MONASH University

Defence Firefighters' Health Study

MONASH
Centre for Occupational
and Environmental Health

School of Public Health & Preventive Medicine

Faculty of Medicine, Nursing and Health Sciences

April 2015

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ACKNOWLEDGMENTS

The study was funded by the Department of Defence.

The team from Monash University would like to acknowledge the Department of Defence's assistance in compiling the cohort, in particular that of Ian Gardner, Catherine Wallis, Stuart Watters, Leonard Brennan and Angela Buchecker. We would also like to thank Jeff Peterson, Chris Taylor and Paul Crawford, members of the Advisory Committee, for their help and guidance.

We also acknowledge the assistance provided by the Australian Institute of Health and Welfare for the timely linkage of the cohort and provision of reference data.

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1 Summary

In 2012, a team from Monash University was commissioned by the Department of Defence to undertake a retrospective study of mortality and cancer incidence among Defence firefighters.

Ethics approval for the study was granted by the Human Research Ethics Committees of Monash University, the Department of Defence and Department of Veterans' Affairs, the State and Territory Cancer Registries, the Australian Institute for Health and Welfare (AIHW) and the National Coronial Information Service.

Defence supplied records of individual firefighters from Air Force, Army and Navy including their job histories where available. The start dates of the personnel records which were provided varied with the branch of Defence, ranging from the 1950s to 2002. The supplied records were loaded into a secure database and checked for quality and completeness. Individuals were followed up from the date of first employment or the date from which the cancer registry/death registry data were complete, whichever was the later.

To obtain mortality and cancer outcomes, the cohort was linked to the National Death Index and the Australian Cancer Database, which are both held by the AIHW. There were too few women in the cohort (n=53) to carry out any mortality or cancer incidence analyses. Among men, there were 36 deaths and 49 cancers among the 924 Air Force firefighters, three deaths and three cancers among the 390 Army firefighters and five deaths and six cancers among the 512 Navy firefighters. Australian population data were used to calculate the expected numbers of deaths and cancers for each male firefighter group, based on its age distribution.

Few statistically significant findings were identified. The overall mortality of Defence firefighters and specifically of the Air Force firefighters was significantly lower than that expected, based on general population rates. This is likely to be the result of a strong healthy worker effect. This is a common finding in such studies, whereby working populations tend to be healthier than the population from which they are drawn and this effect may be more pronounced in Defence personnel who need to meet strict fitness standards at the time of recruitment.

There were no significant increases or decreases in the incidence of all cancers combined for the Defence firefighters as a whole or for firefighters from any of the Service arms.

332 Air Force firefighters who completed employment before 1980 could not be included in the cohort because any deaths or cancers among them may not have been recorded in the AIHW data sets and hence this would be likely to have underestimated risk.

This cohort is young and small and relatively few cancers were found, resulting in low statistical power to identify any excess risks of cancer. There was also no ability to adjust the findings for lifestyle factors, such as smoking or alcohol intake. Further linkages in the future will increase the statistical power of this study.

2 Background to the Study

In 2012, Monash University investigators were asked by the Australian Department of Defence to carry out an analysis of the mortality and cancer incidence of firefighters from the Air Force, Army and Navy. This was prompted, in part, by the results of several overseas studies which had identified excesses of several types of cancers in firefighters. At that time, the investigators had already been commissioned by the Australasian Fire and Emergency Service Authorities Council (AFAC) to conduct a national retrospective study of firefighters' mortality and cancer incidence, known as the Australian Firefighters' Health Study. Because of similar methodological aspects of both study cohorts, the investigators agreed to conduct the Defence Firefighters' Health Study alongside the national cohort study.

3 Previous findings of mortality and cancer incidence in firefighters

The scientific literature indicates that the overall mortality rate in employed firefighters is usually lower than that of the general population, but this is probably explained by the healthy worker effect.[1, 2] This effect is, at least in part, a result of the selection of fit and healthy people to become firefighters. The healthy worker effect is less likely to operate in respect of cancer incidence, as cancers usually occur in later life, often after retirement. A published meta-analysis indicated that there was no evidence of a healthy worker effect in respect of published firefighter cohort cancer incidence studies, however. [2]

The literature is briefly summarised here and is discussed in more detail with the relevant outcomes in the discussion section.

There is evidence that firefighting is associated with an increased risk of some cancers.[3] Several studies have shown an increased risk of the following cancers: testicular cancer, prostate cancer, non-Hodgkin lymphoma and multiple myeloma.[1, 2, 4]

There is also some previous evidence that firefighting may be associated with the following cancers: leukaemia, malignant melanoma, male breast cancer, mesothelioma and cancers of the buccal cavity/pharynx, stomach, colon, rectum, skin, brain and bladder.[1-3, 5-8]

During the course of their work, firefighters can routinely encounter a wide range of hazards. At a fire scene, firefighters are potentially exposed to various mixtures of particulates, toxic gases and fumes and many oxidation and pyrolysis products, including many known or possible carcinogens.[9-14] Exposure by inhalation may not be the only possible route of entry to the body. Work on “smoke diving” in simulators by firefighters using Breathing Apparatus (BA), showed that exposure to polycyclic aromatic hydrocarbons (PAHs) through dermal routes could be significant.[15]

There is some evidence of an association between firefighting and death from cardiovascular disease.[16] However, a meta-analysis showed no increase in ischaemic heart disease among firefighters.[2] Smoking is a significant risk factor, and such data are seldom available for cohort studies. There is some evidence from US studies that there is an increase in cardiac mortality associated with firefighting, particularly close to an alarm or turnout.[17-19]

No published studies specifically of Defence firefighters have been identified, but it is reasonable to assume that they are exposed to a similar spectrum of hazards as civilian firefighters. There are likely to be some differences, such as exposure to burning jet fuel among Air Force firefighters and fighting fires in confined spaces or possibly higher exposure to asbestos among Navy personnel including firefighters.

4 Study Aims and Objectives

The specific aims of the study were, where sufficient numbers permitted, to:

- Investigate differences in the overall death rate and rates for specific causes of death in Australian Defence firefighters, when compared to those of the Australian population. The outcomes of primary interest were deaths from cancer, cardiovascular disease, non-malignant respiratory diseases and traumatic injury.
- Examine differences in the overall cancer rate and rates of specific cancer types in Australian Defence firefighters, compared to the rates of the Australian population. The cancers of primary interest for men were: brain and central nervous system malignancies, melanoma, testicular cancer, prostate cancer, bladder cancer, non-Hodgkin lymphoma, multiple myeloma, leukaemia, cancers of the buccal cavity and pharynx, stomach, colon, rectum, mesothelioma and breast cancer and, for women, cervical cancer, thyroid cancer and breast cancer.

5 Ethics Committee Approvals

Monash University investigators were granted approval from the Monash University Human Research Ethics Committee for a waiver of individual consent to access required personal information for eligible firefighters.[20] A waiver of individual consent was approved by an Ethics Committee, as requiring individual consent would likely result in flaws in the conduct of the study and the public interest outweighed any infringement of privacy. In this study, it would not have been possible to track down all of the firefighters who have left Defence, as for many of whom there would be no current address. In addition, those who had died could not consent and their exclusion would have biased the study findings.

