Review of Selected Research Studies Examining the Occupational Health of Fire Fighters

Completed for DVA (Australia)

A report prepared by King's Centre for Military Health Research
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EXECUTIVE SUMMARY

1. Concerns have been raised that the occupational hazards of being a Fire Fighter (FF) may negatively impact their health. King's College London (UK) was commissioned by the DVA (Australia) to provide an independent and critical review concerning FF occupational health research studies.

2. Eight studies were selected by the DVA and reviewed to provide the DVA with qualified advice on the collective health outcomes assessed in these studies. Evidence on the following health outcomes was summarised and critically examined: cancer (by type), cardiovascular and respiratory conditions, motor neuron disease, musculoskeletal disorders, noise induced hearing loss, psychiatric conditions and traumatic injury.

3. The methodological quality of the studies was independently rated by two epidemiologists, using a study design specific quality assessment tool. The level and the strength of the evidence per health outcome was determined using the Repatriation Medical Authority procedures and practices for assessing sound medical-scientific evidence in combination with the Bradford Hill criteria for association and causation. The grading of the evidence ranged from grade 1 (convincing evidence for a causal association) to grade 5 (inadequate or suggests no causal association).

4. In summary, four were cohort studies, two were case-control studies plus one case file review and a systematic review. Of the six epidemiological studies (defined as a cohort or case-control study), four were Australian based and two used US data. They all primarily focused on FF rather than specifically Defence Fire Fighters (DFF). The five of the six epidemiological studies were assessed for their methodological quality – none were deemed to be of good quality, three were rated as fair and two as poor.

5. Lifestyle data were missing from most of the studies reviewed, meaning that any associations seen could be due to lifestyle rather than occupational exposures.

6. All of the studies included in this review have primarily focused on cancer incidence and mortality. There were few studies that addressed non-cancer health outcomes in FF. Overall, there is mixed evidence regarding the associations between overall cancer mortality and incidence and the occupational hazards of being a FF.

7. Only melanoma was identified as having convincing evidence to determine a causal relationship with the occupational hazards of being a FF. The evidence evaluated supported a convincing causal relationship based on the fulfilment of the Bradford-Hill criteria and supported by the Repatriation Medical Authority Guidelines.

8. There is some evidence to suggest an association between the occupational hazards of being a FF and noise induced hearing loss. For two conditions reviewed, the evidence was inadequate to determine a casual association but these conditions were deemed to be worth

monitoring (lung cancer and amyotrophic lateral sclerosis). Two further conditions were identified as showing very limited evidence of an association (psychiatric conditions and musculoskeletal disorders).

9. The review concludes that there is convincing evidence for a causal association between melanoma and the occupational hazards of being a FF and suggestive evidence for noise induced hearing loss.

10. The following recommendations have been made:
    - To ensure the continual follow up of FF, including DFF
        a. to include other health outcomes especially lung cancer, mental health, noise induced hearing loss and musculoskeletal disorders
        b. to include the additional collection of data on lifestyle factors
    - To establish (and follow-up) a female cohort of FF, including DFF
    - To class melanoma as having convincing evidence for a causal association with the occupational hazards of being a FF
    - To consider melanoma for inclusion in the *Safety, Rehabilitation and Compensation* policies for FF, including DFF

BACKGROUND

The Australian Defence Force (ADF) consists of approximately 57,000 serving regulars and 23,000 reservists. More than half of the regulars, serve in the Army (29,000), followed by 13,550 Navy personnel and 14,200 Air Force personnel. The division by service branch is similar among the reservists (Army 23,100; Navy 14,000; Air Force; 4,300)[1, 2]. Within the ADF, Defence Fire Fighters (DFF) are employed to protect the infrastructure, equipment and people from fires. Consequently, they may get exposed to a variety of products of combustion, toxic agents and chemicals whilst carrying out their duties and these may impact on their wellbeing in the short or long term. A comprehensive study done by Monash University (2015) identified around 2,500 former and current military personnel who had participated in firefighting tasks as part of their role[3]. At the moment, there are nearly 200 trained Fire Fighters (FF) within the ADF and another 20 personnel are undergoing training (personal communication April 2016, Dr Ian Gardner). Further, there are approximately 14,000 fulltime paid career FF and 226,052 civilian volunteer FF in the general population (2014-15), therefore, the wellbeing of DFF and FF warrant further investigation[4].

A substantive body of research has been conducted looking into the effects of firefighting on cardiovascular, respiratory and neurological conditions, malignant cancers, injury and trauma[5]. For a small number of health conditions, especially cancers, convincing causal associations have been identified with firefighting and these have been taken up in the *Safety, Rehabilitation and Compensation* policies[a] for FF. In these cases, personnel are eligible for compensation if they worked as a FF (including DFF) for a qualifying period of time before the diagnosis. The majority of these study findings have been inconclusive and difficult to interpret, due to a variety of issues including the relatively small sample sizes of the studies conducted, the limited number of cases identified, the short length of follow-up in combination with the extensive latency period of most health conditions, missing occupational exposure data and incomplete data on health and lifestyle factor such as smoking and drinking behaviour.

Despite these methodological concerns, it is important to combine and critically review the current findings, thereby providing the DVA with qualified advice on the collective outcomes of these studies.

Scope

The aim of this project is to analyse, evaluate, and collectively summarise findings on eight recently completed and published FF occupational health research studies.

The specific research questions to be addressed are:

1) Are there health issues for FF identified collectively by the studies? If so, what are they?
2) Are these findings clear and robust?

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[a] Safety, Rehabilitation and Compensation Amendments (Fair Protection for Fire Fighters) Act 2011. No 182, 2011. Available from http://comlaw.gov.au/

METHODS

Data Extraction

Eight recently completed FF occupational health research studies were selected by the DVA for inclusion in this review[3, 5-11]. The DVA selected these studies as they addressed the primary health concerns expressed by DFF. These studies were repeatedly read and discussed between the members of the research team. For each study, the following characteristics were extracted: author, year released, country, study design, study population, comparison population and data collection method (appendix 1).

A list of health conditions was compiled that warranted further examination based on sifting through the world literature and the studies nominated by the DVA, in particular the literature review done by Guidotti (2014) and the case file review by Peel (2014). The following were identified:

- Cancer
    - Lip cancer, lung cancer, melanoma, mesothelioma, nasal sinus cancer, parotid gland tumours, thyroid carcinoma, tongue cancer
- Cardiovascular and respiratory conditions
    - Accelerate decline in lung function, acute respiratory failure and decompensation, asthma, chronic obstructed airways disease, heart attack
- Motor neuron disease
    - Amyotrophic lateral sclerosis
- Musculoskeletal disorders (chronic)
- Noise induced hearing loss
- Psychiatric conditions (general)
    - Post-traumatic stress disorder, reactive depression
- Traumatic injury

The cancers listed in the *Safety, Rehabilitation and Compensation Amendment (Fair Protection for Fire Fighters) Act 2011*[b] were excluded, as FF (including DFF) already qualify for compensation if diagnosed with one of these cancers and having worked as a FF for a certain qualifying period of time before diagnosis.

