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

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April, 2000

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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 al[8] 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 al[12] 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.

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. Fortuitously, 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**
Age at start of follow-up (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
Years of entry into cohort:			
1977-81	2,770	19	2,789
1982-86	591	12	603
1987-91	650	29	679
1992-95	210	24	234
Years of follow-up to 31 December 1995: (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
Years as a firefighter (full-time and volunteer): (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 separately. Some of these cancers have SIRs exceeding 1.0 and some less than 1.0. However, as shown by confidence intervals and *p*-values, all of these deviations from the null are well within the bounds of random variation. Of particular note is the fact that 11 testicular cancers occurred in the cohort, but only 7.1 were expected. Although they were part of the cohort, two of the four fire fighters with testicular cancer that comprised the cluster occurring in Wellington in the 1980s[6] were not recorded in the Cancer Registry. Therefore, they are not included in the observed number of testicular cancer cases in Table 4. Addition of these two cases to the observed number in the table would bring the total number of testicular cancers to 13, and raise the SIR to 1.83 (95% CI: 0.97-3.13).

The variation in the overall cancer rate across the time period of follow-up was also investigated. Results of this analysis are shown in Table 6. This shows that although the numbers of cancers in the cohort have been increasing (probably because the average age of cohort members has increased over time), the SIR has generally remained at around 1.0.

Table 6. Variation over time of rates for all cancers (ICD-codes 140-208)

Registration years	Expected	Observed	SIR	95% CI	*p*-value
1977-96	123.8	118	0.95	0.8-1.1	0.60
• 1977-81	12.8	8	0.62	0.3-1.2	0.18
• 1982-86	20.8	20	0.96	0.6-1.5	0.87
• 1987-91	33.1	35	1.06	0.7-1.5	0.74
• 1992-96	57.1	55	0.96	0.7-1.3	0.78

A concern about matching with the NZHIS databases on mortality and cancer is the possibility of incomplete registrations. This is illustrated by the fact that two of the testicular cancers in the original Wellington cluster of the 1980s are not recorded in the Cancer Registry. To the extent that such under-registration occurs it has the potential to reduce the precision of estimated risks, or, if fire fighters with cancer are less frequently registered than other males, cause underestimation of the risks. However, the NZHIS databases are believed to be most complete from about 1990. Therefore, we carried out an analysis of cancer rates in the cohort, limited to cancers occurring in the years 1990-96. Results of this analysis are shown in Table 7. This analysis also serves to examine the question of whether the testicular cancer cluster observed in Wellington fire fighters during the 1980s was part of a phenomenon that continued into the 1990s.

Table 7. Standardised incidence ratios for cancers in New Zealand male fire fighters, 1990-96.

Site	ICD-9	Expected	Observed	SIR	95% CI	*p*-value
All cancers	140-208	71.2	72	1.01	0.8-1.3	0.92
Oesophagus	150	1.1	2	1.80	0.2-6.5	0.10
Stomach	151	2.2	2	0.89	0.1-3.2	0.87
Colon	153	6.9	4	0.58	0.2-1.5	0.27
Rectum	154	4.6	5	1.08	0.3-2.5	0.86
Pancreas	157	1.4	3	2.17	0.4-6.4	0.05
Lung	162	8.6	7	0.82	0.3-1.7	0.59
Melanoma	172	10.1	15	1.49	0.8-2.5	0.12
Prostate	185	8.2	9	1.09	0.5-2.1	0.79
Testis	186	2.7	8	2.97	1.3-5.9	0.001
Bladder	188	2.7	2	0.74	0.1-2.7	0.67
Brain	191	1.9	3	1.59	0.3-4.6	0.12

Table 7 shows that, for the 1990-96 period, the total number of cancers in the cohort was what would have been expected (SIR = 1.01), as were the numbers for most sites. However, eight testicular cancers, compared with 2.7 expected, exceeded what might be expected to occur by chance (SIR = 2.97, 95% CI: 1.3-5.9).

Every one of the eleven testicular cancer cases recorded by the Cancer Registry as occurring in the follow-up period 1977-96 had worked either exclusively (n=10) or partly (n=1) with North Island fire brigades. Five (including two in the original cluster) had been employed mainly by Wellington area brigades. A sixth had also worked in the Wellington area, but only in the year before and the year during which he was diagnosed with testicular cancer. Of the eight testicular cancer cases diagnosed in the 1990-96 period, three had worked in the Wellington area.