Air Force, Army and Navy each provided a letter of approval to the Ethics Committee authorising the release of personal identifying information and occupational history data (where available) to Monash University investigators for the purposes of the study.

Ethics committee approval was also granted by the Human Research Ethics Committee (HREC) for each of the Australian State and Territory Cancer Registries, Australian Defence, Department of Veterans' Affairs and the Australian Institute of Health and Welfare (AIHW) HREC. The AIHW is the custodian of the National Death Index (NDI) and the Australian Cancer Database (ACD), which were used to identify cases of cancer and causes of death in the study. In addition, approval was provided by State Cancer Registry data custodians and Chief Health Officers, where required.

After receipt of all necessary Cancer Registry Ethics Committee approvals, additional approval for data linkage was granted by the AIHW. In respect of the deaths that had been subject to coronial enquiry, approval was also granted by the National Coronial Information Service (NCIS) of the Victorian Department of Justice. Additional Coroner approvals were obtained for Western Australian and Victorian Coroner's cases.

6 Methods

6.1 Study Advisory Committee

Monash had already been commissioned by the Australasian Fire and Emergency Service Authorities Council (AFAC) to carry out a national study of firefighters' mortality and cancer incidence. This study had an Advisory Committee whose membership was drawn from AFAC, firefighter agencies, trade unions and volunteer firefighter organisations. When the Defence study commenced, the Department of Defence nominated individuals to represent the Defence firefighters on this committee.

Below are the contacts who assisted with the study and/or their representatives who attended Advisory Committee meetings:

- Ian Gardner (Senior Physician in Occupational & Environmental Medicine Department of Defence)
- Paul Crawford (Warrant Officer, Firefighter Senior Mustering Advisor, Air Force)
- Robert Paterson (Wing Commander, Staff Officer - Force Protection from Combat Support Group Headquarters)
- Chris Taylor (Wing Commander from Air Force Headquarters)

6.2 Cohort eligibility

The cohort included current and former Air Force, Army and Navy firefighters who had ever attended fires to undertake firefighting tasks as part of their employment. In order to be included in the cohort, participants had to have a full name and birth date provided by Defence and to have served within the cohort follow up period.

6.3 Data extraction and quality assurance

This study was a retrospective cohort study, involving a cohort that was assembled from past and present employee human resources (HR) data provided by the Department of Defence.

Air Force, Army and Navy supplied Monash University investigators with records for Defence firefighters assembled onto separate password protected spreadsheets saved onto password encrypted read only discs, sent via Safe Hand courier services.

The AIHW require several personal identifiers, such as full name and date of birth, in order to link the individuals in the cohort with records held in the registries. The data items requested from Defence are listed in Appendix 1.

The Defence and AIHW data, were uploaded into a secure SQL Server database at Monash and comprehensive data quality checking procedures were applied. More details of the data handling and checking procedures are provided in Appendix 2.

6.4 Cohort start and end dates

For the analysis, each cohort member was followed in terms of person-years and mortality and cancer incidence from a cohort start date. The cohort start date for each cohort member was the date of first employment (Table 1) or 01/01/1980 for the death analysis, and 01/01/1982 for the cancer analysis, whichever was the later. The 01/01/1980 and 01/01/1982 dates were chosen as these were the earliest dates for which the national death data and the national cancer data were available respectively. This means that a firefighter whose service was completed before this date could not be included in the analyses. A firefighter who was still employed at this time would have been included.

Table 1: Dates by service group from which data were defined as being complete

Service Group	Dataset complete from	Dataset complete to
Air Force	Probably 1960	2012
Army	1/7/2002	2013
Navy	1/7/2002*	2013

* some earlier records but enumeration was not complete

Any cancers and/or deaths occurring after the start date for each cohort member were included in the analyses up until 30/11/2011 for deaths, and 31/12/2009 for cancers, being the last dates for which the national death data and national cancer data, respectively, were complete.

The cohort start date was the date from when a cohort member commenced to contribute person-years to the analysis. Any cancers and/or deaths which occurred before each individual's cohort start date were not included in the analyses.

The cohort end date was 30/11/2011 for mortality and 31/12/2009 for cancer incidence, as these were the most recent years for which complete national data are available. A cohort member ceased to contribute person-years after their death, when this was identified from the NDI. However they could stay at risk of another cancer after their first cancer was diagnosed. Population cancer incidence and mortality reference data for the cohort follow up period were also obtained, so that comparison age and sex specific population death and cancer incidence rates could be calculated.

6.5 Completeness of the data provided

The completeness and quality of the data provided by Defence varied among the service groups. The data collection methodologies for each service group, as supplied by Defence, can be found in Appendix 3.

For Air Force firefighters, the data were sourced from the personnel database which was introduced on 1st July 2002. For pre 2002 Air Force firefighters, there was no central database and hardcopy files are stored in various locations so firefighters were primarily identified from the Point Cook Fire Fighting training school rolls of students. Further names were provided through *ad hoc* methods and ex Defence firefighters volunteered names of other firefighters.

For Army firefighters, the data were sourced from the personnel database which was introduced on 1st July 2002, with data migrated from a number of different Defence and Army databases. The dataset did not include any firefighters who left the Army (and did not transfer to one of the various forms of the reserves) prior to 01/07/2002.

In the Navy, all personnel are required to have some training as a firefighter, but very few have to fight fires, at least on a regular basis. The Navy therefore provided records of those who had been posted to a firefighting school and who would therefore be likely to have regular exposure to the firefighting environment.

6.6 Data linkage

The cohort data sent to the AIHW for linkage included: surname, given name(s) and previous name (where known), sex, date of birth and date of last contact.

Data were sent from Monash University investigators to the AIHW using a secure file transfer service. Linkage results were sent back to Monash using the AIHW secure file transfer service.

6.6.1 National Death Index

At the time of linkage in 2013, the NDI was nationally complete from 01/01/1980 until 30/11/2011 for cause of death coding. The NDI had collected deaths until mid-2013 but the cause of death was not coded at the time of the linkage, so these individuals could not be included in the analyses presented here.

The NDI used a probabilistic linkage program to identify likely and possible matches with existing records of the underlying cause of death and then scored each match with a weight as to the probability of it being a true match. The possible matches were supplied to the Monash University investigators for a clerical review and were independently reviewed by two researchers and disagreements examined by a third independent reviewer before a final decision was made as to which records were to be accepted as true death matches.

6.6.2 Australian Cancer Database

The ACD was nationally complete from 01/01/1982 to 31/12/2010, except for the ACT and NSW, which were only complete until the end of 2009. Cancers diagnosed after this period were not included in the linkage.

The ACD uses a probabilistic matching program to identify possible matches with existing cancer incidence records. Each possible match was scored and the probability of false positives and false negatives was assessed by sampling the cohort and clerically examining the matches. The AIHW provided Monash University investigators with a list of cases that were scored as highly certain matches with cohort members i.e. they had a low probability of being an incorrect match or false positive.

For privacy reasons the AIHW was not able to release identified individuals for the clerical review to be carried out at Monash University. However, the AIHW carried out its own clerical review of all firefighters. After the linkage, those cancer cases identified by the clerical review as good quality matches were returned to Monash University investigators in a de-identified list.