The evidence with regards to these health conditions was retrieved and summarised by carefully examining the 8 nominated studies (appendix 2). Throughout the document and in the appendices, cancer (in general) will be addressed first, followed by the different cancer types in alphabetical order. Subsequently, the other health conditions will be addressed, also in alphabetical order.

[b] Brain cancer, bladder cancer, kidney cancer, non-Hodgkin's lymphoma, leukaemia, breast cancer, testicular cancer, myeloma, prostate cancer, ureter cancer, colorectal cancer and oesophageal cancer (all primary site).

Data Quality

The methodological quality of the studies was rated using quality assessment tools derived from the National Heart, Lung and Blood Institute (NHLBI) (http://www.nhlbi.nih.gov/health-pro/guidelines/in-develop/cardiovascular-risk-reduction/tools). These tools were developed by a team of methodologists from the NHLBI and the Research Triangle Institute International. During the development process several other study quality assessment frameworks have been consulted such as from the Cochrane collaboration, Agency for Healthcare Research and Quality, Evidence based Practice Centres and the National Health Service Centre for Reviews and Dissemination.

Two epidemiologists (NTF and SS), independently rated the studies using the study design specific quality assessment tool. Any discrepancies in the ratings were discussed and resolved. After scoring all the criteria, the different ratings were listed and a final overall rating for each study was given jointly (appendices 1, 3 and 4).

The essential key criteria for **cohort studies** to receive a 'good' quality rating include an adequate sample size (no 5), a sufficient timeframe to see an effect (no 7), different levels of the exposure of interest (no 8) and whether key confounding variables were measured and adjusted for (no 12). The essential key criteria for **case control studies** to receive a 'good' quality rating include the pre-specification of in- and exclusion criteria and whether these are applied uniformly across cases and controls (no 5), whether the exposure was assessed prior to the outcome measurement (no 9), the accurate and reliable measurement of exposure variables (no 10) and whether key confounding variables were measured and adjusted for (no 12). Scoring on these essential criteria only is not sufficient to get a good quality rating.

Evidence Grading

The evidence of the study findings per health condition were critically examined and appraised using a similar approach as required by the Repatriation Medical Authority (RMA) for assessing sound medical-scientific evidence (SMSE)[c]. The evidence was also cross-checked with the Bradford Hill criteria for association and causation[12]. Subsequently, the strength of the evidence was categorised according to predetermined grades, also taking into account the Bradford Hill criteria and the quality of the study (see 'data quality', p. 8). This was limited to the evidence given in the 8 studies provided by the DVA. These quality assessments were applied to ensure that the findings could be used to inform the appropriate legislative instruments for the DVA.

The following levels of evidence were used[c]:

- Grade 1 Convincing
    - " There is evidence strong enough to support a judgement of <u>convincing</u> causal relationship"

[c] http://www.rma.gov.au/assets/FOI/SMSEdefinition.pdf

- Grade 2 Suggestive
    - " There is evidence strong enough to support a judgement of a probable causal relationship"
- Grade 3 Limited
    - " The evidence is too limited to permit a judgement of a probably or convincing causal relationship, but supports a judgement of a possible causal relationship"
- Grade 4 Very limited
    - " The evidence is too limited to permit a judgement of a possible causal relationship"
- Grade 5a Inadequate
    - " The evidence is so limited that no firm conclusion can be made"
- Grade 5b Evidence suggesting no causal association
    - " The evidence is strong enough to support a judgement that a particular risk factor is highly unlikely to have a causal relation to the disease or injury"

After the evidence grading was done by NTF and SS, these findings were critically compared to the general consensus in the world literature.

Main Statistical Vocabulary

The majority of the statistics extracted from the eight studies were related to mortality (deaths) and incidence (new occurrence of diseases over a specific time period) in the DFF and FF populations.

- Standard Mortality Ratio (SMR). The SMR examines mortality thereby taking into account the age structure of the population under study. The SMR compares the number of expected deaths in a study population compared to the number of actual deaths if the death rate was similar, for example, to the Australian population.
- Standard Incidence Ratio (SIR). The SIR is a similar statistical measure as the SMR but used for the occurrence of disease. The SIR and SMR are often used to analyse the data of cohort studies.
- Odds Ratio (OR). The OR is a measure of association between an exposure and an outcome. It will represent the odds that an outcome will occur give a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure. The OR is often the statistical measure of choice for data collected using case-control studies.
- 95% Confidence Interval (95% CI). Statistical measures are often given in combination with a 95% CI. The CI provides an estimated range of values, calculated from the study data, which is likely to include an unknown population parameter, for example the OR. It provides an indication of the precision of the study estimate.
- 'Adjusted variables'. In some cases, statistical measures are 'adjusted' meaning that they take into account potential factors that might influence the association under study (for example, smoking behaviour might be an important factor to adjust for, if we are looking into the association between firefighting and lung cancer).

Research Team

This work was undertaken by two formally trained epidemiologists who both have extensive experience in designing and conducting epidemiological studies, analysing and interpreting data. Both conducted their Masters degree in Epidemiology at the London School of Hygiene and Tropical Medicine, University of London, UK. Professor Fear is an occupational epidemiologist who has worked in the field of military health since 2002. Prior to this, Professor Fear worked as an occupational epidemiologist in the field of cancer. Before started working in military health (2012), Dr Stevelink worked in the field of international public and mental health.

RESULTS

Overview of Studies Included *(appendix 1, pages 17-21 and appendices 3 and 4, pages 33-35)*

Eight studies were assessed for their methodology, analytical approaches and results (appendix 1). In summary, four were cohort studies[3, 7, 8, 11], two were case-control studies[6, 9] plus one case file review[10] and a systematic review[5]. Of the six epidemiological studies (defined as a cohort or case-control study), four were Australian based[3, 6, 7, 11] and two used US data[8, 9]. They all primarily focused on FF rather than specifically DFF – the exceptions being the Defence Fire Fighters Health Study and the Jet Fuel Exposure Syndrome Study[3, 6].

Five (out of six) epidemiological studies were assessed for their methodological quality – none were deemed to be of good quality, three were rated as fair[7-9] and two as poor[3, 11]. However, there was not much to distinguish between the studies with regards to quality. None of the cohort studies were conducted over a sufficient time period to allow for certain long term outcomes to develop. None of the studies included data on confounding factors (for example, lifestyle factors), meaning that any associations observed may have been due to residual confounding. Further, detailed occupational exposure information was limited thus dose response effects were often not examined and those that were often used proxy exposure data. In addition, the results from those studies that included women were based on small numbers meaning that caution needs to be taken when interpreting the results for this group. The Jet Fuel Exposure Syndrome Study[6] did not receive an overall quality rating as the study was primarily designed as a laboratory study into jet fuel and solvent exposure.

With regards to the cases/studies included in the case file review and systematic review, they suffered from similar limitations as outlined for the other epidemiological studies. In addition, the case file review was male only and included predominantly Royal Australian Air Force personnel[10]. Further, the methodological quality of the studies included in the systematic review was not examined, what is an important limitation to be considered[5].

