

Retrospective cohort study of mortality and cancer
incidence in New Zealand fire fighters

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Executive summary

Introduction and background

This is a report of a retrospective cohort study of mortality and cancer incidence in full-time (paid) New Zealand fire fighters carried out by the Institute of Environmental Science and Research Ltd. (ESR), in conjunction with the Wellington School of Medicine, for the New Zealand Fire Service. The objectives of the study were to investigate whether there were higher than expected risks for mortality or cancer incidence, particularly for testicular cancer, in New Zealand fire fighters. A cluster of testicular cancers occurred in Wellington fire fighters in the 1980s and other New Zealand studies had produced evidence that laryngeal and kidney cancer risks could be high for New Zealand fire fighters. Studies carried out in other countries have suggested that fire fighters might be at risk for other types of cancer, including lung cancer, colon cancer, malignant melanoma, brain cancer, and cancers of the ureter and bladder, as well as the kidney.

Methods

Retrospective cohort studies have four main components: identification of the study cohort; the identification of a comparison population; the follow-up of the cohort over time; and the comparison of the cancer and mortality rates of the cohort and the reference population. The basis for the cohort for this study was data obtained from the register of all New Zealand fire fighters maintained by the United Fire Brigades Association of New Zealand (UFBA). The study cohort contained fire fighters who had worked for at least one year as a paid fire New Zealand fighter, and at least one day in the period 1 January 1977 to 30 June 1995. The comparison population was the population of New Zealand, for which data to calculate cancer and mortality rates were obtained from the New Zealand Health Information Service (NZHIS).

Names and birth dates of cohort members were matched with mortality and cancer registration records held by the NZHIS. Vital status of the cohort, as close as possible to

the end of the follow-up period (31 December 1995), was confirmed by a variety of methods, including information on the last date of employment by the Fire Service, last date of contact with the New Zealand health system (from NZHIS records), matching with Work and Income New Zealand (WINZ) records to obtain the last date a benefit was received, and matching with electronic and paper electoral rolls.

Person-time of follow-up and population cancer and mortality rates were used to calculate expected numbers of cancer cases and deaths for the cohort, adjusted for age and calendar period. Standardised incidence ratios (SIRs) and standardised mortality ratios (SMRs) were calculated by dividing observed numbers of cancer registrations and deaths in the cohort by the corresponding expected numbers.

Results

The final cohort contained 4,221 males and 84 females. However, the small numbers precluded the use of females for calculation of SMRs and SIRs. The follow-up was successful in tracing 93.5% of the total theoretically possible years of follow-up for the cohort. The total follow-up time for males in the cohort was 58,709 person-years. The cohort had had a total of 67,039 person-years of service as either a paid or volunteer fire fighter, of which 28% occurred before the beginning of 1977.

In the period 1977-96 the overall cancer incidence was close to what would be expected (SMR = 0.95) and no individual cancer site showed evidence of a statistically significant elevated rate. There were 11 testicular cancers recorded, whereas 7.1 would have been expected (SMR = 1.55). However, two of the four fire fighters with testicular cancer in the Wellington cluster of the 1980s were members of the cohort but not registered by the New Zealand Cancer Registry as having had testicular cancer. Inclusion of these two would increase the SIR for testicular cancer to 1.83 (95% confidence interval [CI]: 0.97-3.13).

Because the New Zealand Cancer Registry is believed to be most complete from about 1990, a separate analysis of data for the years 1990-96 was carried out. Again, this showed the overall number of cancers and cancers at most individual sites to be about what would be expected. However, eight testicular cancers occurred in this period, compared with 2.7 expected (SIR = 2.97, 95% CI: 1.3-5.9). This result is particularly notable in that the period 1990-96 did not include the fire fighters with testicular cancer from the Wellington cluster, previously investigated.

A similar analysis was carried out for mortality rates in the cluster, again confined to males. For the 1977-1995 period, the observed number of deaths overall and for specific causes were appreciably below what would be expected. When stratified by 5 calendar-year blocks, a tendency for the overall mortality SMR to increase over time was evident. However, it remained well below 1.0. The years 1990-95 were also examined separately. Although the SMRs for deaths were often higher than corresponding SMRs for the entire cohort follow-up period, they generally remained below expected.

Discussion

This study has confirmed that the high rate of testicular cancer in fire fighters that occurred in Wellington in the 1980s was not an isolated phenomenon. It has continued into the 1990s, although it is more widespread. The elevated rate seems unlikely to be due to chance. No evidence was found to suggest that kidney or laryngeal cancers continue at a high rate in fire fighters. Also, there was no convincing support for any of the other cancer risks that overseas studies have shown to be elevated in fire fighters.