Fire fighters in the cohort were stratified according to the number of years that they had worked (exposure), as a paid fire fighter, or as either a paid or a volunteer fire fighter. SIRs were calculated for each of three exposure categories, for all cancers and for individual cancers sites with reasonable numbers of observed cases. Results based only on periods of service as a paid fire fighter are shown in Table 8, and results based on periods of either paid or volunteer service in Table 9. The period to which this analysis applies is until 30 June 1995, as that is the final date for which Fire Service employment information was regarded as complete.

The results for paid fire fighters only (Table 8) show a clear exposure-response relationship for testicular cancer, and some evidence for such relationships for lung and rectal cancers. Such relationships are less clear when exposure is treated as the sum of years of paid and volunteer exposure (Table 9). However, caution is necessary, as, in both tables, the number of cancers at any one site is small.

Table 8. Cancer by years of service as a paid fire fighter (1 Jan '77 to 30 June '95)

Cancer (ICD)	**Exposure**	**Expected**	**Observed**	**SIR**	**95% CI**	***p*-value**
All cancers	0-10 years	27.2	28	1.03	0.7-1.5	0.88
	11-20 years	22.5	31	1.38	0.9-2.0	0.07
	>20 years	32.7	39	1.19	0.9-1.6	0.27
Colon (153)	0-10 years	2.4	1	0.41	0.0-2.3	0.36
	11-20 years	2.2	1	0.46	0.0-2.6	0.43
	>20 years	3.6	5	1.37	0.4-3.2	0.48
Rectum (154)	0-10 years	1.6	2	1.22	0.1-4.4	0.23
	11-20 years	1.5	2	1.38	0.2-5.0	0.18
	>20 years	2.5	4	1.61	0.4-4.1	0.33
Lung (162)	0-10 years	3.2	3	0.93	0.2-2.7	0.90
	11-20 years	2.8	4	1.45	0.4-3.7	0.45
	>20 years	5.2	8	1.52	0.7-3.0	0.23
Melanoma	0-10 years	4.1	7	1.72	0.7-3.5	0.15
(172)	11-20 years	3.4	6	1.75	0.6-3.8	0.17
	>20 years	3.6	6	1.67	0.6-3.6	0.20
Prostate (185)	0-10 years	2.1	3	1.46	0.3-4.3	0.51
	11-20 years	1.7	1	0.60	0.0-3.3	0.50
	>20 years	3.4	1	0.29	0.0-1.6	
Testis (186)	0-10 years	1.9	3	1.55	0.3-4.5	0.13
	11-20 years	1.1	4	3.51	1.0-9.0	0.006
	>20 years	0.5	2	4.14	0.5-14.9	0.01

Table 9. Cancer by years of paid or volunteer service (1 Jan '77-30 June '95)

Cancer (ICD)	**Exposure**	**Expected**	**Observed**	**SIR**	**95% CI**	***p*-value**
All cancers	0-10 years	15.1	14	0.93	0.5-1.6	0.78
	11-20 years	18.8	33	1.75	1.2-2.5	0.001
	>20 years	49.2	51	1.04	0.8-1.4	0.80
Colon (153)	0-10 years	1.2	1	0.82	0.0-4.6	0.35
	11-20 years	1.7	1	0.58	0.0-3.3	0.51
	>20 years	5.5	5	0.92	0.3-2.1	0.84
Rectum (154)	0-10 years	0.8	1	1.23	0.0-6.8	0.20
	11-20 years	1.1	2	1.75	0.2-6.3	0.11
	>20 years	3.7	5	1.35	0.4-3.1	0.50
Lung (162)	0-10 years	1.5	1	0.66	0.0-3.7	0.45
	11-20 years	2.0	4	2.04	0.6-5.2	0.05
	>20 years	8.0	10	1.25	0.6-2.3	0.48
Melanoma	0-10 years	2.5	4	1.58	0.4-4.0	0.36
(172)	11-20 years	3.3	6	1.83	0.7-4.0	0.13
	>20 years	5.3	9	1.70	0.8-3.2	0.11
Prostate (185)	0-10 years	0.9	1	1.09	0.0-6.1	0.23
	11-20 years	1.1	2	1.9	0.2-6.9	0.09
	>20 years	5.2	2	0.38	0.0-1.4	0.16
Testis (186)	0-10 years	1.4	2	1.39	0.2-5.0	0.18
	11-20 years	1.2	5	4.03	1.3-9.4	0.002
	>20 years	0.8	2	2.65	0.3-9.6	0.04