General Overview of Cancer Incidence and Mortality *(appendix 2, pages 22-32)*

All of the studies included primarily focused on cancer incidence and mortality. Overall, there is mixed evidence regarding the associations between overall cancer mortality and incidence and the occupational hazards of being a FF. Given the potential role of the ‘healthy worker effect’ (e.g. “workers usually exhibit lower overall death rates than the general population because severely ill and disabled people are excluded from employment"[e]), it may be hypothesised that cancer incidence and mortality would be consistently statistically significantly reduced within this occupational group when compared to the general population. Where dose response data were available, the emerging pattern for cancer incidence being that increased exposure was associated with increased incidence. This is not so clear for mortality. It is likely that the observed increased rates are due to a couple of cancers (for example, melanoma which will be discussed later).

There were few studies that addressed non-cancer health outcomes in FF. Mortality due to traumatic injury was examined in three of the epidemiological studies[3, 7, 11]. The other non-cancer outcomes were included in the case series and/or systematic review[5, 10].

Specific Cancers and Morbidity Conditions (appendix 2, pages 22-32)

All data relevant to the outcomes of interest were extracted from each study independently by two members of the research team. All data were then considered, evidence discussed and conclusions are presented below by the strength and level of emerging evidence.

Convincing Evidence:

- Melanoma (appendix 2, page 26) – Of all health outcomes examined, only melanoma has been identified as having convincing evidence to determine a causal relationship with the occupational hazards of being a FF. The evidence evaluated supported a convincing causal relationship based on the fulfilment of the Bradford-Hill criteria and supported by the RMA Guidelines. Strong (measures of effect greater than 2.0) and consistent evidence was observed for melanoma incidence overall and when analyses were repeated by level of exposure (i.e. there was evidence of a dose-response effect). Still, some personal factors should be taken into account, for example the person who presented with a melanoma should have worked as a FF for a certain qualifying period before the cancer occurred and should have been exposed to firefighting duties during that period.

  The main cause of melanoma is ultra violet (UV) exposure but other agents have been identified as causal risk factors (i.e. vinyl chloride (which is present in fire smoke), PCBs, solvents and arsenic)[5, 13]. It is possible that FF have higher exposure to UV than members of the general population due to their occupational role but they undoubtedly have exposure to other agents in the cause of their occupational duties.

Suggestive Evidence:

- Noise induced hearing loss (appendix 2, page 31) – From the results reviewed, there is some evidence to suggest an association between the occupational hazards of being a FF and noise induced hearing loss. There is biological plausibility to support this association, such as vehicle siren blaring whilst in transit. This association was only

[e] www.medilexicon.com/medicaldictionary.php

determined to be of suggestive evidence due to lack of strong and consistent evidence. Further research and monitoring is required, also with regards to hearing loss in general, as findings indicate a potential association with chemical solvents[14].

Inadequate Evidence but Worth Monitoring:

- Lung cancer (appendix 2, page 24-26) – There is currently inadequate evidence to support a causal association with lung cancer but there may be an interaction between the products of combustion and smoking which could mean that FF have a raised risk of lung cancer. However, the current evidence base lacks information on current or past smoking history in the participant populations under study; therefore no causal association can be made.
- Amyotrophic Lateral Sclerosis (ALS) (appendix 2, page 30) – There is no evidence currently to support an association but evidence from other fields (i.e. military and veteran health) suggests that this is worth monitoring[15].

Very Limited Evidence:

Two conditions have been identified as showing very limited evidence of an association:

- Psychiatric conditions (appendix 2, page 31) – There is currently a very limited evidence base in this area but it is widely acknowledged that FF are exposed to high levels of stress and trauma which are likely to impact on their mental wellbeing.
- Musculoskeletal disorders (MSD) (appendix 2, page 30-31) – There is currently very limited evidence to support an association but there is potential biological plausibility between the heavy physical workload likely to be experienced by FF and chronic MSD (i.e. osteoarthritis).

Evidence Suggesting No Causal Association with Occupational Role of Being a FF:

There is strong evidence to show that mesothelioma is associated with asbestos exposure[5]. This is classed as an occupational disease, however, although this is of historical importance it is unlikely to represent a significant occupational exposure and hence risk among the current generation of FF as there is less asbestos.

Some associations have been observed with lip cancer, cardiovascular disease and respiratory diseases but this is all likely to be explained by lifestyle factors (i.e. smoking, alcohol).

There is no evidence to support an association between the occupational hazards of being FF and tongue cancer, parotid gland tumours, cancer of the nasal sinuses, thyroid carcinoma, heart disease, and traumatic injury.

DISCUSSION

Overview

Health outcomes experienced by FF has been an area of interest within Australia and internationally for many years. FF, as well as being exposed to a number of occupational hazards, adhere to strict health and safety guidelines which will to some degree mitigate the extent of the adverse occupational exposures.

This current report – based on eight studies – concludes that there is convincing evidence to support a causal association between the occupational hazards of being a FF and melanoma. Suggestive, inadequate and very limited levels of evidence were observed between the occupational hazards of being a FF and noise induced hearing loss, lung cancer, ALS, MSD and psychiatric conditions, these outcomes should be monitored. No other conditions – at this time – show sufficient evidence to support a causal association.

Although this review was conducted on the eight identified studies, the findings fit with the broader international literature in this field[16-19]. Studies of this occupational group need to be long term to allow the development of chronic disease with long latency periods. It is also relevant to consider the recent and current working practices, environments and health screening of FF – in that historical exposures (i.e. asbestos) may no longer be relevant. Further, protective equipment has advanced considerably over the last few decades and the use of these equipment and changing policies will reduce the likelihood of exposure to chemicals and other agents. Therefore, some types of cancer and other chronic diseases may not be relevant for current FF, but still relevant for the older generations.

Limitations

- Eight studies were selected by the DVA for inclusion in the review and were, therefore, critically examined and appraised. Although these studies are not representative of all the evidence available internationally, the review's findings align with the world literature.
- The eight studies reviewed, have been primarily based on male FF– health issues relevant to female FF have thus not been sufficiently studied. There may be specific mental and physical health needs among female FF.
- The studies have primarily focused on cancer, providing limited data on other conditions (for example, psychiatric, hearing, and musculoskeletal). This emphasis on cancer has been the more traditional approach used when exploring occupational risk factors. However, other occupational cohorts (for example, the Whitehall Study) have expanded to cover a diverse range of outcomes, for example, coronary heart disease and gastrointestinal diseases[20, 21]. Still, although these traditional occupational cohort studies are often large, they do have limited statistical power to examine rare outcomes.
- For many of the health conditions examined, there is evidence of associations between them and a range of lifestyle factors. However, lifestyle data was missing from most studies meaning that any associations seen could be due to lifestyle rather than occupational exposures related to firefighting.

- Specific occupational exposures were rarely examined and crude (or proxy) estimates of exposure were considered.

Justification for decisions

When considering each health condition, a number of factors were considered: the RMA Guidelines, the Bradford Hill Criteria, the quality of the included studies with a focus on the biological plausibility of an association and the size of the observed effects. These are well-established and commonly applied criteria for good practice and used by a range of leading global organisations such as the International Agency for Research on Cancer. The use of these guidelines/criteria will provide the DVA with the foundation to translate the review's findings to the relevant legislations.

Convincing evidence was observed for a causal association with melanoma, strong and consistent effect sizes were reported – overall and dose-response –with evidence of biological plausibility.

