighting
- Prostate cancer risk was increased (1.15, 1.05-1.27) and considered to possibly be related to fire fighting
- Testicular cancer risk was increased (1.38, 1.08-1.68) and considered to probably be related to fire fighting
- Melanoma risk was increased (1.21, 1.02-1.45) and considered to possibly be related to fire fighting
- Colon cancer risk was increased (1.14, 1.06-1.21) and considered to probably be related to fire fighting
- Rectal cancer risk was increased (1.09, 1.00-1.20) and considered to possibly be related to firefighting (rectal cancer mortality was considered to probably be related to firefighting)
- Bladder cancer risk was increased (1.12, 1.04-1.21) and considered to possibly be related to fire fighting
- Thyroid cancer risk was increased (1.22, 1.01-1.48) and considered to probably be related to fire fighting
- Mesothelioma risk was increased (1.60, 1.09-2.34) and considered to probably be related to fire fighting
- The evidence for other cancers was inconsistent and/or not suggestive of an increased risk in fire fighters:
    - Cancer of the eye, cancer of the pancreas, soft tissue sarcoma, malignant melanoma, and Hodgkin's lymphoma were concluded to possibly to be related to firefighting.

This is the most up to date systematic review and meta-analysis. The study appears to have been conducted reasonably well, with appropriate methods and analysis. The search for studies appears to have been thorough.

The main potential limitations appear to have been using the Newcastle-Ottowa Scale to assess study quality, although study quality did not influence the final meta-estimates; not providing analyses taking into account study quality; and limitations in the methodology of some of the individual studies that were included. There was no direct measure of exposure.

The quality of this study was assessed as Moderate.

Kang et al, 2008: Cancer incidence among male Massachusetts firefighters, 1987–2003[15]

This was a cancer incidence study of white male professional firefighters in the United States (Massachusetts) (no minimum period of service was required), covering the years 1987 to 2003 inclusive. All subjects had cancer and were identified from the state cancer registry. The exposure was usual (the longest held) occupation, which was determined from text fields in the registry data. There was no information on employment duration. Twenty-five cancer outcomes were examined. The outcome measure was the Standardised Morbidity Odds Ratio (SMOR), with police and all other occupations serving as reference populations (the presented results here focus on the comparison to police). The analysis allowed control of individual level potential confounders in addition to age, with age and smoking adjusted for in the analysis.

The main findings of relevance were:

- Colon cancer SMOR was increased (1.36, 1.04–1.79)
- Brain cancer SMOR was increased (1.90, 1.10–3.26)
- Melanoma SMOR was decreased (0.65, 0.44–0.97)
- For other cancers, there was no strong evidence of increased risk.

The study had some strengths. It appears to have used appropriate methods and analysis and only professional firefighters were included in the study. There were a considerable number of 'exposed' cases, providing reasonable precision for many cancer types.

There were a number of limitations in the study. Occupational was only available for 64% of subjects. Whether this differed by cancer type and/or by occupation type is not known and the effect of any resulting bias is not known, but the authors argued that it was likely to lead to an underestimate of risk. There was also the possibility of inaccurate recording of occupation; some subjects retiring and starting second jobs; and the lack of direct relationship between occupation and 'exposure' to active firefighting.

Police were thought to be an appropriate comparison group, except that they may have had some of the relevant exposures that firefighters had as they sometimes attended fires. This could have led to an underestimate of risk associated with firefighting. Further, police officers may not have been an appropriate comparison group in terms of lifestyle factors that might have been important potential confounders. There was only a limited control of potential confounders (age, smoking and gender (by exclusion)). This could have resulted in bias in either direction. There was no direct measure of exposure.

The quality of this study was assessed as Weak.

Kullberg et al, 2018: Cancer incidence in Stockholm firefighters 1958–2012: an updated cohort study[16]

This was a cancer incidence study of a cohort of male Swedish (Stockholm) firefighters, covering the years 1958 to 2012 inclusive. Subjects had worked as firefighters for at least one year between 1931–1983. This was a follow-up of a previously analysed cohort. The cohort was assembled from employment records at 15 fire stations in Stockholm. Personal information was linked to the Swedish Cancer Registry. Mean employment duration was 26 years, follow-up time ranged from 29 to 58 years and mean age at employment was 25 years. The outcome measure was the Standardised Incidence Ratio (SIR), calculated using the Stockholm male population as the reference and taking into account age and calendar year. In addition to the overall analysis, separate analyses were conducted based on years of employment (in 10-year groups), age at employment and starting year.