Mortality

As with cancer incidence, names and birth dates were matched with the NZHIS mortality database. However, there were some differences in the process. These may have affected data quality. The process with the cancer registry and mortality data back to 1988 is that names and birth dates for the cohort are first matched, using a system of exact and near matching, with the file of names associated with NHI numbers. Once matches are made, the list of matched NHI numbers is matched with the files for mortality and incident cancers. This provides additional details, such as exact date of death and cause of death or cancer type. However, for the period before 1988, deaths have not been allocated NHI numbers. Therefore, for the earlier period of cohort follow-up, it was necessary to match the names and birth dates of cohort members directly with names and birth dates in the NZHIS mortality file.

There were no deaths of female members of the cohort, and the following analysis is for males only. Table 10 shows the results for the entire period of the cohort follow-up. The table shows that the observed numbers of deaths, overall and for specific causes, are appreciably below what would be expected.

Table 10. Standardised mortality ratios for New Zealand male fire fighters, 1977-95.

Cause of death	**ICD-9 code**	**Exp**	**Obs**	**SMR**	**95% CI**	***p*-value**
All causes	0-999	201	117	0.58	0.5-0.7	<0.001
Malignant tumours	140-208	51.9	42	0.81	0.6-1.1	0.17
• Stomach	151	2.6	3	1.16	0.2-3.4	0.80
• Colon	153	5.0	6	1.19	0.4-2.6	0.67
• Rectum	154	3.3	4	1.21	0.3-3.1	0.70
• Lung	162	11.7	10	0.86	0.4-1.6	0.62
• Melanoma	172	3.1	2	0.65	0.1-2.4	0.54
• Bladder	188	0.7	2	2.73	0.3-9.8	0.04
• Brain	191	3.0	2	0.68	0.1-2.4	0.58
• Haematopoietic	200-208	5.6	4	0.72	0.2-1.8	0.51
Nervous system diseases	320-389	3.6	1	0.28	0.0-1.6	0.18
Circulatory diseases	390-459	70.4	38	0.54	0.4-0.7	<0.001
• Ischaemic heart disease	410-414	49.8	29	0.58	0.4-0.8	0.003
• Cerebrovascular disease	430-438	8.5	5	0.59	0.2-1.4	0.23
Respiratory diseases	460-519	9.5	4	0.42	0.1-1.1	0.07
• Asthma, bronchitis, emphysema	490-493	3.9	2	0.51	0.1-1.8	0.34
Digestive system diseases	520-579	4.5	4	0.89	0.2-2.3	0.81
• Liver cirrhosis	571	2.2	1	0.46	0.0-2.6	0.43
Genitourinary diseases	580-629	1.4	1	0.70	0.0-3.9	0.42
External causes	E800-999	47.4	24	0.51	0.3-0.8	0.001
• Motor vehicle accidents	E810-825	17.3	12	0.69	0.4-1.2	0.20
• Accidental falls	E880-888	1.8	1	0.56	0.0-3.1	0.54
• Suicide	E950-959	14.0	8	0.57	0.2-1.1	0.11

When total deaths were stratified in terms of 5 calendar-year blocks, a tendency for the overall mortality SMR to increase over time was evident (Table 11).

Table 11. Variation over time of SMRs for deaths from all causes (ICD-codes 000-999)

Registration years	**Expected**	**Observed**	**SMR**	**95% CI**	***p*-value**
1977-95	201.0	117	0.58	0.5-0.7	<0.001
• 1977-81	30.4	10	0.33	0.2-0.6	<0.001
• 1982-86	43.0	23	0.54	0.3-0.8	0.002
• 1987-91	62.9	39	0.62	0.4-0.8	0.003
• 1992-95	64.8	45	0.69	0.5-0.9	0.01

We also examined the period 1990-95 separately, on the assumption that mortality data for these years were likely to be the most complete. Results of this analysis are shown in Table 12. The SMR for all deaths is higher than the corresponding figure for the entire period of follow-up for the cohort, but the number of deaths is smaller and the SMRs for individual ICD-codes correspondingly imprecise.