Suggestive evidence was observed for noise induced hearing loss. This is supported by international work. Further research is needed.

Conclusions

This review concludes that there is convincing evidence for a causal association between melanoma and the occupational hazards of being a FF and suggestive evidence for noise induced hearing loss. Other conditions requiring further investigation were identified (lung cancer, ALS, mental health and MSD).

Recommendations

The following recommendations have been made:

- To ensure the continual follow up of FF, including DFF
    a. to include other health outcomes especially lung cancer, mental health, noise induced hearing loss and musculoskeletal disorders
    b. to include the additional collection of data on lifestyle factors
- To establish (and follow-up) of a female cohort of FF, including DFF
- To class melanoma as having convincing evidence for a causal association with the occupational hazards of being a FF
- To consider melanoma for inclusion in the *Safety, Rehabilitation and Compensation* policies for FF, including DFF

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ABBREVIATIONS

ADF: Australian Defence Force
AF: Air Force
AHR: adjusted hazard ratio
ALS: Amyotrophic Lateral Sclerosis
AOR: adjusted odds ratio
CI: confidence interval
COPD: chronic obstructive pulmonary disease
DFF: Defence Fire Fighters
DVA: Department of Veterans Affairs
FF: Fire Fighters
HR: hazard ratio
ICD: international classification of diseases
MSD: musculoskeletal disorders
NA: not applicable
NHLBI: National Heart, Lung and Blood Institute
OR: odds ratio
PAHs: polycyclic aromatic hydrocarbons
PCBs: polychlorobiphenyl
PTSD: post-traumatic stress disorder
PVC: polyvinyl chloride
RMA: Repatriation Medical Authority
SIR: standard incidence ratio
SMR: standard mortality ratio
SMSE: sound medical-scientific evidence
UV: ultra violet

Appendix 1: Characteristics of the papers reviewed (order of papers as listed in the terms of reference).

Study no.	Author	Year released	Country	Study design	Study population	Comparison population	Data collection method	Limitations and strengths	Study quality rating*
1	Glass D.	2014	Australia	Retrospective cohort study	14,081 career full time Fire Fighters, 11,062 part time Fire Fighters, 199,490 volunteer Fire Fighters, Total: 224,633 Fire Fighters (male and female)	General population Australia	National Death Index Australian Cancer Database HR resources	- no information on smoking, other lifestyle or genetic factors - small number of women - short follow-up period (average age at end of follow up under 50 years) + females included + looked at exposure response to certain extent + large sample size	Fair
2	Glass D.	2014	Australia	Retrospective cohort study	609 Fire Fighters who all attended Fiskville Training College (3 females included)	General population Australia and Victoria	National Death Index Australian Cancer Database Victorian Cancer Registry HR resources	- no information on smoking, other lifestyle or genetic factors - females excluded - exposure response based on exposure to materials at the training site, not their usual Fire Fighter duties - small sample size - ascertainment bias - average length of follow-up 25.5 years (average age at end of follow up around 55 years)	Poor

								- only small number of deaths (n=28) and incidence cases (n=69) + sensitivity analyses undertaken for missing data and showed limited differences + internal group comparisons to limit healthy worker effect	
3	Glass D.	2015	Australia	Retrospective cohort study	1,796 defence Fire Fighters (male only)	General population Australia	National Death Index Australian Cancer Database HR resources	- no information on smoking, other lifestyle or genetic factors - females excluded - short follow up period (average age at end of follow up 45 years) - no exposure data - no stratification per service branch, only for Air Force due to anonymity issues - small sample - no information on duration of employment - 1 in approximately 9 had missing date of birth and therefore excluded - unsure about their actual exposure to fire; those who ever served in a	Poor

								firefighting role - only small number of deaths, (n=44 AF; n=44 all DFF) + Australian Defence Fire Fighters	
4	Daniels et al.,	2015	US (San Francisco, Chicago and Philadelphia)	Retrospective cohort study	19,309 career Fire Fighters (male only)	US population	National Death Index-Plus Social Security Administration Death Master File Personnel and pension board records State vital records Previous studies State cancer registries	- no information on smoking, other lifestyle or genetic factors (however they tried to do this by examining patterns of diseases strongly related to smoking and alcohol abuse) - females excluded + adequate sample size + career Fire Fighters + some sort of exposure data used	Fair
5	Tsai et al.,	2015	US (California)	Case-control study	3,996 career Fire Fighters (male only)	General population California with a control cancer (e.g. assumed not to be associated with firefighting)	California cancer registry	- no information on smoking, other lifestyle or genetic factors - females excluded - military personnel were excluded - difficulty in identifying Fire Fighters as such ('all Fire Fighters instead of structural Fire Fighters') - large numbers of records were excluded due to not	Fair

								meeting the eligibility criteria/missing data (50%) - no occupational exposure data + large sample size based on data from a (complete) cancer registry + examining race/ethnicity as a potential modifier	
6	Bowling et al.,	2014	Australia	Case-control study in combination with laboratory cell studies of DeSeal/ReSeal compounds	175 people who worked (in)directly in the Deseal/Reseal project or had (in)direct exposure to F111 jet fuel	77 controls from the general community or current and ex-Air Force personnel who were matched for age and gender	Participant assessment of health outcomes, blood collection and clinical data.	- no information on smoking, other lifestyle or genetic factors - females excluded - small sample size - poor selection of controls	CD#
7	Guidotti T.	2014	Worldwide	Systematic review	Career Fire Fighters	NA	Systematic search of electronic databases, internet, books, symposia proceedings, grey and secondary literature and consultation of experts	- some recommendations given cannot be traced back to the relevant literature presented - no quality rating for the studies included + extensive, comprehensive and thorough search of available resources	NA
8	Peel G.	2015	Australia	Case file	71 Royal Air	NA	DVA case files	- no information on	NA

				review	Force, Royal Navy and Army Fire Fighters		and ADF health records	smoking, other lifestyle or genetic factors - no information on exposure history - no females included - small sample size - no information given on how cases were selected + Australian Defence Fire Fighters	

ADF: Australian Defence Force; AF: Air Force; CD: cannot be determined; DFF: Defence Fire Fighters; DVA: Department of Veterans Affairs; HR: Human Resources; NA: not applicable.

* The strengths and limitations of the systematic review and the case file review were identified, however the methodological quality of these studies was not assessed with the quality assessment tools because these were not applicable.

An overall quality rating for this particular study was not given, as it was primarily designed as a laboratory study and not as a case-control study.

Appendix 2: Data extraction table of the papers reviewed.