The possibility that the elevated testicular cancer risk might be explained by some bias in the information collected was examined. However, no plausible explanations were found.

The results for mortality in the cohort were reassuring, although the mortality rate was lower than might be expected, even taking into account the "healthy worker effect". The

possibility was examined that the low mortality SMRs might be a result of errors in recording of data, either in the UFBA or the NZHIS mortality databases, making the data matching process incomplete. Only limited evidence was found to support this possibility and it was unlikely that it could explain more than a portion of the low mortality rate found.

The reason for the elevated testicular cancer rate is unknown. The possibility that it might be caused due to chance or by some form of bias could not be totally discounted, but seems unlikely. The question arises why similar results have not been found in other studies of fire fighters. There are two possible reasons. First, most studies of fire fighters have been of mortality. Since testicular cancer is rarely fatal it is not likely to be detected in such studies. Second, of the relatively few studies that have examined cancer incidence, none have had a follow-up period that went later than 1989. It is possible, for example, that there could be a new building material that produces a combustion product that is a testicular carcinogen, and which only recently has begun to manifest itself in terms of an increased cancer incidence. Alternatively there might be new fire fighting work practices or materials that carry an increased testicular cancer risk. It was beyond the scope of this study to investigate such possibilities. A nested case-control study would be the most appropriate epidemiological study design to investigate possible risk factors for testicular cancers in fire fighters. Also, it would be important to extend this cohort study in, say, 5-10 years, to investigate whether the high incidence of testicular cancer was continuing, or even increasing.

Conclusions

On the basis of the results of this study, it was concluded that:

1. The raised incidence of testicular cancer that occurred in Wellington fire fighters during the 1980s continues, although it is now no longer confined to Wellington. There are no indications of what could be causing it. Further studies, both in New Zealand and overseas, are needed to clarify the situation.

2. There was no evidence that paid fire fighters in New Zealand are at particular risk for other types of cancer.
3. On average, paid fire fighters in New Zealand have a low risk of premature mortality compared with the general New Zealand population.

Recommendations

It was recommended:

1. That the New Zealand Fire Service:
 - through its medical service, advise all New Zealand fire fighters that there may be an increased risk of testicular cancer associated with being a fire fighter in New Zealand, and provide advice on self-examination of the testicles; and
 - introduce a surveillance system to detect new cases of testicular cancer diagnosed in fire fighters, both paid and volunteer; and
 - encourage the carrying out of cohort studies of cancer incidence in fire fighters in other comparable countries.
2. That a nested case-control study be carried out to investigate possible risk factors for testicular cancer in New Zealand fire fighters. The cases investigated by this study should be augmented by any additional cases detected by the recommended surveillance system.
3. That efforts be made to keep up-to-date the register of all New Zealand fire fighters maintained by the UFBA, and mechanisms be put in place to ensure good quality of the data.
4. That, using the UFBA register as a basis, the cohort study of paid New Zealand fire fighters be updated in 5 to 10 years to (i) investigate whether the elevated risk of testicular cancer is continuing; and (ii) to provide additional statistical power for the identification of any other cancer or mortality risks for New Zealand fire fighters.

Introduction

In November 1998, the Institute of Environmental Science and Research Ltd. (ESR), in conjunction with the Wellington School of Medicine, was contracted by the New Zealand Fire Service to carry out a retrospective cohort study of cancer incidence and mortality in full-time (paid) New Zealand fire fighters. This is the report of that study, including methods, results and their interpretation, conclusions and recommendations. First, following a statement of the objectives of this study, some background information is presented – on what was known prior to the study about cancer and other health risks to fire fighters, as well as an outline of the methodology of retrospective cohort studies.

Objectives of this study

1. To determine whether there is an elevated risk for testicular cancer in New Zealand fire fighters generally.
2. To determine whether other cancer and mortality risks for New Zealand fire fighters are elevated above what would be expected.

Background

Cancer and causes of death in fire fighters

The possibility of an increased cancer or mortality risk for fire fighters is a concern because of the wide range of pyrolysis products, including a number of known carcinogens (eg. polycyclic aromatic hydrocarbons, formaldehyde, benzene, and methylene chloride), that fire fighters may be exposed to in smoke. There have been a number of studies of health risks in fire fighters, particularly for cancer, both overseas and in New Zealand. The outcomes of most of these studies have been well summarised in three recent reviews.