The main findings of relevance were:

- All-cancer SIR was decreased (0.81, 0.71-0.91)
- Stomach cancer SIR was increased (1.89, 1.25–2.75) but risk was not related to length of employment.
- Prostate cancer SIR was decreased (0.68, 0.52–0.87) but risk was not related to length of employment
- Melanoma SIR was decreased (0.30, 0.06–0.88) (too few cases to look at length of employment)
- For other cancers, there was no strong evidence of increased risk.
- Overall risk increased with length of employment, but for all length categories the SIR was not raised
- Overall risk increased with earlier year of employment, but for all length categories the SIR was not raised.

The study appears to have used appropriate methods and analysis. It appears only professional firefighters were included in the cohort. The long follow-up and the age of the cohort members should have been adequate to provide reasonable quality information on cancers due to employment in firefighting. The identification of cancer should have been essentially complete, given the high quality of the death registry in Denmark.

As with most SIR studies, the major potential weaknesses were selection bias that can result if the comparison group used was not appropriate; and the limited control of potential confounding, with only age, calendar time and gender (by exclusion of females) able to be controlled for. This is a concern in regards to these issues in this study, with firefighters expected to have been healthier than the general population and they might well have had a lower exposure to important lifestyle and other factors that are known to increase the risk of cancer, with smoking a key example of this. This would have the tendency to under-estimate any increase risk that might be associated with exposure arising from work as a firefighter. Alternatively, there was the possibility of some uncontrolled confounding from other important potential confounders, such as alcohol and other occupations, which result in bias in either direction. There was no direct measure of exposure.

The quality of this study was assessed as Moderate.

LeMasters et al, 2006: Cancer risk among firefighters: a review and meta-analysis of 32 studies[2]

This was a systematic review and meta-analysis of studies published to 2003 that provided information on the incidence and mortality of cancer in firefighters (subjects were required to have had at least one year of service except for those in mortality studies). Twenty-eight relevant studies were identified. Twenty-one cancer outcomes were examined. Both fixed and random-effects models were used, depending on the degree of heterogeneity, to calculate the meta-analytic estimate of effect. Analyses were conducted separately for some study types and overall. There does not appear to have been any formal consideration of study quality. An attempt was made to assess the likelihood of a true cancer risk related to firefighting by taking into account the meta-analytic estimate, the contributing study types and the extent of heterogeneity.

The main findings of relevance were:

- Multiple myeloma risk was increased (1.53, 1.21-1.94) and considered to probably be related to fire fighting
- Non-Hodgkin's lymphoma risk was increased (1.51, 1.31-1.73) and considered to probably be related to fire fighting
- Prostate cancer risk was increased (1.28, 1.15-1.43) and considered to probably be related to fire fighting
- Testicular cancer risk was increased (2.02, 1.30-3.13) and considered to probably be related to fire fighting
- Skin cancer risk was increased (1.39, 1.10-1.73) and considered to possibly be related to fire fighting
- Melanoma risk was increased (1.32, 1.10-1.57) and considered to possibly be related to fire fighting
- Brain cancer risk was increased (1.32, 1.12-1.54) and considered to possibly be related to fire fighting
- Rectal cancer risk was increased (1.29, 1.10-1.51) and considered to possibly be related to fire fighting
- Stomach cancer risk was increased (1.22, 1.04-1.44) and considered to possibly be related to fire fighting
- The evidence for other cancers was inconsistent and/or not suggestive of an increased risk in fire fighters:
    - Cancer of the skin, brain, rectum, buccal cavity and pharynx, stomach and colon; melanoma; and leukaemia were concluded to be possibly to be related to firefighting
    - Cancer of the larynx, bladder, oesophagus, pancreas, kidney, liver, lung; Hodgkin's disease; and all-cancers were concluded to be unlikely to be related to firefighting.

The study appears to have been conducted reasonably well, with appropriate methods and analysis. The search for studies appears to have been thorough.

The main potential limitations appear to have been not assessing study quality; not providing analyses taking into account study quality; and limitations in the methodology of some of the individual studies that were included. There was no direct measure of exposure.

The quality of this study was assessed as Moderate.

Ma et al, 2006: Cancer Incidence in Florida professional firefighters, 1981 to 1999[17]

This was a cancer incidence study of a cohort of United States (Florida) professional firefighters, covering the years 1981 to 1999 inclusive (no minimum employment period was mentioned). The cohort was assembled from employment records. Personal information was linked to the Florida Cancer registry and to other state administrative data to determine vital status. The median follow-up time was 13 years. The outcome measure was the Standardised Incidence Ratio (SIR), calculated using the Florida population as the reference, taking into account age and calendar year and conducted separately by gender.