Health conditions#	Results	Exposure-response effect	Biological plausibility
Cancer			
Cancer, general *(ICD-10; C00-D48)*	S2 (mortality): SMR 0.90 (95%CI 0.51-1.45, n=16) Compared to Victorian population S2 (incidence): SIR 1.11 (95%CI 0.86-1.41, n=69) Compared to Victorian population S3 (mortality): *All defence Fire Fighters* SMR 0.78 (95%CI 0.44-1.28, n=15) *Air force only* SMR 0.84 (95%CI 0.46-1.41, n=14) Air force n=924 Compared to Australian population S3 (incidence): *All defence Fire Fighters* SIR 1.00 (95%CI 0.76-1.29, n=58) *Air force only* 1.02 (95%CI 0.76-1.35, n=49) Air force n=924 Compared to Australian population	S1 (mortality): *Career full-time male Fire Fighters* **SMR 0.81 (95%CI 0.72-0.90, n=329)** *Part-time paid male Fire Fighters* SMR 0.84 (95% CI 0.70-1.00, n=124) *Volunteer male Fire Fighters* **SMR 0.59 (95%CI 0.57-0.62, n=123**) *Volunteer female Fire Fighters* **SMR 0.75 (95%CI 0.66-0.84, n=1900)** Career full-time male Fire Fighters n=17,394 Part-time paid male Fire Fighters n=12,663 Volunteer male Fire Fighters n=163,159 Volunteer female Fire Fighters n=37,973 Compared to Australian population S1 (incidence): *Career full-time male Fire Fighters* **SIR 1.08 (95%CI 1.02-1.14, n=1208)** *Part-time paid male Fire Fighters* **SIR 1.11 (95%CI 1.01-1.21, n=485)** *Volunteer male Fire Fighters* **SIR 0.86 (95%CI 0.84-0.88, n=7057)** *Career full-time female Fire Fighters* SIR 0.82 (95%CI 0.35-1.61, n=8) *Part-time paid female Fire Fighters* SIR 1.38 (95%CI 0.84-2.13, n=20) *Volunteer female Fire Fighters* SIR 0.97 (95%CI 0.91-1.03, n=1027) Career full-time male Fire Fighters n=17,394 Part-time paid male Fire Fighters n=12,663 Volunteer male Fire Fighters n=163,159 Career full-time male Fire Fighters n=641 Career full-time female Fire Fighters n=8 Part-time paid female Fire Fighters n=1041	

		Volunteer female Fire Fighters n=37,973 Compared to Australian population S2 (mortality): *Low exposure* SMR 0.29 (95%CI 0.01-1.64, n=1) *Medium exposure* SMR 0.87 (95%CI 0.40-1.65, n=9) *High exposure* SMR 1.47 (95%CI 0.54-3.19, n=6) Low exposure n=252 Medium exposure n=256 High exposure n=95 Compared to Victorian population *Medium exposure, career Fire Fighters* SMR 0.89 (95%CI 0.24-2.27, n=4) *Medium exposure, volunteer Fire Fighters* SMR 0.85 (95%CI 0.28-1.99, n=5) S2 (incidence): *Low exposure* **SIR 0.40 (95%CI 0.15-0.87, n=6)** *Medium exposure* SIR 1.13 (95%CI 0.80-1.55, n=38) *High exposure* **SIR 1.85 (95%CI 1.20-2.73, n=25)** Low exposure n=252 Medium exposure n=256 High exposure n=95 Compared to Victorian population *Medium exposure, career Fire Fighters* SIR 1.26 (95% 1.20-2.73, n=25) *Medium exposure, volunteer Fire Fighters* SIR 1.05 (95%CI 0.66-1.59, n=22) S4 (mortality)*: **$AHR_{exposed}$: 0.95 (95%CI 0.90-0.99, n=1333)** $AHR_{fireruns}$: 0.95 (95%CI 0.89-1.01, n=1162)	

		AHR firehours: 0.97 (95%CI 0.90-1.05, n=810) * adjusted for race, fire department and birth cohort S4 (incidence)*: AHR exposed: 0.96 (95%CI 0.87-1.05, n=2609) AHR fireruns: 0.95 (95%CI 0.89-1.01, n=2197) AHR firehours: 0.97 (95%CI 0.90-1.05, n=1395) * adjusted for race, fire department and birth cohort	
Lip cancer *(ICD-10; C00-C14)*	S2 (incidence, lip combined with buccal cavity and pharynx): SIR 0.66 (95%CI 0.08-2.40, n=2) compared to Victorian population S3 (incidence, lip combined with oral pharynx): *All defence Fire Fighters* SIR 1.00 (95%CI 0.76-1.29, n=3) *Air force only* SIR 1.10 (95%CI 0.23-3.21, n=3) Air force n=924 Compared to general Australian population S5 (incidence)*: *all Fire Fighters* AOR 1.44 (95%CI 0.89-2.33, n=19) *white Fire Fighters* AOR 1.36 (95%CI 0.82-2.25, n=17) *other race/ethnicity Fire Fighters* AOR 6.56 (95%CI 0.87-49.58, n=1) *(*Hispanic 62.2%, Black 27.7%, Asians <10%) * adjusted for age of diagnosis, race and year of diagnosis General population with control cancers S7 (incidence): Cancer of the lip suggested in recommendations but only addressed very briefly in the systematic review Systematic review	S1 (incidence): *Full-time male Fire Fighters* SIR 1.11 (95%CI 0.70-1.66, n=23) *Part-time male Fire Fighters* SIR 1.27 (95%CI 0.63-2.27, n=11) *Volunteer male Fire Fighters* SIR 1.15 (95%CI 0.96-1.37, n=125) *volunteer female Fire Fighters* SIR 1.18 (95%CI 0.43-2.56, n=6) Career full-time male Fire Fighters n=17,394 Part-time paid male Fire Fighters n=12,663 Volunteer male Fire Fighters n=163,159 Volunteer female Fire Fighters n=37,973 Compared to Australian population S2 (incidence, lip combined with buccal cavity and pharynx): *Low exposure* SIR - *Medium exposure* SIR 0.65 (95%CI 0.02-3.62, n=1) *High exposure* SIR 1.61 (95%CI 0.04-8.98, n=1) Low exposure n=252 Medium exposure n=256 High exposure n=95 Compared to Victorian population *Medium exposure, career Fire Fighters* SIR 1.74 (95%CI 0.04-9.72, n=1) *Medium exposure, volunteer Fire Fighters* SIR -	S7: The majority of the risk factors for oral and pharyngeal cancers are related to life style factors (smoking, alcohol, tobacco chewing) and nickel subsulfide exposure
Lung cancer	S2 (incidence, respiratory (lung/larynx)):	S1 (incidence):	S4:

(ICD-10; C33-C34)	SIR 0.65 (95%CI 0.18-1.66, n=4) S3 (mortality, respiratory, including lung): *All defence Fire Fighters* SMR 1.56 (95%CI 0.43-4.01, n=4) *Air force only* SMR 1.78 (95%CI 0.49-4.56, n=4) Air force n=924 Compared to general Australian population S3 (incidence, lung) *All defence Fire Fighters* SIR 1.12 (95%CI 0.37-2.62, n=5) *Air force only* SIR 0.99 (95%CI 0.27-2.54, n=4) Air force n=924 Compared to general Australian population S5 (incidence)*: *all Fire Fighters* **AOR 2.01 (95%CI 1.38-2.93, n=42)** *white Fire Fighters* **AOR 2.02 (95%CI 1.34-3.04, n=37)** *other race/ethnicity Fire Fighters* AOR 2.42 (95%CI 0.86-6.80, n=5) *(*Hispanic 62.2%, Black 27.7%, Asians <10%) * adjusted for age of diagnosis, race and year of diagnosis General population with control cancers S7 (incidence and mortality): Inconclusive evidence from various studies with regards to lung cancer incidence and mortality, probably due to confounding (smoke, lifestyle factors, healthy worker effect). Potential for synergistic or additive interaction between cigarette smoking and fire smoke. Systematic review	*full-time career male Fire Fighters* SIR 0.81 (95%CI 0.65-1.00, n=86) *part-time male Fire Fighters* **SIR 0.42 (95%CI 0.23-0.69, n=15)** *volunteer male Fire Fighters* **SIR 0.48 (95%CI 0.55-0.54, n=371)** *volunteer female Fire Fighters* SIR 0.93 (95%CI 0.72-1.18, n=65) Career full-time male Fire Fighters n=17,394 Part-time paid male Fire Fighters n=12,663 Volunteer male Fire Fighters n=163,159 Volunteer female Fire Fighters n=37,973 Compared to Australian population S2 (incidence, respiratory (lung/larynx)): *Low exposure* SIR 0 (n=0) *Medium exposure* SIR 0.84 (95%CI 0.17-2.46, n=3) *High exposure* SIR 0.68 (95%CI 0.02-3.77, n=1) Low exposure n=252 Medium exposure n=256 High exposure n=95 Compared to Victorian population S4 (mortality)*: $AHR_{exposed}$: 0.93 (95%CI 0.86-1.03, n=429) $AHR_{fireruns}$: 1.11 (95%CI 0.95-1.29, n=398) **$AHR_{firehours}$: 1.39, 95%CI 1.12-1.73, n=288)** (Especially driven by Chicago Fire Fighters Department) * Race, fire department and birth cohort S4 (incidence)*: $AHR_{exposed}$: 1.05 (95%CI 0.84-1.33, n=382) $AHR_{fireruns}$: 1.10 (95%CI 0.94-1.28, n=358) **$AHR_{firehours}$: 1.39 (95%CI 1.10-1.74, n=243)** * Race, fire department and birth cohort	Lung carcinogens in inhaled smoke (arsenic, asbestos, benzo(a)pyrene and cadmium)

	S8: Lung adeno carcinoma (latency period of 41 years) Case file review		
Melanoma *(ICD-10; C43)*	S2 (incidence): **SIR 2.08 (95%CI 1.14-3.50, n=14)** Compared to Victorian population S3 (incidence): *All defence Fire Fighters* SIR 0.96 (95%CI 0.44-1.82, n=9) *Air force only* SIR 0.98 (95%CI 0.39-2.01, n=7) Air force n=924 Compared to general Australian population S5 (incidence)*: *all Fire Fighters* **AOR 1.75 (95%CI 1.44-2.13, n=265)** *white Fire Fighters* **AOR 1.71 (95%CI 1.40-2.09, n=254)** *Other race/ethnicity Fire Fighters (*Hispanic 62.2%, Black 27.7%, Asians <10%) **AOR 4.51 (95%CI 1.85-10.97, n=7)** * adjusted for age of diagnosis, race and year of diagnosis General population with control cancers S7 (incidence and mortality): Unlikely due to ultraviolet radiation in occupational settings, however there is indication of elevated risk, potentially due to other chemical exposures. Systematic review	S1 (incidence): *Full-time male Fire Fighters* **SIR 1.45** **(95%CI 1.26-1.66, n=209)** *Part-time male Fire Fighters* **SIR 1.43** **(95%CI 1.15-1.76, n=89)** *Volunteer male Fire Fighters* SIR 1.00 (95%CI 0.93-1.06, n=912) *Part-time female Fire Fighters* SIR 2.10 (95%CI 0.68-4.90, n=5) *Volunteer female Fire Fighters* **SIR 1.25** **(95%CI 1.05-1.46, n=147)** Career full-time male Fire Fighters n=17,394 Part-time paid male Fire Fighters n=12,663 Volunteer male Fire Fighters n=163,159 Career full-time male Fire Fighters n=641 Part-time paid female Fire Fighters n=1041 Volunteer female Fire Fighters n=37,973 Compared to Australian population S2 (incidence): *Low exposure* SIR 1.43 (95%CI 0.29-4.18, n=3) *Medium exposure* SIR 1.51 (95%CI 0.49-3.52, n=5) *High exposure* **SIR 4.59 (95%CI 1.68-9.99, n=6)** Low exposure n=252 Medium exposure n=256 High exposure n=95 Compared to Victorian population *Medium exposure, career Fire Fighters* SIR 2.45 (95%CI 0.50-7.15, n=3) *Medium exposure, volunteer Fire Fighters*	S5: Exposure to ultraviolet radiation, benzene, PAH, PCBs, aromatic hydrocarbons, and heavy oil S7: Exposure vinyl chloride, PAHs, PCBs, ultraviolet radiation, possibly solvents

		SIR 0.96 (95%CI 0.12-3.47, n=2)	
Mesothelioma *(ICD-10; C45)*	S5 (incidence): *all Fire Fighters* AOR 1.40 (95%CI 0.89-2.21, n=21) *white Fire Fighters* AOR 1.34 (95%CI 0.83-2.16, n=19) *other race/ethnicity Fire Fighters* (Hispanic 62.2%, Black 27.7%, Asians <10%) AOR 2.86 (95%CI 0.67-12.28, n=2) * adjusted for age of diagnosis, race and year of diagnosis General population with control cancers S3: number of observed cases <3, no results reported S7 (incidence and mortality): Few studies looked at this cancer but the findings strongly suggest that mesothelioma might be an occupational disease. However latency period can be long, up to 40-50 years. For current Fire Fighters, the risk might be lower as there is less asbestos than in the earlier years. Systematic review	S1 (incidence): *full-time career male Fire Fighters* SIR 1.33 (95%CI 0.66-2.37, n=11) *part-time male Fire Fighters* SIR 1.38 (95%CI 0.37-3.52, n=4) *volunteer male Fire Fighters* **SIR 0.64 (95%CI 0.46-0.87, n=42)** *volunteer female Fire Fighters* SIR 1.47 (95%CI 0.30-4.29, n=3) Career full-time male Fire Fighters n=17,394 Part-time paid male Fire Fighters n=12,663 Volunteer male Fire Fighters n=163,159 Volunteer female Fire Fighters n=37,973 Compared to Australian population	S7: Asbestos exposure
Nasal sinus cancer *(ICD-10; C31)*	S7 (incidence): Nasal sinus cancer suggested in recommendations but only 1 study was discussed in the body of the systematic review systematic review		
Parotid gland tumours *(ICD-10; C07-C08)*	S5 (incidence): *all Fire Fighters* AOR 1.30 (95%CI 0.75-2.25, n=14) *white Fire Fighters* AOR 1.19 (95%CI 0.66-2.15, n=12) *other race/ethnicity Fire Fighters* AOR 3.60 (95%CI 0.83-15.59, n=2) (Hispanic 62.2%, Black 27.7%, Asians <10%) * adjusted for age of diagnosis, race and year of diagnosis General population with control cancers S7 (incidence): Parotid gland tumours suggested in recommendations		