Howe and Burch reviewed the evidence for several cancers that had been reported in epidemiologic studies as being associated with occupation as a fire fighter.¹ These

cancers were lung cancer, colon cancer, brain tumors, malignant melanoma, and multiple myeloma. The review concluded that the evidence for a positive association was strongest for brain tumors and multiple myeloma, with some evidence for an association with malignant melanoma. It was concluded that the combined analysis provided no evidence of an association with lung or colon cancers.

In a more recent review Guidotti examined the evidence for occupational mortality risks among fire fighters.² He concluded that there was strong evidence for an association between fire fighting as an occupation and risk of mortality from genitourinary cancer, including cancers of the kidney, ureter, and bladder. He also found some evidence supporting associations with mortality from cancers of the lung, brain, lymphatic and haematopoietic tissue, and cancers of the colon and rectum. No evidence was found for increased mortality risks for cardiovascular disease or acute lung disease.

In a further review of nineteen epidemiological studies of cancer risk among firefighters Golden et al.³ found that the data suggested that employment as a firefighter increased the risk of dying from leukemia, nonHodgkin's lymphoma, multiple myeloma, and cancers of the brain, urinary bladder, and possibly prostate, large intestine and skin (malignant melanoma).

New Zealand studies

Public concern about the occupational health risks associated with fire-fighting in New Zealand arose after a chemical fire in an Auckland warehouse. On 21 December 1984, the ICI (NZ) Ltd chemical store in Mount Wellington, Auckland, was destroyed by fire. The store contained large quantities of chemical products, including swimming pool chemicals and agricultural herbicides and pesticides. A total of 340 fire-fighters were involved in fighting the fire and the subsequent clean up of the site and fire fighting equipment. Public concern about the health of these fire fighters culminated in a Ministerial Inquiry.⁴ A component of this inquiry was an epidemiological study designed to investigate any possible causal links between the health status of fire-fighters and exposure to the ICI fire. This cross-sectional study included 245 of the 340 fire-fighters

who attended the ICI fire and a referent group of 217 Wellington fire-fighters who had not been involved in the ICI fire.⁵

The study did not find any evidence of increased cancer risks in the Auckland fire fighters. However, three cases of testicular cancer were found among the Wellington fire-fighters who acted as the comparison group. No cases of testicular cancer were found in the Auckland fire fighters. Subsequently, another case of testicular cancer in a Wellington fire fighter came to the attention of the Fire Service. A further study was undertaken to investigate whether the cluster of testicular cancers in Wellington fire-fighters was evidence of an occupational cancer risk. This study confirmed an increased risk of testicular cancer among Wellington fire fighters between 1980 and 1991 (relative risk [RR] = 8.2, 95% confidence interval [CI]: 2.2-21.0, based on four cases).⁶ No obvious explanation for the elevated risk was found, nor was there any evidence found of an increased rate of testicular cancer among fire fighters in the rest of New Zealand. However, the authors concluded that such a risk could only be adequately assessed, and confirmed or ruled out, by a more extensive epidemiological investigation, such as a cohort study.

An earlier cancer registry-based case-control study of occupational associations with testicular cancer, during the period 1958-79, had found no evidence of an increased risk for New Zealand fire fighters.⁷ However, as all the cases in the Wellington investigation were diagnosed after 1983, it is possible that any risk factor for testicular cancer may not have been apparent before that year. One overseas study has also found evidence of an increased testicular cancer risk in fire fighters. Aronson et al⁸ reported a standardised mortality ratio of 252 (95% CI: 52-737) for testicular cancer in the Toronto Metropolitan Fire Brigade from 1950-1989. These results were based on only three cases. Another study found no increased risk of testicular cancer among Melbourne firefighters between 1980 and 1989.⁹

A New Zealand Cancer Registry-based case-control study of male occupational risk for renal carcinoma, from 1978 to 1986, found an elevated risk of renal cell cancer in fire

fighters after adjustment for age and smoking history (RR = 4.89, 95% CI: 2.47-8.93)¹⁰. This result is consistent with results that have been obtained in overseas studies.²

Most recently, in a study of New Zealand male occupational associations with cancer, during 1972-84, Firth et al. showed a strong association between being a fire fighter and having laryngeal cancer (standardised incidence ratio adjusted for age and socio-economic level = 1074, 95% CI: 279-2776).¹¹ This was not an association that has been observed in other studies.