6.6.3 Quality control measures for death and cancer linkage

The data from the AIHW was also validated in the following ways:

- Death notifications which had been provided by Defence were checked against all possible death matches to identify whether all deaths had been ascertained.
- NDI cancer deaths were compared to the ACD cancer incidence matches to ensure that all cancer deaths had also been registered as incident cancers.

6.7 Classification of causes of death and cancer

The International Classification of Diseases (ICD) coding system has been used in this study to report causes of death and cancer incidence, which enables comparisons with other studies.

The underlying cause of death for death notifications was coded by the Australian Bureau of Statistics (ABS) according to ICD-9 [21] for records up to the end of 1996, and according to ICD-10 [22] for records from 1997 onwards. Together with the introduction of the ICD-10, the ABS implemented the Automated Coding System (ACS) in 1997 for processing deaths. The ACS provides more consistent coding practices and has enabled more efficient production of statistics for multiple causes of death.

Applicable ICD-9 codes and ICD-10 codes were grouped into similar broad categories, such as ‘All Malignancies’ or ‘All Injury and Trauma’ which includes all external causes (Table 2). All deaths were counted in the ‘All Death Causes Combined’ category and every death was assigned to a broad death category classification, including an 'Other' classification which captured all deaths that were not assigned to one of the major groups.

The AIHW coded all cancer incidence records in the ACD according to ICD-10, based on ICD-O-3 histology, primary site and behaviour codes. Cases were then grouped into broad cancer categories (Table 3). Where the numbers of cancers of a particular type were very low, they were amalgamated into the 'All Other Causes' category.

Non-melanotic skin cancers, i.e. basal cell carcinomas and squamous cell carcinomas, are not collected by Australian Cancer Registries so could not be examined in this study (ICD-10 C44).

Where a cancer had spread, only the site of the original primary cancer was included in the results. However, if a person was diagnosed with more than one primary cancer, then all of these cancers were included in the analyses. The population data included all primary cancers and did not include secondary tumours spreading from the primary site.

Table 2: Cause of death classification in ICD-9 and ICD-10 used in this study

Cause of Death	ICD-9 codes (1983-1996)	ICD-10 codes (since 1997)
All Malignancies	**140 - 208, 238.4, 238.6, 238.7, 273.3, 273.8, 273.9**	**C00 - C97, D45 - D46, D47.1, D47.3**
All Nervous System	**320-359**	**G00 - G99**
All Circulatory	**390 - 459**	**I00 - I99**
Hypertensive Diseases	401 - 405	I10 - I15
Ischaemic Heart Disease	410 - 414	I20 - I25
Cerebrovascular	430 - 438	I60-I69
All Respiratory	**460 - 519**	**J00 - J99**
All Digestive	**520 - 579**	**K00 - K93**
All Injury and Trauma	**E800 - E999**	**V01 - Y98**
All Accidents	E800 - E929	V01 - X59, Y85 - Y86
Fire	E890 - E899,E924	X00 - X19
Suicide	E950 - E959	X60 - X84
All Other Causes*		
All Causes of Death	**000 - 999**	**A00 - Z99**

* combined category across major death categories

Table 3: Cancer classification in ICD-10 used in this study*

Cancer Categories	ICD-10 codes
Lip, Oral Cavity and Pharynx	**C00 - C14**
Digestive Organs	**C15 - C25**
Colorectal	C18 - C21
Respiratory and Intrathoracic Organs	**C30 - C38**
Lung	C33 - C34
Melanoma	**C43**
Mesothelioma	**C45**
Male Reproductive Organs	**C60 - C63**
Prostate	C61
Urinary Tract	**C64 - C68**
Brain and Other CNS	**C70 - C72**
Thyroid and Other Endocrine Glands	**C73 - C75**
Lymphoid, Haematopoietic, Related Tissue, Myeloproliferative & Myelodysplastic	**C81 - C96, D45 - D46, D47.1, D47.3**
All Other Cancers ł	C40-42, C46-49, C69 C96 C97
All Malignancies	C00 **- C43, C45 -** C97, D45 **-** D46, D47.1, D47.3

* Myeloproliferative & Myelodysplastic disease are now classified with LH cancers
ł Includes bone and connective tissue, eye, rare LH conditions and cancer of multiple sites

6.8 Analysis and statistics

6.8.1 Statistical analyses

External analyses are where the mortality and cancer incidence rates are calculated from the observed numbers of deaths and cancer cases in the cohort compared to the expected numbers, based on age-standardised rates in the Australian population. The population reference rates were taken from data published by the AIHW in five year age bands.[23]

The Standardised Mortality Ratio (SMR) for all deaths was calculated and, where numbers permitted, SMRs were also calculated for the major death categories in Table 2. A similar approach was taken for cancer where the Standardised Incidence Ratio (SIR) was calculated for all cancers combined and, where numbers permitted, SIRs were calculated for major cancer categories in Table 3. The SMRs and SIRs were estimated using Stata software.[24] More details about the methodology are presented in Appendix 4

6.8.2 Tests for significance

The formal test for statistical significance is that there is less than a one in 20 probability that it was a chance finding, i.e. was due to random variation. This would be shown by 95% confidence intervals that do not include one in the lower and upper range associated with the risk ratios (SMR, SIR) (see Appendix 4).

7 Results

7.1 Cohort structure

The following flow chart (Figure 1) shows the structure of the cohort, the number of records provided by each service group and the numbers of Defence firefighters which were included in the cohort. In order to be included in the cohort, participants must have had a complete name and birth date, have served in a firefighting role and served within the cohort follow up period. Some cohort members were excluded from the analyses because of missing or incomplete data or because their service was completed before 1980. This is because 1980 is the date when death and cancer records became nationally available for matching.

There were too few women (n=53) to carry out any mortality or cancer incidence analyses.