The main findings of relevance were:

- All cancer SIR was decreased (0.84, 0.79-0.90) in male firefighters
- All cancer SIR was increased (1.63, 1.22-2.14) in female firefighters
- Bladder cancer SIR was increased (1.29, 1.01–1.62) in male firefighters.
- Testicular cancer SIR was increased (1.60, 1.20–2.09) in male firefighters.
- Thyroid cancer SIR was increased (1.77, 1.08–2.73) in male firefighters.
- Stomach cancer SIR was decreased (0.50, 0.25–0.90) in male firefighters.
- Lung cancer SIR was decreased (0.65, 0.54–0.78) in male firefighters.
- All lymphopoietic cancer SIR was decreased (0.68, 0.54–0.85) in male firefighters.
- Cervical cancer SIR was increased (5.24, 2.93–8.65) in female firefighters.
- Thyroid cancer SIR was increased (3.97, 1.45–8.65) in female firefighters.
- Hodgkin's disease SIR was increased (6.25, 1.26–18.26) in female firefighters.
- For other cancers, there was no strong evidence of increased risk.

The study appears to have used appropriate methods and analysis. It appears only professional firefighters were included in the cohort. The identification of cancer should have been essentially complete, given the high quality of the death registry in California. The number of cancer cases in males was big enough to provide good precision.

As with most SIR studies, the major potential weaknesses were selection bias that can result if the comparison group used was not appropriate; and the limited control of potential confounding, with only age, calendar time and gender (by separate analyses) able to be controlled for. This is a concern in regards to these issues in this study, with firefighters expected to have been healthier than the general population and they might well have had a lower exposure to important lifestyle and other factors that are known to increase the risk of cancer, with smoking a key example of this. This would have the tendency to under-estimate any increase risk that might be associated with exposure arising from work as a firefighter. Alternatively, there was the possibility of some uncontrolled confounding from other important potential confounders, such as alcohol and other occupations, which could result in bias in either direction. There was no direct measure of exposure. The follow-up was not long, which meant there may have been under-recognition of increased (or decreased) cancer risk due to firefighting. In addition, the low number of cancer cases in females led to considerable imprecision.

The quality of this study was assessed as Weak.

Muegge et al, 2018: Excess mortality among Indiana firefighters, 1985-2013[28]

This was a “case-comparison” study of mortality, including cancer mortality, in firefighters in the United States (Indiana), covering the years 1985 to 2013. All subjects were identified by death registry staff and all information came from death records. Death records of firefighters (based on the occupation on their death certificate) were matched to death certificates of people who had not been firefighters, with four people matched (using age at death, sex, race, ethnicity and year of death) to each firefighter. The exposure was usual (the longest held) occupation, which was determined from text fields in the deaths records data. There was no information on employment duration. Multiple cancer outcomes were examined but it is not clear how many. The outcome measure was the odds ratio, as a measure of risk. The potential confounders age at death, sex, race, ethnicity and year of death were adjusted for by the selection and analysis approach. Results were only presented for cancers for which the point estimate was elevated and the confidence interval did not cross one.

The main findings of relevance were:

- The all-cancer risk was increased (1.19, 1.08-1.30)
- Buccal cavity and pharynx cancer risk was increased (2.15, 1.19-3.79)
- Other parts of the buccal cavity cancer risk was increased (4.0, 1.07-15.0)
- Pharynx cancer risk was increased (2.26, 1.05-4.65)
- Pancreas cancer risk was increased (1.45, 1.01-2.06)
- Kidney cancer risk was increased (1.84, 1.17-2.83)
- Cancer of other and unspecified sites risk was increased (1.27, 1.02-2.56)
- Connective tissue cancer risk was increased (2.50, 1.01-5.86)
- Brain cancer risk was increased (1.98, 1.23-3.12)

The study had several strengths. The general methods and analysis appeared appropriate for the study type but the study design was unusual. The coverage of cases would be expected to be almost complete and the recording of cancer type to be accurate.

The study had several limitations. It is based only on numerator data (people who have died from cancer) – the potential for and extent of unrecognized biases that might result are not clear. There was the possibility of some uncontrolled confounding from important potential confounders (e.g. smoking, alcohol, other occupations), which could have resulted in bias in either direction. There was also the possibility of inaccurate recording of occupation; some subjects retiring and starting second jobs; and the lack of direct relationship between occupation and ‘exposure’ to active firefighting. The effect of these potential measurement issues is not clear. The precision for most cancer types was limited, making it difficult to assess the importance of many of the findings.

The quality of this study was assessed as Weak.