Overview and explanation of the cohort study method

This section is intended to assist the non-epidemiologist reader by providing a general explanation of the retrospective cohort study methodology. More detailed descriptions of the methods used in the present study are given in the Methods section of this report.

This study was carried out using a standard epidemiological approach, known as an historical or retrospective cohort study. Cohort studies follow over time populations that have a particular exposure and investigate whether that exposure is associated with increased risks of disease or mortality. In this case, the exposure of interest was employment as a paid fire fighter. Cohort studies may be prospective or retrospective. In a retrospective cohort study the cohort is defined as a group or population that existed at some earlier time. The health and mortality experience of each of the members of the cohort is then tracked until a time closer to the present. The number of health and mortality events in the cohort is then compared with that of a comparable, but unexposed, group.

Checkoway et al¹² have described four components of cohort studies. These are:

1. The identification of the study cohort;
2. The identification of a comparison population;
3. The follow-up of the cohort over time;
4. Comparison of the disease/ mortality rates of the cohort and the reference population.

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The identification of the study cohort

The cohort is the population that is followed in time over the period of follow-up of the study. In a retrospective cohort study the population may be defined as a group that existed at a particular point in time in the past (e.g., all people who worked in a particular industry in, say, 1980), or anyone who had a certain exposure during a particular time period (e.g., anyone who worked in that industry for at least one year during the period 1980-1990). This study is of the latter type.

It is important that the cohort consist of a complete list of the people who were eligible for inclusion. If only some of the people eligible for the cohort can be identified, then there is the possibility that those who could not be identified might tend to be different in some way to those who are included in the cohort. Therefore, incompleteness of the cohort could lead to a bias in the study results.

It is important for each of the cohort study members to be identified at least by their full name, date of birth, and sex. As explained below, this information is necessary for the successful follow-up of the cohort. The fire fighter cohort used in this study is believed to be very complete and the necessary identifier information was available for most cohort members.

The identification of a comparison population;

In order to determine whether a particular exposure is related to increased rates of disease or mortality it is necessary to compare the disease and mortality rates in the exposed population to corresponding rates in an unexposed reference population. Similar disease and mortality data must be available for the reference population. Reference populations may be one of two types. A non-exposed group may be included in the cohort. This is an internal reference group. Disease and mortality outcomes may then be compared for the two groups. Alternatively, the exposed cohort may be compared to an external reference population. An external reference population has been used in this study, as fire fighters cannot be separated into exposed and unexposed groups. The external reference population is the total population of New Zealand, for which cancer and mortality information is available through the New Zealand Health Information Service (NZHIS).

The follow-up of the cohort over time

In most cohort studies the largest component is the follow-up of the cohort over the period of follow-up of the study. For each member of the cohort the period of follow-up is the time from when they first become eligible for entry into the cohort and until either their date of death or the designated finish date for follow-up of the cohort, whichever is the sooner. There are two components to the follow-up: (1) identification of disease events (in this study, cancer diagnosis) or death; and (2) confirmation that each cohort member was alive and living in New Zealand during the follow-up period of the study. The second component is often referred to as confirmation of vital status.

a) The occurrences of disease or mortality.

For each person in the cohort, information about disease and mortality must be collected in a manner similar to that in which the equivalent data are collected for the referent population. The only source of readily available cancer diagnosis and mortality data for the entire New Zealand population is the NZHIS. Cancer and mortality rates for the New Zealand population can be calculated from the Cancer Registry and mortality databases.

To obtain the cancer incidence and mortality rates for the cohort itself, it is necessary to match the personal identifier information for the cohort (names and birth dates) against the records of the NZHIS. This identifies all those members of the cohort who have been diagnosed with cancer or died during the period of follow-up. Matching can be difficult and time-consuming if full identifier information is not available for everyone in the cohort. If matching is incomplete, there is the danger that not all of those in the cohort who have been diagnosed with cancer or died will be identified. This can lead to underestimation of cancer or mortality risks. Therefore considerable efforts must be made to achieve a complete matching with the NZHIS data.

b) Confirmation of vital status for each cohort member.

Assessment of whether or not there are increased risks associated with the exposure of interest depends on comparison of rates of cancer and mortality in the exposed and comparison groups. A rate can be calculated by dividing the number of disease events by the total person-time of follow up of the cohort. Each cohort member contributes a number of person-years of follow-up to the total person-time for the cohort. For any individual the number of person-years is calculated in terms of the difference between the date of entry into the cohort and whichever of the following dates comes first: death, loss to follow-up, date of cancer diagnosis (in the analysis of cancer incidence), or the end of the cohort follow-up period.