Figure 1: Cohort Structure

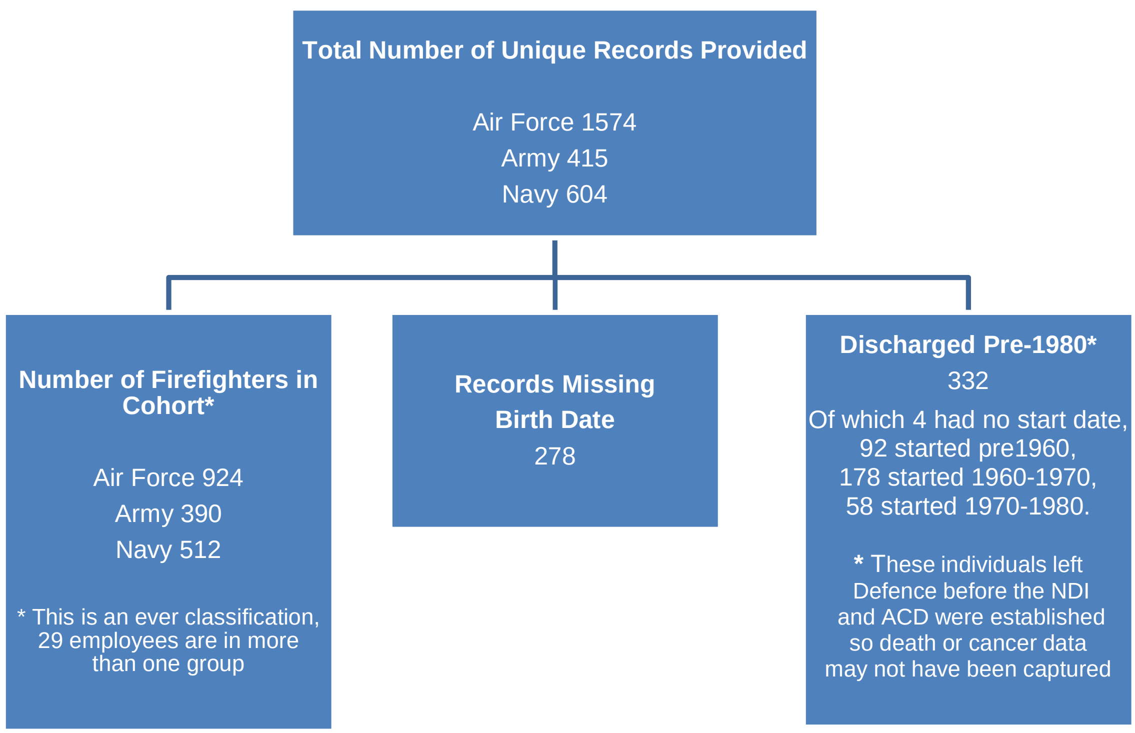


Table 4 presents a summary description of the individuals in the cohort, including the person-years at risk, numbers of deaths and cancers and ages at various time points.

The average age at the start of the cohort was 27 years. The average age for those who died was 55 years and for those contracting cancer was 52. The cohort is young, so relatively few cancers and deaths have occurred, especially for Army and Navy personnel. As there were few deaths and cancers for Army and Navy firefighters, to avoid identification of individuals, these data are presented in the all Defence Firefighter results.

Table 4: Description of the male members of the cohort

	Air Force	Army	Navy	All Defence
Firefighters in the cohort*	924	390	512	1,796
Mean age (SD) at cohort start date	25.6 (6.9)	27.7 (6.6)	28.5 (7.1)	26.9 (7.0)
Number (%) started pre 1970	129 (14)	0	0	129 (7)
Number (%) started 1970-1980	134 (15)	0	0	134 (7)
Number (%) started after 1980	661 (72)	390 (100)	512 (100)	1533 (85)
Mortality				
Person-years of follow up	18,435	3,387	6,228	27,553
Mean age (SD) alive at 30/11/2011	45.1 (13.7)	36.4 (8.5)	40.5 (8.8)	42.0 (12.1)
Number of deaths from NDI linkage	36	3	5	44
Mean age (SD) at death if deceased 30/11/2011	57.3 (14.1)	40 (11.3)	51.4 (7.8)	55.4 (14.0)
Cancer				
Person-years of follow up	16,208	2,666	5,307	23,742
Mean age (SD) at diagnosis of first cancer	54.7 (9.9)	35.7 (15.0)	40.5 (12.7)	52.0 (11.9)
Number of cancers from ACD linkage (%)	49	3	6	58

* These are ever classifications as 29 firefighters were in more than one service branch

7.2 Mortality and cancer incidence findings

There were too few women for epidemiological analyses therefore, the remainder of this section deals with men only. Among men there were 36 deaths and 49 cancers among the 924 Air Force firefighters, three deaths and three cancers among the 390 Army firefighters and five deaths and six cancers among the 512 Navy firefighters (Table 5).

Three deaths notified by the Defence were not found from the NDI linkage (see Section 8.1.3).

The overall mortality of Defence firefighters and specifically of the Air Force firefighters was significantly lower than expected, based on general population data. The mortality findings for the other two branches of Defence were also low, but the smaller numbers make it difficult to draw firm conclusions.

There was a significant reduction in accidental deaths for Air Force. There were 3 deaths among the Army firefighters where 4.48 were expected resulting in an overall SMR of 0.67 (0.14 – 1.96). There were 5 deaths among the Navy firefighters against 9.83 expected resulting in an overall SMR of 0.51 (0.17 – 1.19). There were twice as many liver disease deaths in the whole cohort than expected, and more deaths from respiratory disease than expected but the numbers were small and the increase was not statistically significant.

Table 5 Standardised Mortality Ratios (SMR)* and 95% confidence intervals (95%CI) Air Force firefighters and all Defence firefighters, deaths to 30/11/2011 compared to the Australian population

Cause of Death Categories	Air Force			All Defence Firefighters		
	O[ł]	E	SMR (95%CI)	O[ł]	E	SMR (95%CI)
All Causes of Death Combined	36	52.76	**0.68 (0.48 – 0.94)**	44	66.44	**0.66 (0.48 – 0.89)**
All Malignancies	14	16.64	0.84 (0.46 – 1.41)	15	19.27	0.78 (0.44 – 1.28)
All Nervous System	<3	1.31	–	<3	1.71	–
All Circulatory	11	12.47	0.88 (0.44 – 1.58)	12	14.62	0.82 (0.42 – 1.43)
Hypertensive	<3	0.21	–	<3	0.25	–
IHD	8	8.10	0.99 (0.43 – 1.95)	8	9.37	0.85 (0.37 – 1.68)
Cerebrovascular	<3	1.74	–	<3	2.02	–
All Respiratory	4	2.25	1.78 (0.49 – 4.56)	4	2.56	1.56 (0.43 – 4.01)
All Digestive	<3	2.21	–	4	2.75	1.46 (0.40 – 3.73)
All Injury & Trauma	6	12.49	0.48 (0.18 – 1.05)	9	18.56	**0.48 (0.22 – 0.92)**
All Accidents	<3	6.87	–	3	10.05	0.30 (0.06 – 0.87)
Fire	<3	0.14	–	<3	0.19	–
Suicide	3	4.71	0.64 (0.13 – 1.86)	4	7.10	0.56 (0.15 – 1.44)
All Other Causes	<3	<3ł	–	<3	6.98	–

***** Statistically significantly reduced SMR results are in **blue**

[ł] For cell sizes <3, the number is not reported

There were no significant increases or decreases in the incidence of all cancers combined or for any specific types of cancer for the Defence firefighters as a whole, or for Army or Air Force firefighters. Numbers were small however resulting in wide confidence intervals. There were 3 cancers in the Army firefighters where 3.15 were expected, resulting in an SIR of 0.95 (0.20 – 2.78). There were 6 cancers in the Navy firefighters where 7.20 were expected resulting in an SIR of 0.83 (0.31 – 1.81).

There were some higher than expected numbers for some specific cancer types among Air Force firefighters, but the numbers were small and none were in significant excess.