Paget-Bailly et al, 2013: Occupation and head and neck cancer risk in men results from the ICARE Study, a French population-based case–control study[24]

This was a population-based case-control study of potential occupational causes of head and neck cancer (defined in this study as squamous cell carcinomas of the oral cavity, pharynx (excluding nasopharynx) and larynx) in males in France, covering the years 2001 to 2007. Cases came from cancer registries. Controls were selected from the population using random digit dialing. Data came from face-to-face interviews. Response rates appear to have been 60% for cases (83% of contacted cases) and 76% for controls (81% of contacted controls). Analyses were adjusted for age, geographic area, alcohol and smoking.

The main finding of relevance was:

- A raised odds ratio for firefighters (3.9, 1.4-11.2), with most of this increase arising from cancer of the oral cavity
- A raised odds ratio for firefighters who had worked more than ten years but not for those who had worked for less than 10 years.

The study had several strengths. The general methods and analysis appeared appropriate. The identification of cases would be expected to be almost complete and the choice of controls from the population was appropriate. The recording of cancer type should have been accurate. Control of confounding was reasonable in that the main confounders of interest (age, smoking and alcohol) were included. The large number of cases and controls provided reasonable precision.

The study had several limitations. The participation was only moderate for cases and reasonable for controls and there was no information to allow an assessment of the effect this might have been expected to have on the estimate of effect. Measurement of occupation and of many of the confounders was based on self-report, which is subject to inaccuracy. The extent and effect of this is difficult to judge. Occupation is a broad measure and really a proxy for whatever specific exposures might be associated and linked to an increased risk of head and neck cancer. There were also many comparisons made, raising concern that some of the results might have occurred due to chance.

The quality of this study was assessed as Moderate.

Petersen et al, 2018a: Mortality in a cohort of Danish firefighters; 1970–2014[19]

This was a mortality study of a cohort of male Danish firefighters, covering the years 1970 to 2014 inclusive. Cancer was not the focus but was included in the outcomes of interest. The cohort was assembled from employment and union records. Personal information was linked to the Danish Register of Causes of Death using a unique personal identification number. Mean employment duration was 15 years, mean follow-up was 28 years and mean age at the end of follow-up was 57 years. The outcome measure was the Standardised Mortality Ratio (SMR), calculated using two reference populations – the Danish male working population and a male military population – and taking into account age and calendar year. In addition to the overall analysis, separate analyses were conducted based on type of employment (full time, part-time and volunteer) and years of employment (<1, >=1, >=10, >=20).

The main findings of relevance in full time firefighters (compared to the military population) were:

- All-cancer SMR had a suggestion of slight increase, but the evidence for this was not strong (1.12, 1.00–1.26)
- Stomach cancer SMR was increased (1.96, 1.22–3.16)
- Prostate cancer SMR was increased in the part time/volunteer group (1.89, 1.22–2.93) but was low in full-time firefighters (0.66, 0.40–1.07)
- For other cancers, there was no strong evidence of increased risk.
- No apparent relationship of risk to length of employment, apart from the SMR for prostate cancer in part time/volunteer workers.

The study appears to have used appropriate methods and analysis. It appears only professional firefighters were included in the cohort. The follow-up time and the age of the cohort members should have been adequate to provide reasonable quality information on cancers due to employment in firefighting, but longer follow-up would have provided more definitive information. The main comparison population (military) appears appropriate. . The identification of firefighters and their designation regarding full-time or other is likely to have been accurate. The identification of cancer should have been essentially complete, given the high quality of the death registry in Denmark. The measurement of the included confounding variables should have been accurate.

As with most SMR studies, the major potential weaknesses were selection bias that can result if the comparison group used was not appropriate; and the limited control of potential confounding, with only age, calendar time and gender (by exclusion of females) able to be controlled for. This is a concern in regards to these issues in this study, with firefighters expected to have been healthier than the general population and they might well have had a lower exposure to important lifestyle and other factors that are known to increase the risk of cancer, with smoking a key example of this. This would have the tendency to under-estimate any increased risk that might be associated with exposure arising from work as a firefighter. Alternatively, there was the possibility of some uncontrolled confounding from other important potential confounders, such as alcohol and other occupations, which could result in bias in either direction. There was no direct measure of exposure. There were also many comparisons made, raising concern that some of the results might have occurred due to chance.

The quality of this study was assessed as Moderate.