Date of loss to follow-up is the last date at which a cohort member can be confirmed as living in New Zealand if they are not recorded as having died or are not recorded as living in New Zealand at the end of the follow-up period. This is important because there is always the possibility that a cohort member might go overseas and, while there, be diagnosed with cancer or die. Diagnoses of cancer and deaths occurring overseas are not recorded by the NZHIS. For example, it might be assumed that a person who had died overseas was still alive and living in New Zealand, just because the NZHIS had no record of their death. This would lead to an underestimate of mortality in the cohort. Therefore, it is necessary to confirm that cohort members, who are not recorded as having died, are

actually living in New Zealand, as close to the end of the follow-up period as possible. For example, if there was no trace of a cohort member after they had left Fire Service employment then their contribution to the cohort, in terms of person-years of follow-up, would be limited to their years of service as a fire fighter.

There is no list of who is living in New Zealand at any particular time. Therefore, cohort studies need to use a number of methods for confirming the status of cohort members as alive and living in New Zealand over the course of the follow-up period. The methods used in this study are explained in more detail in the Methods section.

Comparison of the cancer/ mortality rates of the cohort and the reference population.

Determination of whether the exposure of interest (in this case, employment as a paid fire fighter) is associated with an increased risk, is based on statistical comparison of corresponding cancer and mortality rates in the exposed and reference populations. However, cancer and mortality rates vary by age and calendar-period, and the age and sex distribution of the cohort is different to the age and sex distribution of the general population. Therefore, it is necessary to adjust the reference population rates so that they reflect the demographic and calendar period-specific composition of the cohort population. This calculation produces an “expected” number of cancer cases and deaths for the cohort. An expected number is the number of cancers or deaths that would be expected to occur in an unexposed population of exactly the same demographic composition as the cohort, over the corresponding period of time. It is calculated using population-based cancer and mortality rates. The actual (observed) numbers of cancers and deaths that occurred in the cohort during the follow-up period can then be compared with the expected numbers. This leads to the calculation of standardised mortality ratios (SMRs) for deaths and standardised incidence ratios (SIRs) for cancers. Both SMRs and SIRs are calculated by dividing the observed numbers of events by the expected numbers. If there is no association between the exposure and the cause of death or type of cancer then the SMR or SIR will be approximately equal to 1.0. However, if there is an association between exposure and death or cancer then the corresponding SMR or SIR

will be greater than one. Whether the excess of the observed number over the expected number is likely to represent a real risk or random variation can be tested with appropriate statistical techniques.

Methods

Identification and definition of the cohort

The United Fire Brigades Association of New Zealand (UFBA) maintains a register of volunteer and paid fire-fighters that dates back to the beginning of this century. The register is believed to be complete and is maintained mainly for the purpose of confirming eligibility for length-of-service awards. For each fire fighter the register contains full name, date of birth, and sex. The register also records the fire brigades that each person belonged to, their joining and retiring dates from each brigade, and whether they were paid or volunteer fire-fighters. The data from the register were made available to the investigators for the purposes of this study. The register was regarded as current to mid-1995 at the time that a copy of the data was made available for the study.

The study cohort was defined as every person in the UFBA database who:

- (1) had worked in New Zealand as a paid fire fighter for a total period of at least one year, and
- (2) who also worked as a paid fire fighter for at least one day during the period 1 January 1977 to 30 June 1995, inclusive.

The date of entry into the cohort was the first date from the beginning of 1977 at which one year of service as a paid fire fighter had been achieved. This could be as early as 1 January 1977 if they had already completed a year of service before 1977.

The reason for the beginning date for the recruitment and follow-up period is that it is date at which computerised cancer and mortality data are available through the NZHIS. The end of the recruitment period is the last date for which the UFBA database made available for this study is believed to be complete.

The reason for the minimum period of one year as a fire fighter is that it ensures that all cohort members have had at least that minimum amount of exposure to work as a paid fire fighter.

The requirement for at least one day's service is to ensure that all cohort members were alive at the beginning of the follow-up period.

The database included the following variables:

1. Surname
2. Given names
3. Date of birth
4. Sex
5. For each brigade by which the fire fighter was employed:
 - Joining and leaving dates
 - Brigade code
 - Address of brigade
 - Volunteer or paid status
6. A field for comments that recorded, in some cases, date of death.

The database of cohort members contained a number of duplicate entries, and also gaps in the data. Duplicates were actively sought and eliminated as they were identified.