Table 6 Standardised Cancer Incidence Ratios (SIR)* and 95% confidence intervals for Air Force firefighters and all Defence firefighters to 31/12/2009 compared to the Australian population

Cancer Categories	Air Force			All Defence Firefighters		
	O[ǂ]	E	SIR (95%CI)	O[ǂ]	E	SIR (95%CI)
All Malignancies	49	47.97	1.02 (0.76 – 1.35)	58	57.95	1.00 (0.76 – 1.29)
Lip, Oral Pharynx	3	2.73	1.10 (0.23 – 3.21)	3	3.45	0.87 (0.18 – 2.54)
Digestive Organs	13	9.31	1.40 (0.74 – 2.39)	16	10.78	1.48 (0.85 – 2.41)
Colorectal	7	5.88	1.19 (0.48 – 2.45)	9	6.77	1.33 (0.61 – 2.52)
Respiratory	6	4.74	1.27 (0.46 – 2.75)	7	5.27	1.33 (0.53 – 2.74)
Lung	4	4.04	0.99 (0.27 – 2.54)	5	4.45	1.12 (0.37 – 2.62)
Melanoma	7	7.17	0.98 (0.39 – 2.01)	9	9.40	0.96 (0.44 – 1.82)
Mesothelioma	<3	0.32	–	<3	0.35	–
Male Reproductive	13	11.98	1.09 (0.58 – 1.86)	15	13.91	1.08 (0.60 – 1.78)
Prostate	10	9.99	1.00 (0.48 – 1.84)	11	10.91	1.01 (0.50 – 1.80)
Urinary tract	<3	2.65	–	<3	3.13	–
Brain & Other CNS	<3	1.12	–	<3	1.48	–
Thyroid & Other Endocrine	<3	0.62	–	<3	0.90	–
Unknown	<3	1.08	–	<3	1.26	–
Lympho-haematopoetic	3	5.21	0.58 (0.12 – 1.68)	3	6.64	0.45 (0.09 – 1.32)
All Other Cancers	<3	1.04	–	<3	1.38	–

ǂ For cell sizes <3, the number is not reported

8 Discussion

Few statistically significant findings were identified. The overall mortality of Defence firefighters and specifically of the Air Force firefighters was significantly lower than that expected, when compared to the general population. The causes of death with the largest numbers were cancer (n=15) and cardiovascular disease, (n=12) however no excess risk was found but numbers were small. Respiratory disease deaths and deaths from liver disease were elevated but not significantly so, but power was limited. The mortality rates were similar to that of other Australian firefighters although respiratory mortality was higher than in civilian firefighters.[4] Comparison with Air Services firefighters would have been interesting but it was a small group of firefighters with a short follow up so few events had been recorded.

Monash University investigators were provided with no information on smoking rates for individuals in the cohort and this is a major determinant of respiratory and cardiovascular disease and some cancers. A meta-analysis found heart disease among firefighters was the same as that of the general population.[2] There is, however, evidence from the literature that deaths from coronary heart disease are linked to some specific firefighting duties, such as emergency call outs.[18, 25] The Defence study cohort could not examine this because information about the activities being carried out just prior to the death was not available.

There were no significant increases or decreases in the incidence of all cancers combined for the Defence firefighters as a whole or for Air Force firefighters. The rate of all cancers combined, of melanoma and prostate cancer were in significant excess for full-time firefighters in the Australian Firefighter's Health Study but these were not in excess in this study. [4]

There were more than the expected number of several uncommon cancers, but there were no statistically significant excesses and numbers were too small to make a meaningful interpretation of whether these were true excesses or due to chance. Some of these cancers have been observed to be in excess among firefighters in previous studies including thyroid cancer,[2, 5, 6, 26] digestive system cancers[1, 2, 7, 26, 27] and testicular cancer.[1, 2, 6, 7]

Elevated rates of melanoma and prostate cancer were not identified in this study but were seen in the recent Australian Firefighters Health study [4] and in other studies of paid firefighters.[2, 3, 6, 7] This study did not show an increased risk of cancers identified in other studies such as brain cancer[1, 2, 28] and lympho-haematopoetic (LH) cancer.[3, 26, 29]

Smoking is a major disk factor for respiratory cancers. These results do not suggest a relationship between firefighting and increased risk of lung cancer but effects may be masked by a lack of individual information on smoking. Lung cancer has not been shown to be increased in firefighters in most previous studies,[1, 2] or in the recent Australian study, [4] although significant excesses in lung cancers has been found in two more recent studies.[6, 7] It would be difficult to show an excess except perhaps among non-smoking firefighters.[3, 28]

8.1 Sources of uncertainty in the risk estimates

8.1.1 Cohort inclusion/exclusion

Firefighters serving in or after 1980 were included in the cohort. The 332 firefighters whose service was complete before 01/01/1980 could not be included because if they had died or contracted cancer before this date the relevant cause of death or cancer type could not have been collected in and therefore could not be identified from the national registry data. We were notified of nine deaths in this group but cannot be sure that these are all the deaths that had occurred before 1980 and cannot verify the cause of death.

If deaths/cancers are not identified risks would be likely to have been under estimated. In addition general population comparison data necessary to calculate risks were not available before 1980. The comparison rates they would need to have been extrapolated back from 1980 which would introduce uncertainty because they change over time.

If Defence were to ascertain from other records e.g. perhaps pension records, showing that individuals were alive in 1980 then we could theoretically include these individuals in the cohort but this would exclude those who have known to have died and would introduce a bias, reducing the observed death rate including the cancer death rate.

8.1.2 Statistical power

The power of this study to determine risk associated with cancer or specific causes of death was limited by the very small numbers and the short period of follow up for some members of the cohort. The mean age for the cohort at the end of the study was only 45 years. Most deaths occur later than this, as well as most types of cancer, which are primarily diseases of old age. This means that it is only possible to identify relatively large statistically significant increases or decreases in specific cancers or causes of death. Among the Defence Force groups, power was extremely limited for the Army and Navy groups. There were 278 Air Force personnel with no date of birth so these could not be matched to the AIHW data. If the dates of birth can be identified by Defence the power of the study would be improved.

The formal test for statistical significance is whether the 95% confidence intervals includes one. This implies that there is less than a one in 20 probability that the finding is due to chance, i.e. is due to random variation. However when more than 20 risks estimates are made, it becomes more likely that one of these may be a chance finding.[30]

8.1.3 Healthy worker effect

When the mortality of occupational cohorts is compared with that of the Australian population, the mortality rate in the occupational cohort is typically lower. This is the well-established healthy worker effect.[31, 32] This effect has been shown in other firefighter cohorts in respect of mortality.[8, 33-36] One cause of the healthy worker effect is the relative social and economic advantage of employed people. Another factor is that people with life-threatening conditions, such as cancer and other chronic illnesses which increase the risk of death, are less likely to enter the workforce after diagnosis, further lowering the mortality rate in the workforce compared with the Australian population. Members of the Defence force are selected, in part, on the basis of their high level of physical fitness.

Monash University investigators only have records for the Army and Navy going back to 2002, so the healthy hire effect may be compounded by the healthy survivor effect, whereby those who become ill leave the workforce.[32] Those firefighters who become ill, may leave the workforce early as they can no longer carry out this physically demanding job and their records may have been deleted. In addition to the healthy worker effect, a healthy warrior effect has been seen in the military where those who are deployed tend to be healthier than those who are not deployed.[37] It is possible that those who are retained as reservists and are included in this cohort are healthier than those who are not retained. Once a complete roll was identified, the nationally complete mortality and cancer incidence registries would capture all deaths and cancers occurring among these firefighters even if they had left Defence and moved interstate.