Petersen et al, 2018b: Long-term follow-up for cancer incidence in a cohort of Danish firefighters[18]

This was a cancer incidence study of a cohort of male Danish firefighters (half full-time professional; half part-time or volunteer), covering the years 1968 to 2014 inclusive (the results presented here focus on those for fulltime (professional) firefighters). The cohort was assembled from employment and union records. Personal information was linked to the Danish Civil Registration System and the Danish Cancer Registry using a unique personal identification number. Mean employment duration was 16 years, mean follow-up was 31 years and mean age at the end of follow-up was 59 years. Forty-three cancer sites or combination of cancer types were examined. The outcome measure was the Standardised Incidence Ratio (SIR), calculated using three reference populations – the Danish male population, a sample of the Danish male working population, and a male military population – and taking into account age and calendar year. In addition to the overall analysis, separate analyses were conducted in an attempt to use proxy exposure measures – era of first deployment (before 1970, 1970–1994, after-1994), type of employment (full time, other), years of employment (<1, >=1, >=10, >=20), age at first employment (<25 years, ≥25 to <35 years, ≥35 years), and function (regular, specialised). In addition, internal analyses were conducted, adjusting for age and calendar year.

The main findings of relevance in full time firefighters (compared to the military population) were:

- All-cancer SIR was not increased (1.06, 0.99–1.15) compared to the general population
- Pancreas cancer SIR was increased (1.54, 1.05–2.25) compared to the general population
- For other cancers, there was no strong evidence of increased risk.

The study appears to have used appropriate methods and analysis. Some separate results were presented for professional firefighters only. The follow-up time and the age of the cohort members should have been adequate to provide reasonable quality information on cancers due to employment in firefighting, but longer follow-up would have provided more definitive information. Three comparison populations were used, which helps to assess the likelihood of selection bias. The identification of firefighters and their designation regarding full-time or other is likely to have been accurate. The identification of cancer should have been essentially complete, given the high quality of the death registry in Denmark. The measurement of the included confounding variables should have been accurate.

As with most SIR studies, the major potential weaknesses were selection bias that can result if the comparison group used was not appropriate; and the limited control of potential confounding, with only age, calendar time and gender (by exclusion of females) able to be controlled for. This is a concern in regards to these issues in this study, with firefighters expected to have been healthier than the general population and they might well have had a lower exposure to important lifestyle and other factors that are known to increase the risk of cancer, with smoking a key example of this. This would have the tendency to under-estimate any increase risk that might be associated with exposure arising from work as a firefighter. Alternatively, there was the possibility of some uncontrolled confounding from other important potential confounders, such as alcohol and other occupations, which could result in bias in either direction. There was no direct measure of exposure. There were also many comparisons made, raising concern that some of the results might have occurred due to chance.

The quality of this study was assessed as Moderate.

Pukkala et al, 2014: Cancer incidence among firefighters: 45 years of follow-up in five Nordic countries[20]

This was a cancer incidence study of the whole population of male firefighters aged 30 to 64 years from five Nordic countries (no minimum period of service was mentioned), covering the years 1961 to 2005 inclusive. The cohort was assembled from Census records. Personal information was linked to national statistics and to the relevant cancer registries. Mean employment duration was 29 years. Approximately 40 cancer outcomes appear to have been examined. The outcome measure was the Standardised Incidence Ratio (SIR), calculated using the entire adult population of the relevant countries as the reference population and taking into account age and calendar year.

The main findings of relevance were:

- All cancer SMR was slightly increased (1.06, 1.02–1.11)
- Lung adenocarcinoma SIR was increased (1.29, 1.02–1.60)
- Melanoma SIR was increased (1.25, 1.03–1.51)
- Prostate cancer SIR was increased (1.13, 1.05–1.22)
- Non-melanoma skin cancer SIR was increased (1.33, 1.10–1.59)
- Testicular cancer SIR was slightly decreased (0.51, 0.23–0.98)
- For other cancers, there was no strong evidence of increased risk
- For persons 70 years and over the SIR was raised for all cancers (1.14, 1.07-1.21), lung adenocarcinoma (1.90, 1.34–2.62), non-melanoma skin cancer (1.40, 1.10–1.76), mesothelioma (2.59, 1.24–4.77) and multiple myeloma (1.69, 1.08-2.51).

The study had several strengths. It appears to have used appropriate methods and analysis and only professional firefighters were included in the cohort. The measurement of the presence and type of cancer, and of the included confounders, would be expected to be good, given the sources and nature of the information. The follow-up time and the age of the cohort members should have been adequate to provide reasonable quality information on cancers due to employment in firefighting. The very large number of subjects and cases allowed excellent precision with most of the measures.

As with most SMR and SIR studies, the major potential weaknesses were selection bias that can result if the comparison group used was not appropriate; and the limited control of potential confounding, with only gender (by exclusion), age and calendar year controlled for. This is a concern in regards to these issues in this study, with firefighters expected to have been healthier than the general population and they might well have had a lower exposure to important lifestyle and other factors that are known to increase the risk of cancer, with smoking a key example of this. This would have the tendency to under-estimate any increased risk that might be associated with exposure arising from work as a firefighter. The authors argued that data suggested firefighters smoked less but otherwise had similar distribution of lifestyle factors to the general population. Alternatively, firefighters could have worked in other occupations with exposure to carcinogens. This would have the tendency to over-estimate any increased risk that might be associated with exposure arising from work as a firefighter. There was no information on exposure or on duration of employment. There were also many comparisons made, raising concern that some of the results might have occurred due to chance.