There were a number of people on the UFBA list for whom there was no date of birth.

There were also a number of people who, according to UFBA records, were less than 14 years old at the time they joined the association. These names were submitted to the Fire Service, to check dates of birth against personnel records, medical records and volunteer lists back to 1983.

Some fire fighters on the UFBA register had only initials recorded, and no given names.

In other cases the given names appeared to be nicknames. Using other information sources, as far as we were able, we sought actual names to replace initials and nicknames.

Follow-up process

Procedures for obtaining data on deaths and cancers

After elimination of identified duplicates and replacement (as far as possible) of initials with actual names the list of cohort members (names, dates of birth and sex) was matched by the NZHIS with names on the National Health Index. Each person in New Zealand is allocated a National Health Index (NHI) number when they first have contact with the public hospital service. All public hospital records, cancer registrations and deaths are linked to NHI numbers. All cancer records back to 1977 are identifiable through the associated NHI numbers, as are mortality records since 1988.

Once a match is found with an NHI number, cancer and mortality data, by dates and disease codes can be obtained for each person. Mortality records for 1977-1987 are not linked to NHI numbers and a separate matching process, directly using names and birth dates, was necessary to identify deaths in the cohort during that period. The initial match with the NHI number database yielded NHI numbers for 85% of the cohort. The matching process also provided additional information that was incorporated into the follow-up process. In particular, additional middle names and alternative spellings of some names were found. Towards the end of the follow-up period, names still unmatched with NHI numbers were resubmitted to the NZHIS, together with additional information found through the follow-up process. Forty-seven percent of the previously unmatched names were matched with NHI numbers in this way. This improved the follow-up, including detection of deaths and cancers.

Confirmation of vital status

For cohort members not recorded by the NZHIS as having died, a variety of methods were used to confirm that they were alive as close as possible to the final date of follow-up. The final date of follow-up for confirmation of vital status was 31 December 1995. This is the final date for which complete cancer registration data were available from the NZHIS.

For some records, especially those with incomplete data (e.g., initials rather than first names) the follow-up process also provided a means of confirming or providing additional data about names and dates of birth. The additional data were then resubmitted to NZHIS for matching with cancer and mortality databases.

Methods used to confirm vital status were:

1. Period of service with the Fire Service. The last date recorded in the UFBA database that a person was still working as a fire fighter was taken as confirming that they were alive at least until that date.
2. Health system contact. The last date of contact with the New Zealand public health system, for whatever reason, based on records linked to NHI numbers, was taken as meaning that a cohort member was alive and living in New Zealand at least until that date.
3. Work and Income New Zealand (WINZ). Matching was carried out with the WINZ database of national superannuitants and people receiving other pensions. The last date of contact with WINZ was taken as evidence that a person was alive and living in New Zealand at least up to that date. When death was the reason for discontinuation of contact with WINZ, this information was used as a check on the completeness of the matching with the NZHIS mortality database.
4. Defence Force database. Some fire fighters were employed in the New Zealand Defence Force as fire fighters. Fortunately, a separate cohort study being carried out by ESR involves Defence Force personnel. It was possible to match names with the Defence database to confirm the vital status of some members of the fire fighter cohort.
5. Electronic electoral rolls – Matching was carried out with electronic electoral rolls from 1997 and 1999. This was limited in that the rolls only record year of birth, but not date of birth. Identification of any cohort members on the electoral roll was taken to indicate that those people were alive at the end of the follow-up period.

6. Paper electoral rolls – For a small proportion of cohort members for whom all other tracing methods had been unsuccessful, manual searches of printed rolls were carried out. The paper electoral rolls contain no indication of date or year of birth. Their usefulness was, therefore, very limited. By locating a person on the roll during their period as a fire fighter it was often possible to extend their period of follow-up by tracing them at the same address, on later rolls. However, once people change their address, this method becomes much less satisfactory, especially when searching for people with common surnames.

Exposure database

The primary measure of exposure is length of service, calculated from the differences between the beginning and finishing dates with brigades. Exposure calculations were based on years of paid service, and also on total years of service, paid plus volunteer.

Initially, an attempt was made to use the Fire Service's Fire Incident Reporting System (FIRS) to construct an exposure index that took into account the number of fires attended by fire fighters from each fire station. However, gaps in the FIRS data, a lack of data covering the early years of the cohort, and historical changes in fire brigade and fire district boundaries, made it impossible to construct a satisfactory index of exposure.