8.1.4 Identification of deaths and cancer cases

Cancer and death registration is mandatory in all Australian States and Territories, and registration, including for cancer, is virtually complete.[38] Cancers diagnosed overseas and not treated in Australia and deaths occurring overseas are not included however. It is possible that the 3 deaths not identified on the NDI occurred overseas.

Matching the cohort names to those in the NDI and ACD is a probabilistic process. Some deaths and cancer cases may be missed e.g. where names were spelled wrongly or dates of birth were wrong, either in the data supplied by Defence or in the cancer and death registries, or both. The linkage process included similarly spelled names and common shortenings e.g. Bob for Robert, so few cases should be missed because of this. However, it was also possible that matches were made with people who were not in the cohort but who had similar names and dates of birth i.e. there may be deaths/cancer cases in the analyses that should not have been included. Monash University investigators carried out a thorough clerical review of the possible death matches and are confident that all of the good quality matches were included. The clerical review of possible matches for cancer cases was done by the AIHW, using well-established protocols, so, again, this factor is likely to have only a small impact on the validity of the findings.

Previous validation studies of the NDI have found good sensitivity and specificity of the matching process, with sensitivity (chance of finding a true match) between 88%[39] and 95%[40] and specificity (chance of rejecting a false match) of about 98%. [39, 40]

8.1.5 Latent period

It is generally accepted that there is a latent period between first exposure or first employment as a firefighter and diagnosis of cancer. The latent period can be short, with perhaps 5-10 years for leukaemia,[41] around 10-15 years for many solid tumours[28] and can be 30-40 years for mesotheliomas.[42] In view of this latency, it was unlikely that many cancers in this cohort would have arisen before 1982 when the ACD commenced. There could have been some cancers among the 332 who left ADF before 1980 but these would not have been captured on the ACD. However for those members of the cohort who joined Defence in 2000, it is probably too early for many solid tumours to have developed as yet and this emphasises the need to continue to monitor the cancers occurring in this cohort into the future.

8.1.6 Other possible confounding factors

There were other potential confounding factors that could affect the observed risk estimates for some cancers and deaths, which could not be measured or accounted for in this study design. The study could not take into account individual genetic, or lifestyle factors such as ethnicity, smoking, alcohol consumption, diet or non-firefighting job exposures experienced, for example in previous jobs and for other jobs held by Defence firefighters. These factors may increase or decrease risk of some cancer and mortality outcomes.

Ethnic origin was not identified and therefore could not be investigated. Genetic factors play a part in the risk of some diseases. For example prostate cancer is more common among African Americans than Caucasian Americans[43] and those with paler skin who do not tan easily[44] are more susceptible to melanoma. For melanoma, sun exposure is an important risk factor, but no information was available on this for the cohort members on an individual basis.

8.2 Further research

Now that the cohort has been assembled and a database constructed for linkage to the NDI and the ACD, regular linkages into the future can be undertaken in a very cost-effective manner. There have been relatively few deaths and cancers so far because the cohort is relatively young. As the cohort ages, more cancers and deaths will accumulate and this will increase precision of the risk estimates. Future linkages are therefore likely to give more robust estimates of cancer and mortality risk. If the missing dates of birth can be identified by Defence the power of the study would be improved.

The expected numbers for all-cause cancer and four selected cancers of interest, based on projections from the age structure of the existing cohort and current cancer rates in the general population are shown in Table 7. It can be seen that, based on these projections, there would be a projected increase of 77-177% in the number of these cancers by 2020, which would add certainty to the findings.

Table 7: Projected expected numbers of cancers in the cohort and percentage relative increase over the next 15 years

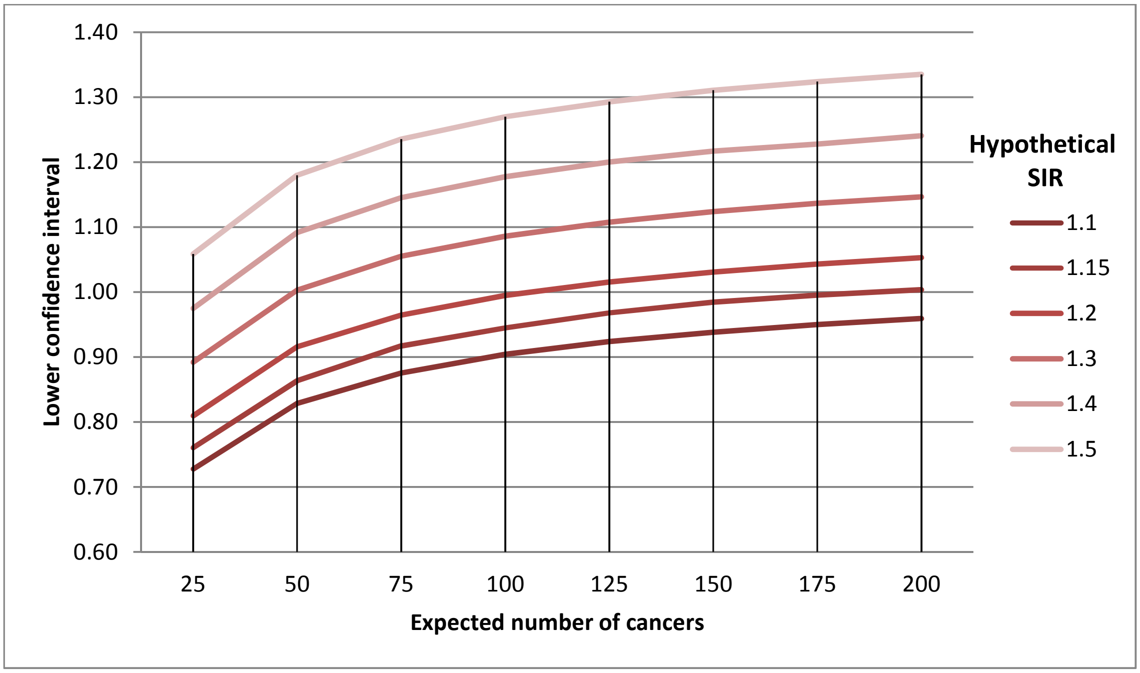
	Cohort matched to 2009 ACD data		Projected cancers in cohort					
			Projected Expected*			Relative Increase (%)		
	Observed	Current Expected*	2015	2020	2025	2015	2020	2025
All Malignancies	58	58	84	122	175	45%	110%	202%
Digestive Organs	16	11	16	24	35	47%	119%	223%
Melanoma	9	9	13	17	22	33%	77%	135%
Respiratory and Intrathoracic Organs	7	5	8	11	16	42%	110%	213%
Prostate	11	11	19	30	47	72%	177%	332%

*Expected numbers rounded to nearest whole number

Figure 2 presents the calculated lower confidence interval (on the y-axis) against a range of expected number of cancers (on the x-axis) for a series of hypothetical SIR values. For example, it is anticipated that the Defence cohort will have approximately 100 cancers, based on current national cancer rates, the age distribution of the study population and an extended period of follow-up of 10 years. If the standardised incidence ratio is 1.2, the expected lower limit will be approximately 1.0 (thereby achieving statistical significance). By inspection, the expected lower confidence limit around a range of hypothetical SIRs might be determined for a given expected number of cancers. This figure can be used to assist in planning how long to continue following the Defence cohort and thereby determine when to re-match against the cancer registry.