	but not discussed in the body of the systematic review. Systematic review S8: Parotid carcinoma (36 years latency period) Case file review		
Thyroid carcinoma *(ICD-10; C73)*	S5 (incidence): *all Fire Fighters* AOR 1.27 (95%CI 0.88-1.84, n=41) *white Fire Fighters* AOR 1.21 (95%CI 0.81-1.80, n=36) *other race/ethnicity Fire Fighters* *(*Hispanic 62.2%, Black 27.7%, Asians <10%) AOR 1.92 (95%CI 0.66-5.60, n=5) * adjusted for age of diagnosis, race and year of diagnosis General population with control cancers S3: number of observed cases <3, no results reported S7 (incidence): Insufficient evidence for an association as an occupational disease, further also unsure about possible biological mechanism. Systematic review	S1 (incidence): *Full-time male Fire Fighters* SIR 1.18 (95%CI 0.63-2.01, n=13) *Part-time male Fire Fighters* SIR 1.26 (95%CI 0.51-2.59, n=7) *Volunteer male Fire Fighters* SIR 0.83 (95%CI 0.63-1.07, n=58) *Female part-time Fire Fighters* SIR 2.90 (95%CI 0.60-8.49, n=3) (thyroid & other endocrine) *Female volunteer Fire Fighters* SIR 0.97 (95%CI 0.69-1.33, n=39) Career full-time male Fire Fighters n=17,394 Part-time paid male Fire Fighters n=12,663 Volunteer male Fire Fighters n=163,159 Volunteer female Fire Fighters n=37,973 Compared to Australian population	
Tongue cancer *(ICD-10; C01-C02)*	S5 (incidence): *all Fire Fighters* AOR 1.18 (95%CI 0.82-1.70, n=35) white Fire Fighters AOR 1.10 (95%CI 0.75-1.61, n=31) *other race/ethnicity Fire Fighters* **AOR 3.57 (95%CI 1.23-10.35, n=4)** *(*Hispanic 62.2%, Black 27.7%, Asians <10%) * adjusted for age of diagnosis, race and year of diagnosis General population with control cancers S7: Almost no studies looked specifically at cancer of the tongue, but just examine oral and pharyngeal cancers as one group. No substantial elevations have been found.		S7: The majority of the risk factors for oral and pharyngeal cancers are related to life style factors (smoking, alcohol, tobacco chewing) and nickel subsulfide exposure

	Systematic review S8: Tongue squamous cell carcinoma (latency period of 17 years) Case file review		
Cardiovascular conditions *(ICD-10; I00-I99)*	S1 (mortality) *Career Fire Fighters, all circulatory* **SMR 0.64 (95%CI 0.55-0.73, n=209)** *Career Fire Fighters, hypertensive* SMR 0.84 (95%CI 0.27-1.96, n=5) *Career Fire Fighters, IHD* **SMR 0.71 (95%CI 0.60-0.84, n=150)** *Career Fire Fighters, cerebrovascular* **SMR 0.54 (95%CI 0.36-0.78, n=27)** S8: 2.5% (n=14) of case files reviewed (including hypertension, ischaemic heart disease) Case file review		
Accelerated decline in lung function (in a non-smoker) *(ICD-10; J40-J70)*	S7 (incidence): For the current generation of Fire Fighters there is no evidence of a decline in ventilator function in their early careers, however for older cohorts some decline might have occurred. If the protective respiratory methods are used adequately, no decline in pulmonary function should be noted. Systematic review		S7: Exposure to products of combustion, toxic agents as carbon monoxide and cyanide and PVC
Acute respiratory failure and decompensation within 24 hrs of work *(ICD-10; I20-I25/I30-I52)*	S1 (mortality):*Career Fire Fighters, all respiratory* **SMR 0.58 (95%CI 0.41-0.80, n=38)**		
Asthma, irritant induced (associated with a particularly intense event or exposure history) *(ICD-10; J40-J70)*	S7 (incidence): Intense events/exposure history are plausible may interact with vulnerability at individual level. Potentially preventable by wearing respiratory protection. Interaction with individual susceptibility. Systematic review		S7: Exposure to products of combustion, toxic agents as carbon monoxide and

			cyanide and PVC
Asthma, irritant induced (sufficient to cause respiratory impairment) *(ICD-10; J40-J70)*	S7 (incidence): Rare but plausible since the high intensity of some of the exposures, however respiratory protection should act preventive. Confounded by a variety of factors such as childhood asthma/smoking. Further, it might be additive till a tipping point has been reached. Systematic review		S7: Exposure to products of combustion, toxic agents as carbon monoxide and cyanide and PVC
Chronic obstructed airways disease with minimal or no smoking history) *(ICD-10; J40-J44)*	S1 (mortality): *Career Fire Fighters, COPD* **SMR 0.61 (95%CI 0.39-0.92, n=22)** S7 (incidence and mortality): No occupational risk for chronic fixed obstructive airways disease. Systematic review S8: 1.6% (n=9) of case files reviewed (respiratory – chronic obstructive airways disease)	S4 (mortality)*: $HR_{exposed}$: 0.83 (95%CI 0.59-1.19, n=130) $HR_{fireruns}$: 0.93 (95%CI 0.73-1.26, n=84) $HR_{firehours}$: 1.47 (95%CI 0.86-2.59, n=113) * Race, fire department and birth cohort	
Heart attacks¬ *(ICD-10; I20-I25/I30-I52)*	S7 (incidence and mortality): Most cardiovascular conditions are due to shared risk factors among peers. However, some are associated with occupational risk factors such as fire suppression, training, knockdown and response to alarms. These may precipitate hearth attacks in those with pre-existing coronary artery disease. Systematic review		S7: Exposure to cardio toxic substances, exertion, heat stress, dehydration, shift work, alarm reaction, psychogenic stress and exertion/stress-related
Motor neuron disease *(ICD-10; G12)*	S8: Motor neuron disease (latency period unspecified) Case file review		
Amyotrophic lateral sclerosis *(ICD-10; G12)*	S7 (incidence): Insufficient evidence till so far to draw a conclusion; contradictive results and only small number of studies. Systematic review		S7: Unknown
Musculoskeletal	S7 (incidence):		S7:

disorders (chronic) resulting in impairment leading to disability *(ICD-10; M00-M99)*	Low back pain, no evidence for higher prevalence Osteoarthritis (hip and knee, strong evidence but only 1 or 2 studies given. Systematic review S8: 29.6% (n=168) of case files reviewed (includes degenerative spine, joint diseases, factures, sprains)		Heavy physical workload (osteoarthritis)
Noise-induced hearing loss *(ICD-10; H90-H95)*	S7 (incidence): Limited research has been done but compelling evidence suggests that it is an occupational hazard. Systematic review	S7 (incidence): Prevalence is associated with duration of service. Systematic review	S7: Transit vehicles, siren blaring, water exiting the hose at high pressure
Psychiatric conditions *(ICD-10; F00-F99)*	S1 (mortality): *Career Fire Fighters, dementia and Alzheimer's* SMR 0.85 (95%CI 0.39-1.61, n=9) S8: 10.1% (n=57) of case files reviewed (psychiatric/psychological conditions such as depression, anxiety, PTSD, alcohol abuse) Case file review		
Post-traumatic stress disorder *(ICD-10; F43)*	S7 (incidence): No accurate summary of the literature given. Systematic review		S7: High levels of stress and exposure to traumatic events
Reactive depression *(ICD-10; F30-F39)*	S7 (incidence): No accurate summary of the literature given. Systematic review		S7: High levels of stress and exposure to traumatic events
Traumatic injury resulting in impairment leading to disability *(ICD-10; V01-Y98)*	S2 (mortality, all injury and trauma): SMR 0.40 (95%CI 0.11-1.01, n=4) S3 (mortality, all injury and trauma): *all defence Fire Fighters* **SMR 0.48 (95%CI 0.22-0.92, n=9)** *Air force only* SMR 0.48 (95%CI 0.18-1.05, n=6) Air force n=924 Compared to general Australian population	S1 (mortality all injury and trauma): *Career full-time male Fire Fighters* **SMR 0.51 (95%CI 0.41-0.63, n=88)** *Part-time male paid Fire Fighters* **SMR 0.76 (95%CI 0.59-0.96, n=68)** *Volunteer male Fire Fighters* **SMR 0.72 (95%CI 0.66-0.77, n=663)** *Volunteer female Fire Fighters* SMR 1.07 (95%CI 0.83-1.36, n=66) Career full-time male Fire Fighters n=17,394	