The quality of this study was assessed as Moderate.

Sauve et al, 2016: Occupation, industry, and the risk of prostate cancer: a case-control study in Montréal, Canada[25]

This was a population-based case-control study of potential occupational causes of prostate cancer in Canada (Montreal), covering the years 2005 to 2009. Cases came from all French-speaking hospitals (said to cover 80% of prostate cancer cases). Controls were selected from the French-speaking population using random selection from the electoral list. Data came from face-to-face interviews. Response rates appear to have been 79% for cases and 56% for controls. Analyses were adjusted for age, first-degree family history of prostate cancer, ancestry, screening for prostate cancer, level of physical activity, alcohol intake, annual household income, highest level of education attained and body mass index.

The main finding of relevance was:

- A raised odds ratio for low-grade prostate cancer in firefighters (2.23, 1.12-4.45), although the confidence interval included one after the correction for multiple testing (1.80, 0.99-3.25)
- A raised odds ratio of uncertain significance for all prostate cancer in firefighters (1.72, 0.88-3.37).

The study had several strengths. The general methods and analysis appeared appropriate. The choice of controls from the population appears appropriate. The recording of cancer type should have been accurate. Control of confounding appeared good. Screening rates in controls were high, suggesting there was low likelihood of cases being wrongly included as controls. The large number of cases and controls provided reasonable precision.

The study had several limitations. The selection of cases from hospitals meant that a considerable minority (20%) of cases were not eligible. The extent to whether this would introduce bias, and the effect of any such bias, is not known. The participation proportion was reasonable for selected cases and but not good for controls. Some information comparing included and non-included subjects separately for cases and controls suggested there was no important difference, but concern remains there might have been resulting bias of the estimate of effect, with the size and direction of any such bias not known. Measurement of occupation and of many of the confounders was based on self-report, which is subject to inaccuracy. The extent and effect of this is difficult to judge. Occupation is a broad measure and really a proxy for whatever specific exposures might be associated and linked to an increased risk of prostate cancer. There were a very large number of comparisons made, raising concern that some of the results might have occurred due to chance. The authors tried correcting for this using a Bayes adjustment but the concern regarding multiple comparisons remains.

The quality of this study was assessed as Moderate.

This was found in a search of reference lists

Sritharan et al, 2017a: Prostate cancer in firefighting and police work: a systematic review and meta-analysis of epidemiologic studies[32]

This was a systematic review of studies that provided information on the incidence and mortality of cancer in firefighters and police officers. (The firefighting data were provided separately to the police officer data and only the firefighting aspects are described here.) Papers published from 1980 to 2017 inclusive were included, but the earliest year covered by any of the included papers was 1950 and the most recent year covered was 2011. Twenty-six relevant studies were identified. A random-effects model was used to calculate the meta-analytic estimate of effect. Several sub-group analyses (based on study type, years covered by the study, incidence versus mortality) were undertaken.

The main findings of relevance were:

- Overall prostate cancer incidence was mildly increased (1.17, 1.08-1.28), but there was a large amount of heterogeneity (I^2=72%)
- Overall prostate cancer mortality had a similar point estimate but the results were equivocal (1.12, 0.92-1.36). There was a moderate amount of heterogeneity (I^2=50%)
- There was minimal evidence of publication bias.

The study appears to have been conducted reasonably well, with appropriate methods and analysis. The search for studies was reasonably thorough, although only two databases (PubMed and Web of Science) were used and grey literature did not appear to have been accessed. Study quality was assessed but it appears all eligible studies were included regardless of quality.

The main potential limitations were not conducting a more thorough search (although it seems unlikely important studies would have been missed); the considerable heterogeneity; not providing analyses taking into account study quality; and limitations in the methodology of some of the individual studies that were included, particularly the potential for differing screening patterns to influence the results.

The quality of this study was assessed as Moderate.

Sritharan, 2017b: Occupation and risk of prostate cancer in Canadian men: A case-control study across eight Canadian provinces[26]

This was a population-based case-control study of potential occupational causes of prostate cancer in Canada (eight provinces), covering the years 1994 to 1997. Cases appear to have come from province cancer registries. Controls were selected from the population using various methods, depending on the province. Data came from self-administered questionnaires. Response rates were reported as 69% for both cases and controls, but it is not clear if the 69% for controls was of those who had agreed to take part after initially being contacted (which seems likely), which would mean the participation was actually a lot lower than 69% for the controls. Analyses were adjusted for age, province of residence, family history of prostate cancer, education, ethnicity, smoking (pack-years), marital status, body mass index, physical activity and total radiation exposure.