Based on Figure 2 and Table 7, it would appear that the cohort will achieve adequate numbers of cancers to detect significant all malignancies SIR of 1.2 (or greater) after 10 years of additional follow-up. Statistical significance would also be achieved for specific cancers with an underlying SIRs of 1.3 or greater when the expected number of cause-specific cancers reaches 50 (a level that would appear to require 15 years of additional follow-up for the prostate cancer as presented in this analysis). An additional 15 year period of follow-up would be required in order to detect SIRs of a smaller magnitude of excess cause-specific cancer risk.

Figure 2: Lower confidence limit under hypothetical SIR values



For most individuals, it was not possible to distinguish the years of employment as a firefighter from the service records, this might be of interest in future analyses where risk by duration of firefighting service could be examined. An alternative exposure metric would be to use the number of incidents attended and their type, if this information is recorded by Defence on an individual basis.

Other data that would be important to collect would be smoking data and perhaps alcohol consumption if the liver disease excess is of interest. BMI is also a cancer risk factor but the absence of comparable population data and the changes over time make this problematic to collect and to interpret.

The NDI linkage was carried out to 30/11/2011 to identify causes of death. The cancer linkage was completed to 31/12/2009. Following the cohort into the future, and rematching to the NDI and ACD would result in an increased number of deaths and cancers, which would increase the power to detect any increases in risk although the cohort is small.

9 Conclusions

There was no increased mortality or cancer incidence among Defence firefighters in this cohort, but the young age of the cohort, small numbers and short period of follow-up, especially for Army and Navy, limited statistical power, and absence of any information on firefighter duties and lack of information on lifestyle factors makes it difficult to draw definitive conclusions from these analyses.

Further follow up and re-matching of the cohort in the future would increase the power of the study to detect an increase in cancer rate in Defence firefighters.

Glossary

From: Goddard, D. (2002) *Glossary of Terms Relating to Occupational Health & Epidemiology.* Department of Epidemiology and Preventive Medicine, Monash University, Melbourne.

Association (in epidemiology)
A finding of co-existence between exposure to an agent and a changed (usually increased) incidence of disease brought about because (1) the exposure causes the disease, or (2) the disease brings about the exposure, or (3) there is confounding. Causation is a sub-set of association; they are not identical. It is the extent to which the occurrence of two or more characteristics are linked either through a causal or non-causal relationship.

Bias
A non-random error in an epidemiological study that leads to a distorted result.

Case
A person with a disease of interest.

Cohort
A group of persons who share a common attribute, such as birth in a particular year, residence in a particular town or exposure to a particular agent, and who are observed over a period.

Cohort study
An observational study in which subjects are sampled based on the presence (exposed) or absence (unexposed) of a risk factor of interest. All cohort studies proceed forward in time from exposure (or not) to health outcome, although the exposure status may be decided either from historical record or determined after the study commences.

Confidence interval
A range of values, calculated from the sample observations that are believed, with a particular probability, to contain the true parameter value. A 95% confidence interval, for example, implies that, were the estimation process repeated again and again, then 95% of the calculated intervals would be expected to contain the true parameter value. Other confidence intervals often used are 90% and 99%.

Confounding
An association between an exposure of interest and a disease which is not directly causal but where both exposure and disease are linked by their association with a third factor. It has the potential to bring an error in the interpretation of the results of a study.

Epidemiology
The study of the distribution and determinants of disease in groups of people i.e. who suffers what and why.

Exposure
The presence of a noise, substance or form of radiation in the environment of a person or animal. A measurement of this presence.

Incidence
The proportion of new cases of interest in a study population in a given period.

Mortality
Death. Usually the cause (specific disease, condition, or injury) is stated.

Person years
Describes the accumulated amount of time that study participants were being followed up. So, if five people were followed up for ten years each, this would be equivalent to 50 person-years of follow up. Sometimes the rate of an event in a study is given per person year rather than as a simple proportion of people affected, to take into account the fact that different people in the study may have been followed up for different lengths of time.

Population
The total set of persons, things or events under investigation or relevant to a study. If a population is large, a sample may be drawn from it and the characteristics of the population then inferred from the characteristics of the sample through use of statistics.

Rate
A proportion that takes the additional dimension of time, e.g. 6 new cases per thousand of population per year. Incidence is an example of a rate.

Ratio
A comparison of two numbers - the number of observations with a characteristic of interest compared with or divided by the number without that characteristic.

Risk (in statistics & epidemiology)
The probability that an event, e.g. the occurrence of a specific disease, will happen during the study period. [This is the way that the term risk is used in 'relative risk' which refers to association but not necessarily causation. However, in most situations where the term risk is used in preventive medicine, there is an implication of causation - the probability that harm will occur. Hence, risk factors.]

Sample
A relatively small set of observations or individuals drawn from a larger universe of potential observations or individuals. The sample is usually assumed to have all the essential characteristics of the larger population from which it is drawn, but this does not always happen in practice.

Selection bias
One of the major classes of bias in an epidemiological study which happens when there is a difference between the characteristics of the people selected for the study and the characteristics of those who were not selected.

Significance level
This refers to the probability that chance is the explanation of a difference between means, proportions or counts; it provides the means of decision-making once a statistical test of significance is underway. It is simply an arbitrary level of probability, usually 0.05, below which chance is rejected as the explanation of difference, i.e. it is the level at which the null hypothesis is rejected in favour of the alternative hypothesis.

Standardise
Alter in a way that enables fair and ready comparison with a recognised model.

Standardisation
A change to findings to make them more readily comparable with others that refer to similar things.

Standardised Incidence Ratio (SIR)
Compares the cohort data with the Australian population.

Standardised Mortality Ratio (SMR)
Compares the actual number of deaths from a particular cause in the cohort with the expected number of deaths in the cohort if the death rate in the cohort was the same as that of the Australian population.

Statistically significant

'Not likely to happen just by chance'. The phrase 'not likely' is made more exact by setting a level of probability below which we reject chance as the explanation. This arbitrary level is designated 'a'; it is most commonly set at 0.05. This means that if:

- the 95% [1] confidence interval of a ratio does not include the value 1, or
- the 95% confidence interval of a difference does not include 0, then chance can be rejected as the explanation of why one group differs from another.