Calculation of population rates for cancers and deaths

Individual level anonymised data on incident cancer cases and deaths were obtained from the NZHIS for the period from 1977 to 1995 inclusive. Data were coded according to the Australasian Version of ICD-9-CM, using three and four digit codes.

Population statistics for the total population of New Zealand, by age and sex, were obtained from Statistics New Zealand for the Census years 1971, 1976, 1981, 1986, 1991 and 1996. The age- and sex-specific inter-censal populations were estimated by straight-line interpolation.

Cancer and cause of death rates for strata designated by 5-year calendar period, 5-year age-bands, and separately by sex, were calculated for each of the three and four digit ICD codes. This was done by dividing the number of cases in each stratum by the corresponding number of person-years in that stratum. These rates were used in the calculation of the expected numbers of cases.

Calculation of SIRs and SMRs

SIRs for cancers and SMRs for causes of death were calculated by dividing the number of observed cases by the number of expected cases for each cancer site or cause of death. Expected numbers of cases were calculated by multiplying the number of person-years of follow-up for the cohort that fell within each 5-year calendar period, 5-year age interval stratum by the corresponding population-based cancer or mortality rate for that stratum. Expected numbers were then summed across strata for each cancer type or cause of death. Because of the relatively small number of females who had served in the Fire Service, calculation of SMRs and SIRs was confined to males only.

P-values and 95% confidence intervals for SMRs and SIRs were calculated using standard methods.¹³ When the expected number of events was two or more the *p*-value was calculated using the Chi-square test, with one degree of freedom; when the expected number of events was less than two the *p*-value was calculated with the Poisson distribution, using λ (lambda) as equal to the expected number.

Results

Follow-up of the cohort

After first matching with the NZHIS mortality database to identify those who were dead, a variety of methods were successfully used to confirm that the remaining fire fighters were alive and living in New Zealand, up to the end of the follow-up period (31 December 1995), or as close to that date as possible. Table 1 shows the methods that were used and the numbers of fire fighters for whom the various methods provided the latest date of confirmation that they were alive and living in New Zealand. Some methods showed people to be alive and living in New Zealand in the years after the end of follow-up. We could not make full use of this later follow-up information, as the NZHIS mortality data were only complete until the end of 1995. This limited the follow-up period for the mortality study to the end of 1995. However, complete cancer registration information for the NZHIS was available to the end of 1996. Therefore, the cancer analysis was extended to include the year 1996.

Table 1. Methods used to confirm vital status closest to (or later than) end of follow-up (31 December 1995).

Method	Number of fire fighters		
	Male	Female	Total (%)
Deceased (NZHIS mortality data)	117	0	117 (2.7)
Still employed by NZ Fire Service	360	13	373 (8.7)
Electronic electoral roll [†]	3,472	64	3,536 (82.1)
Contact with the health system	77	5	82 (1.9)
WINZ records	117	0	117 (2.7)
Defence Force records	26	1	27 (0.6)
Manual search of electoral roll	52	1	53 (1.2)
TOTAL	4,221	84	4,305 (100)

[†] Electoral rolls for 1997 and 1999 were used.

As the original UFBA database did not contain complete details for all fire fighters potentially eligible for the cohort, the follow-up methods were used, whenever possible, to supply missing details. For example, the UFBA database sometimes contained only initials and not first names, or the date of birth was missing. Sometimes it was not possible to confirm the sex of fire fighters. When it was possible to obtain the missing details through follow-up methods, the completed records were matched with NZHIS data for cancers and mortality. A total of 53 fire fighters were excluded from the cohort on the grounds that their sex was unclear, or their birth date was missing or uncertain, and they could not be confidently identified using other methods. In particular, one fire fighter was excluded because his recorded birth date gave him an age of two years at the start of his follow-up period, and two others would have been aged 15 at entry into the cohort. Since entry criteria required completion of a year of service, these two were also excluded from the cohort. At the end of the process, prior to the statistical analysis, the resulting database contained 4,305 firefighters eligible for the cohort (4,221 males and 84 females). These were the people for whom full name and date of birth were available and who, during the follow-up period, died, were lost to follow-up, or were confirmed alive at the end of the follow-up period (Table 2).

Table 2. Outcome of follow-up, to 31 December 1995

Outcome	Number of fire fighters		
	Male	Female	Total (%)
Deceased	117	0	117 (2.7)
Lost to follow-up [†]	436	15	451 (10.4)
Followed to end	3,668	69	3,737 (86.8)
TOTAL	4,221	84	4,305 (100)

[†] Mean years lost to follow-up: males, 7.4; females, 5.6, assuming no deaths.