The main finding of relevance was:

- A raised odds ratio for firefighters (1.67, 0.94–2.95) of uncertain relevance as the confidence interval crossed one.

The study had several strengths. The general methods and analysis appeared appropriate. The identification of cases would be expected to be almost complete and the choice of controls from the population was appropriate. The recording of cancer type should have been accurate. Control of confounding was comprehensive. The large number of cases and controls provided reasonable precision.

The study had several limitations. The participation was only moderate (69% for cases; probably quite a bit lower for controls) and there was no information to allow an assessment of the effect this might have been expected to have on the estimate of effect. Measurement of occupation and of many of the confounders was based on self-report, which is subject to inaccuracy. The extent and effect of this is difficult to judge. Occupation is a broad measure and really a proxy for whatever specific exposures might be associated and linked to an increased risk of prostate cancer.

The quality of this study was assessed as Weak.

Sritharan et al, 2018: Prostate cancer surveillance by occupation and industry: the Canadian Census Health and Environment Cohort (CanCHEC)[21]

This study used a large Canadian cohort that was established by linking Census data from 1991 to mortality (1991-2011), cancer incidence (1969-2010) and tax (1981-2011) data. This analysis focussed on occupations and industries associated with prostate cancer incidence or mortality. A Cox Proportional Hazards approach was used, adjusting for age, province of residence, ethnicity, education and marital status.

The main findings of relevance were:

- Prostate cancer hazard ratio for firefighters was increased (1.17, 1.01-1.36)
- Overall prostate cancer mortality for firefighters had a similar point estimate but the results were equivocal (1.12, 0.92-1.36). There was a moderate amount of heterogeneity (I^2=50%)
- There was minimal evidence of publication bias.

The study appears to have been conducted reasonably well, with appropriate methods and analysis. The large number of cases provided good precision in the estimates. Measurement of included variables should have been accurate, except that for nearly all they were only single measurements (in 1991) and so didn't take into account later changes. The effect of this potential inaccuracy is difficult to assess as bias could be in either direction, depending on which variable was affected and its distribution between exposed and unexposed persons.

The study had some limitations. Employment information came only from 1991; there was no information on changes after that time. Presuming such changes were not related to prostate cancer occurrence, any bias should have led to an underestimation of any increased (or decreased) risk from firefighting. There was no information on several potentially important confounders such as family history, physical activity and screening behaviour. There were also many comparisons made, raising concern that some of the results might have occurred due to chance.

The quality of this study was assessed as Moderate.

Tsai et al, 2015: Risk of cancer among firefighters in California, 1988–2007[27]

This study examined cancer risk in male firefighters (probably primarily paid firefighters) in the United States (California). Cases were identified from the California Cancer Registry (CCR), covering incidents cases from 1988 to 2007 inclusive. Controls also came from the CCR, selected randomly from those people diagnosed over the same time-period with a cancer not thought, based on the literature, to be related to firefighting. These were cancer of the pharynx, stomach, liver and pancreas. Exposure was defined as work as a firefighter. This was determined using an electronic search of information in the narrative fields of the CCR data that covered the longest held occupation and industry. Included cases were primarily those subjects who had worked as "firefighters, fire chief's aides, smoke jumpers, forest-fire fighters or crash-crew men". Other subjects defined as exposed had occupations related to active firefighting but which were more likely to involve supervision and/or not to involve active firefighting, although the authors argued that many of these people had probably worked earlier as firefighters. The outcomes of interest were 35 individual or grouped cancer types. Potential confounders considered in the analysis were age, year of diagnosis and race. Sub-analyses were conducted based on race. The results reported here focus on the all-firefighters analyses.

The main findings of relevance were:

- Melanoma risk was increased (1.75, 1.44–2.13)
- Prostate cancer risk was increased (1.45, 1.25–1.69)
- Brain cancer risk was increased (1.54, 1.19–2.00)
- Oesophageal cancer (adenocarcinoma) risk was increased (1.85, 1.34–2.55)
- Lung cancer (non-small cell) risk was increased (2.01, 1.38–2.93)
- Acute myeloid leukemia risk was increased (1.44, 1.02–2.02)
- Kidney cancer risk was increased (1.27, 1.01–1.59)
- Multiple myeloma risk was increased (1.35, 1.00–1.82)
- All leukemia risk was increased (1.32, 1.05–1.66)
- Laryngeal cancer risk was decreased (0.59, 0.39–0.89)
- The remaining cancers did not appear to have an increased risk.