		Part-time paid male Fire Fighters n=12,663 Volunteer male Fire Fighters n=163,159 Volunteer female Fire Fighters n=37,973 Compared to Australian population *Career full-time male Fire Fighters, all accidents* **SMR 0.38 (95%CI 0.27-0.53, n=35)** *Career full-time male Fire Fighters, fire* SMR 0.48 (95%CI 0.01-2.68, n=1) *Career full-time male Fire Fighters, suicide* **SMR 0.74 (95%CI 0.55-0.98, n=50)** S2 (mortality): *Low exposure* SMR 0.24 (95%CI 0.01-1.32, n=1) *Medium exposure* SMR 0.69 (95%CI 0.14-2.03, n=3) *High exposure* SMR – (n=0) *Medium exposure, career Fire Fighters* SMR 1.08 (95%CI 0.13-3.90, n=2) *Medium exposure, volunteer Fire Fighters* SMR 0.40 (95%CI 0.01-2.25, n=1)	

AHR: adjusted hazard ratio; AOR: adjusted odds ratio; HR: hazard ratio; ICD: International classification of diseases; IHD: ischemic heart disease; SIR: standard incidence ratio; SMR: standard mortality ratio; PAHs: polycyclic aromatic hydrocarbons; PCBs: polychlorobiphenyl; PVC: polyvinyl chloride.

Of the 8 studies given by the DVA, only the studies that are examining this particular health condition are listed.

¬ following an alarm or knockdown by up to 24 to 72 hours, resulting in disability.

Bold and dark red is statistically significant (increased risk), **blue and bold** is statistically significant (decreased risk).

Study 1: Glass D. Australian Fire Fighters' Health Study by Monash University (released Dec 2014)
Study 2: Glass D. Fiskville Fire Fighters' Health Study by Monash University (released Nov 2014)
Study 3: Glass D. Defence Fire Fighters' Health Study by Monash University (released July 2015)
Study 4: Daniels et al. Study of Cancer among U.S. Fire Fighters (United States Centres for Disease Control and Prevention: National Institute for Occupational Safety and Health (NIOSH) (released February 2015).
Study 5: Tsai et al. Risk of cancer among Fire Fighters in California, 1988-2007 (released May 2015).
Study 6: Bowling et al. Jet Fuel Exposure Syndrome Study (JFESS) (released July 2014)
Study 7: Guidiotti T. Health Risks and Occupation as a Fire Fighter (released May 2015)
Study 8: Peel G. Defence Fire Fighter Case File Review (released May 2015)

Appendix 3: Quality assessment: cohort studies included in the review.

Criteria	S1	S2	S3	S4
1. Was the research question or objective in this paper clearly stated?	Y	Y	Y	Y
2. Was the study population clearly specified and defined?	Y	Y	Y	Y
3. Was the participation rate of eligible persons at least 50%?	Y	Y	Y	CD
4. Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study pre-specified and applied uniformly to all participants?	N	Y	N	Y
5. Was a sample size justification, power description, or variance and effect estimates provided?	N	N	N	N
6. For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	CD	CD	CD	CD
7. Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?	N	N	N	N
8. For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?	Y	Y	N	Y
9. Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	N	N	Y	Y
10. Was the exposure(s) assessed more than once over time?	N	N	N	Y
11. Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Y	Y	Y	Y
12. Were the outcome assessors blinded to the exposure status of participants?	CD	CD	CD	CD
13. Was loss to follow-up after baseline 20% or less?	N	NR	Y	CD
14. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	N	N	N	N
Overall rating (good, fair or poor)	**Fair**	**Poor**	**Poor**	**Fair**

Y: Yes; N: No; CD: cannot be determined; NR: not reported; NA: not applicable

Appendix 4: Quality assessment: case-control studies included in the review.

Criteria	S5	S6*
1. Was the research question or objective in this paper clearly stated and appropriate?	Y	N
2. Was the study population clearly specified and defined?	Y	Y
3. Did the authors include a sample size justification?	N	NR
4. Were controls selected or recruited from the same or similar population that gave rise to the cases (including the same timeframe)?	Y	N
5. Were the definitions, inclusion and exclusion criteria, algorithms or processes used to identify or select cases and controls valid, reliable, and implemented consistently across all study participants?	Y	N
6. Were the cases clearly defined and differentiated from controls?	Y	Y
7. If less than 100 percent of eligible cases and/or controls were selected for the study, were the cases and/or controls randomly selected from those eligible?	NA	N
8. Was there use of concurrent controls?	N	N
9. Were the investigators able to confirm that the exposure/risk occurred prior to the development of the condition or event that defined a participant as a case?	Y	CD
10. Were the measures of exposure/risk clearly defined, valid, reliable, and implemented consistently (including the same time period) across all study participants?	N	CD
11. Were the assessors of exposure/risk blinded to the case or control status of participants?	CD	NR
12. Were key potential confounding variables measured and adjusted statistically in the analyses? If matching was used, did the investigators account for matching during study analysis?	N	N
Overall rating (good, fair or poor)	**Fair**	**CD#**

Y: Yes; N: No; CD: cannot be determined; NR: not reported; NA: not applicable

* Only the quality of the 'exposed workers' study was assessed.

An overall quality rating for this particular study was not given, as it was primarily designed as a laboratory study and not as a case-control study.

Study 1: Glass D. Australian Fire Fighters' Health Study by Monash University (released Dec 2014)
Study 2: Glass D. Fiskville Fire Fighters' Health Study by Monash University (released Nov 2014)
Study 3: Glass D. Defence Fire Fighters' Health Study by Monash University (released July 2015)
Study 4: Daniels et al. Study of Cancer among U.S. Fire Fighters (United States Centres for Disease Control and Prevention: National Institute for Occupational Safety and Health (NIOSH) (released February 2015).
Study 5: Tsai et al. Risk of cancer among Fire Fighters in California, 1988-2007 (released May 2015).
Study 6: Bowling et al. Jet Fuel Exposure Syndrome Study (JFESS) (released July 2014)
Study 7: Guidiotti T. Health Risks and Occupation as a Fire Fighter (released May 2015)
Study 8: Peel G. Defence Fire Fighter Case File Review (released May 2015)