Abbreviations

95%CI	95% Confidence Interval
ABS	Australian Bureau of Statistics
ACS	Automated Coding System used by ABS to code deaths
ACT	Australian Capital Territory
ADF	Australian Defence Force
AFAC	Australasian Fire and Emergency Service Authorities Council
AIHW	Australian Institute of Health and Welfare
E	Expected
HR	Human resources
HREC	Human Research Ethics Committees
IARC	International Agency for Research on Cancer
ICD-10	International Classification of Disease Version 10
ICD-9	International Classification of Disease Version 9
IHD	Ischaemic heart disease
LH	Lympho-haematopoetic
MonCOEH	Monash University Centre for Occupational and Environmental Health
NCIS	National Coronial Information Service
NHMRC	National Health and Medical Research Council
O	Observed
SIR	Standardised Incidence Ratio
SMR	Standardised Mortality Ratio

Appendix 1 Data items requested from Defence

The following data items were obtained

1. A data set containing personal information including (where available):
    - ID or registration number
    - Surname
    - First name
    - Middle name (if available)
    - Preferred name (if available)
    - Previous name
    - Date of birth
    - Sex
    - Last known postcode
    - Live status (any death notification)
    - Other jobs (if known)

2. A data set containing service history information including (where available):
    - ID or registration number
    - Occupational status
    - Job /position code
    - Job /position title or rank
    - Job start date
    - Job end date
    - Job location
    - Platoon/ Area
    - Additional job code/title/dates/location/platoon data relevant to position changes over time

3. The following would also be of interest, if available:
    - Smoking history;
    - BMI or fitness testing results

Appendix 2 Data handling and cleaning processes

The data were loaded into a study database which has two components, the front end and back end. The back end contains all the data which was stored in an SQL Server database on a secure Monash University server. A comprehensive data dictionary was prepared and stored with this database. Identifiers such as names and dates of birth were kept separate from the de-identified data set, which contains details of causes of death and cancer diagnoses. The records were linked by a common study-specific identification number (Fire-ID). Analysis was undertaken on a de-identified data set.

The front end was written in Microsoft Access and access to the data was limited only to MonCOEH staff working on the study and constituted a password login with user access and data modification rights controlled by the MonCOEH data manager.

The data were checked for completeness by the research team before being collated and passed to the AIHW for linkage.

The date of last contact for individual cohort members was the date when the data set was sent from Air Force, Army and Navy for current employees, or the date when the employee resigned for former firefighters. Given that only incomplete or no job history was provided, the date when the relevant HR data system commenced was used as the date of last contact.

Each original data set was archived unchanged and a copy was loaded into the study database and the following cleaning procedures carried out to produce the final data set. At each step, clarification was sought from Defence where there was missing or conflicting information.

- Duplicates were merged
- Missing or implausible birth dates and employment start and end dates or other missing data were followed up with Defence, checked and confirmed.

Appendix 3 Defence data collection methodology as provided by Defence

1. **Purpose of this document**

This document provides a description of the methodology Defence team followed to identify and verify the details of individuals to be included in the “Defence Firefighters’ Health Study”.

2. **Objectives of the study**

Defence commissioned Monash University to undertake the the “Defence Firefighters’ Health Study” to examine risk of cancer and mortality among Defence firefighters during the period 1981-2010.

3. **Defence personnel to be included in the study**

Groups	Number of records provided to Monash	Number of records after cleaning by Monash	Dataset complete from	Data set complete to
Air Force	963		Probably 1960	2012
Army	415		01/07/2002	2013
Navy	890		01/0/2002*	2013

* some earlier records but enumeration not complete

4. **Sources and completeness of data used to identify individuals in the datasets**

Air Force

A range of methods were utilised to identify firefighters. More recent firefighters were identified through the PMKeyS personnel data base which was established in 2003.

There is no central database for firefighters or Defence personnel and hardcopy files may be stored in various locations so other firefighters were primarily identified from the Point Cook Fire Fighting training school rolls of students. Additionally, further names were provided through *ad hoc* methods and ex ADF firefighters who volunteered names of other ADF fire-fighters.

The identified names were cross referenced with personnel files held in Defence Archives and the Australian War Memorial. Where it could be confirmed that an individual did complete firefighting service, the individual’s data was extracted from the personnel file and entered into the database provided to Monash University.

The information that was provided to Monash University is an accurate reflection of the personnel records; subject to any data entry errors that may have arisen. There is no capacity to cross reference this data with any other files to confirm the accuracy of the data.

Army

The Army data includes soldiers who fell into one or more of the following categories:

a. currently full-time serving (ARA (98)) emergency responders;

b. currently part-time serving (RES-A (38), RES-HRR (3) and RES-RRF (1)) emergency responders;

c. previously serving (RES-I (109)) emergency responders with on-going ‘emergency call-out obligation’ that has not been activated; and/or

d. previously serving emergency responders with no ongoing service obligations (either discharged – “terminated” (165) or deceased (2)).

The data were sourced from the personnel database is known as PMKeyS – Personnel Management Key Solution and was based on the PeopleSoft Human Resource Management System. It was introduced on 1 Jul 2002 with data migrating from a number of different Defence and Army databases, primarily AUSMIS – Australian Management Information Systems. The PMKeyS has central data storage with sophisticated data protection processes. Data were extracted from PMKeyS on 28 Aug 2013. No paper-based records were accessed.

The Army are confident that the dataset represents Army fire-fighters data accurately from 1 Jul 2002. The date of completing emergency responder training is only accurate for dates after 1 Jul 2002. The date provided prior to 1 Jul 2002 is the date of enlistment which is usually 3-6 months before commencing emergency responder training.

The dataset will not include any firefighters who left the Army (and didn’t transfer to one of the various forms of the reserves) prior to 1 Jul 2002. The dataset for deceased firefighters only includes those known to have died during Service. This will be very accurate for full-time emergency responders, less accurate with an unpredictable lag for active reservists and it is unlikely that the in-active Reserve (RES-I) will identify when a former emergency responder dies.

Navy

Everyone in Navy gets training as a firefighter, but very few have to fight fires, at least on a regular basis. The Navy therefore sought to limit the records provided to those who have been posted to a Fireground (firefighting school) and who would therefore have regular exposure to the firefighting environment.

The data were sourced from the personnel database is known as PMKeyS – Personnel Management Key Solution and was based on the PeopleSoft Human Resource Management System. It was introduced on 1 Jul 2002. All individuals posted to a Fireground were included.

Pre-2002 records are problematic for the firefighter category. There are limited records available on these personnel and these were generated from a legacy version of the IT system in use pre-PMKEYs. There is very limited capability to generate more detail other than that provided. The pre 2002 records are unlikely to be complete.

Includes those who have been posted to Navy firegrounds. It has been organised by periods spent at each Fireground - a number of members have completed multiple periods and this is reflected in the records.

Appendix 4 Analysis methodology

There are two main ways to analyse the cohort data these are summarised below [45]:

1. The Standardised Mortality Ratio and
2. Standardised Incidence Ratio which compare the cohort data with the Australian population.

The Standardised Mortality Ratio (SMR) compares the actual number of deaths from a particular cause in the cohort with the expected number of deaths in the cohort if the death rate in the cohort was the same as that of the Australian population. To find the expected number of deaths, the numbers of person-years, grouped by age group and calendar time, were calculated in the cohort, and the Australian death rates were projected to this population. The actual number of deaths was divided by the expected number of deaths to calculate the SMR. If the death rate in the cohort is the same as that of the Australian population, the SMR is equal to 1 (sometimes reported as a percentage i.e. 100). If the SMR is greater than 1 then the death rate in the cohort is greater than that of the Australian population. The same calculations can be done for incident cancers as a group and for individual cancers of interest, to calculate a Standardised Incidence Ratio (SIR).

The SMR and SIR will be accompanied by 95% confidence intervals. If the confidence intervals do not include 1, the risk will be considered statistically significantly increased or decreased.

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