Table 3. Demographic details for the cohort

Characteristic	Males	Females	Total
<i>Age at start of follow-up</i> (Means: males, 30.2 yrs; females, 28.9 yrs).			
< 20	158	4	162
20-24	1,092	21	1,113
25-29	1,325	29	1,354
30-34	710	16	726
35-39	392	6	398
40-44	232	6	238
45-49	150	2	152
50-54	111	0	111
55-59	43	0	43
≥ 60	8	0	8
<i>Years of entry into cohort:</i>			
1977-81	2,770	19	2,789
1982-86	591	12	603
1987-91	650	29	679
1992-95	210	24	234
<i>Years of follow-up to 31 December 1995:</i> (Means: males, 13.9 yrs; females, 7.3 yrs).			
< 5	397	34	431
5-9	745	25	770
10-14	641	11	652
15-19	2,438	14	2,452
<i>Years as a firefighter (full-time and volunteer):</i> (Means: males, 15.9 yrs; females, 5.5 yrs)			
0-10	1,433	74	1,507
11-20	1,406	10	1,416
21-30	1,098	0	1,098
31-40	254	0	254
> 41	30	0	30

Table 3 shows demographic details for the cohort, in terms of ages of cohort members at the beginning of follow-up, the years in which fire fighters entered the cohort, the distribution of years of follow-up, and the distribution of years of exposure (years as a fire fighter).

To the end of 1995, the total follow-up time for the cohort was 59,322 person-years, comprised of 58,709 for males and 613 for females. [Note: For the cancer analysis, which included the year 1996, there was additional follow-up time of 3,735 person-years, comprising 3,657 for males and 78 for females]. The theoretically possible follow-up time (if all fire fighters had been traced until either death or the end of 1995) would have been 63,437 person-years. Therefore, the follow-up was successful in tracing 93.5% of the total. The fire fighters excluded from the cohort because of incomplete or inadequate identifier details could have supplied a maximum (assuming no deaths) of 687 person-years of follow-up.

There was a total for the cohort of 67,503 person-years of service as either a paid or volunteer fire fighter, of which 67,039 years were by males. Eighty-four percent of the years of service by the cohort were as full-time fire fighters. Twenty-eight percent of these years occurred before the beginning of 1977 (the beginning date of follow-up for the cohort).

Cancer incidence

Names and birth dates for cohort members were matched with records of the New Zealand Cancer Registry. Standardised incidence ratios (SIRs) for cancers detected were calculated after adjusting for age and calendar period.

Results for the period 1977 to 1996, inclusive, are shown in Table 4. Computation of SIRs was limited to male fire fighters. However, three cancers, all at different sites, had been recorded as occurring in female fire fighters. These are shown in Table 5. No

useful statistical analysis could be performed on these data because of the small numbers of cancers and the limited total follow-up time.

Table 4. Standardised incidence ratios for cancers in New Zealand male fire fighters, 1977-96.

Site	ICD-9	Expected	Observed	SIR	95% CI	p-value
All cancers	140-208	123.8	118	0.95	0.8-1.1	0.60
Oesophagus	150	1.8	3	1.67	0.3-4.9	0.11
Stomach	151	3.9	3	0.76	0.2-2.2	0.64
Colon	153	11.8	7	0.60	0.2-1.2	0.17
Rectum	154	7.8	9	1.15	0.5-2.2	0.68
Pancreas	157	2.3	3	1.28	0.3-3.7	0.67
Lung	162	15	17	1.14	0.7-1.8	0.60
Melanoma	172	18.3	23	1.26	0.8-1.9	0.27
Prostate	185	10.2	11	1.08	0.5-1.9	0.81
Testis	186	7.1	11	1.55	0.8-2.8	0.15
Bladder	188	4.4	5	1.14	0.4-2.7	0.77
Kidney	189	3.5	2	0.57	0.1-2.1	0.42
Brain	191	3.9	5	1.27	0.4-3.0	0.59
Myeloleukaemia	205	2.2	4	1.81	0.5-4.6	0.23

Table 5. Cancers occurring in female New Zealand fire fighters, 1977-96

ICD-9 code	Site	Year	Number
172	Melanoma	1994	1
180	Cervix	1992	1
183	Ovary	1988	1

Results for male fire fighters during 1977-96 (Table 4) show that, overall, the number of cancers during that period is very close to what would be expected (i.e., an SMR of approximately 1.0). Sites for which two or more cancer cases were recorded are shown