Strengths of the study include the large number of cases and controls (although the number of exposed cases and controls was not high, limiting the power) and the high coverage of cancer cases by the CCR.

The study had several important limitations.

It is not clear that the controls appropriately represented the study base from which the cases came (presumably the whole of California). The subjects who formed the control group had one of four specific cancers and the proportion exposed (being a firefighter) varied between the groups defined by cancer type (from 0.40% to 0.46%). In addition, there is good reason to consider that the relevant exposure experience (the proportion for whom firefighting was their main occupation) of people with cancer is different to the relevant exposure experience of the entire population. Any resulting bias could have led to an under- or overestimate of any increased risk. It might be expected that people who developed one of the four relevant cancers were in general less healthy than firefighters. If that was the case, the choice of controls would have led to an underestimation of the risk of firefighting. However, there is insufficient information in the paper to provide further insight into this.

Another selection issue was that approximately one third of potentially eligible subjects were missing information on occupation or industry and so were excluded. The authors argued it was unlikely that the lack of information would have been different for persons with included cancers as compared to those with non-included cancers. Whether this was likely to be correct or not cannot be determined – arguments could be raised either way.

The other important issue was with the lack of control of confounders apart from age, race and gender (by exclusion). In particular, there was no control of the potential confounding effects of smoking, alcohol, diet, other relevant lifestyle-related exposures and occupational exposures. Any confounding effects could have led to an over or underestimation of increased (or decreased) risk.

In terms of measurement, information on exposure (occupation) came from written information in the CCR and only represented the reported longest held occupation. There was no information presented about the accuracy of this information or the accuracy of the identification of firefighters within the subject group. To the extent there was some error in the measurement of occupation, it is not likely to have differed between cases and controls and so any resulting bias would be expected to lead to an underestimation of any harmful (or (protective) effect of work as a firefighter. There was also no direct measure of exposure. There shouldn't have been any important error in the measurement of cancer type, as the CCR would be expected to have highly valid diagnostic procedures, but no information on this was presented. There were also many results calculated, raising the possibility of spurious findings.

The quality of this study was assessed as Weak.

Youakim, 2007: Risk of cancer among firefighters: a quantitative review of selected malignancies[33]

This was a systematic review of studies published between 1966 and 2005 inclusive (the years covered by the included studies were not mentioned) that provided information on the incidence and mortality of selected cancers in firefighters (no minimum length of service was stated). The cancers of interest were cancer of the bladder, brain, colon and kidneys; non-Hodgkin's lymphoma; and leukemia. Twenty-six relevant studies were identified and 23 included. Twenty-one cancer outcomes were examined. A fixed-effect model was used to calculate the meta-analytic estimate of effect. There does not appear to have been any formal consideration of study quality. Sub-analyses were undertaken to examine potential effects of duration of employment and length of tenure on risk of cancer.

The main findings of relevance were that for firefighters:

- All-cancer mortality risk was slightly increased (1.04, 1.02-1.07)
- Kidney cancer mortality risk was increased (1.22, 1.02-1.43)
- Non-Hodgkin's lymphoma mortality risk was increased (1.40, 1.20-1.60)
- The evidence for mortality for other cancers was inconclusive
- Bladder cancer incidence was increased (1.36, 1.01-1.80)
- The evidence for increased risk for other cancers was inconclusive.
- There was no conclusive evidence of increased mortality or incidence for any of the six cancers when only cohort studies were examined.
- The highest risks appeared to be at the longest employment duration for most of the six cancers but there did not appear to be any formal dose-response testing undertaken.

The analysis appears to have been generally appropriate. The search for studies appears to have been thorough.

The main potential limitations appear to have been having only one person do all searching and extraction of data; not assessing study quality; not providing analyses taking into account study quality; and limitations in the methodology of some of the individual studies that were included.

The quality of this study was assessed as Moderate.

McGlynn and Trabert, 2012: Adolescent and adult risk factors for testicular cancer[42]

This was a narrative review of factors that affected the risk of testicular cancers. Firefighters were one of a large number of potential risk factors examined. There were no methods published but apparently no limits placed on the years of the included publications. Study quality was not formally assessed.

The report mentioned ten studies and two reviews that examined the relationship between work as a firefighter and the risk of testicular cancer. The authors noted that studies before 1995 did not identify any increased risk but studies after 1995 had identified an increased risk. There was no numeric finding regarding the relationship between work as a firefighter and the risk of testicular cancer.

As this was a narrative review (and thus there was no structured assessment of studies or study results and no meta-analysis conducted), the review has very limited relevance to the current report and was excluded from consideration.