Fire fighters in the cohort were stratified according to the number of years that they had worked (exposure), as a paid fire fighter, or as either a paid or a volunteer fire fighter. SMRs were calculated for each of the three exposure categories, for all deaths and for deaths caused by circulatory diseases (ICD codes 390-459), for which there is a reasonable number of cases. Results are shown in Table 13. There are some differences depending on whether exposure is assessed on the basis of paid service only, or as paid and volunteer service combined. However, in general, the patterns remain similar, even if the magnitudes of some SMRs vary. No clear exposure-response relationships are apparent.

Table 12. Standardised mortality ratios for New Zealand male fire fighters, 1990-95.

Cause of death	**ICD-9 code**	**Exp**	**Obs**	**SMR**	**95% CI**	***p*-value**
All causes	0-999	92.2	61	0.66	0.5-0.9	0.001
Malignant tumours	140-208	26.8	20	0.75	0.5-1.2	0.19
• Stomach	151	1.3	2	1.57	0.2-5.7	0.14
• Colon	153	2.7	2	0.74	0.1-2.7	0.67
• Rectum	154	1.7	1	0.58	0.0-3.2	0.51
• Lung	162	6.2	6	0.97	0.4-2.1	0.95
• Melanoma	172	1.4	2	1.43	0.2-5.2	0.17
• Bladder	188	0.4	1	2.49	0.0-13.8	0.06
• Brain	191	1.3	1	0.76	0.0-4.2	0.38
• Haematopoietic	200-208	2.7	0	0	-	-
Nervous system diseases	320-389	1.6	0	0	-	-
Circulatory diseases	390-459	33.8	19	0.56	0.3-0.9	0.01
• Ischaemic heart disease	410-414	23.6	15	0.63	0.4-1.0	0.08
• Cerebrovascular disease	430-438	4.3	3	0.70	0.1-2.1	0.54
Respiratory diseases	460-519	4.1	2	0.49	0.1-1.8	0.30
• Asthma, bronchitis, emphysema	490-493	1.1	0	0	-	-
Digestive system diseases	520-579	2.1	4	1.92	0.5-4.9	0.19
• Liver cirrhosis	571	0.9	1	1.12	0.0-6.2	0.23
Genitourinary diseases	580-629	0.7	0	0	-	-
External causes	E800-999	16.7	15	0.90	0.5-1.5	0.68
• Motor vehicle accidents	E810-825	5.5	6	1.08	0.4-2.4	0.84
• Accidental falls	E880-888	0.6	1	1.57	0.0-8.8	0.13
• Suicide	E950-959	6.85	6	0.88	0.3-1.9	0.75

Table 13. Mortality by years of service as a fire fighter (1 Jan '77 to 30 June '95)

Cause of death (ICD)	Exposure	No. of fire fighters	Person-years	Expected	Observed	SMR	95% CI	*p*-value
A. Paid fire fighting								
All causes	0-10 years	1,789	16,216	52.0	37	0.71	0.5-1.0	0.04
(000-999)	11-20 years	1,315	10,339	38.7	40	1.03	0.7-1.4	0.84
	>20 years	1,117	7,225	54.6	37	0.68	0.5-0.9	0.02
Circulatory	0-10 years	1,789	16,216	16.9	11	0.65	0.3-1.2	0.15
diseases	11-20 years	1,315	10,339	14.4	15	1.04	0.6-1.7	0.88
(390-459)	>20 years	1,117	7,225	24.0	11	0.46	0.2-0.8	0.01
B. Paid and volunteer fire fighting								
All causes	0-10 years	1,357	11,534	30.2	20	0.66	0.4-1.0	0.06
(000-999)	11-20 years	1,389	10,646	32.5	38	1.17	0.8-1.6	0.33
	>20 years	1,475	11,012	83.8	56	0.67	0.5-0.9	0.002
Circulatory	0-10 years	1,357	11,534	8.4	5	0.60	0.2-1.4	0.24
diseases	11-20 years	1,389	10,646	11.1	15	1.35	0.8-2.2	0.24
(390-459)	>20 years	1,475	11,012	36.9	17	0.46	0.3-0.7	0.001

Discussion

A primary motivation for carrying out this study was to investigate whether the high rate of testicular cancer that occurred in Wellington fire fighters in the 1980s was an isolated phenomenon.[6] In particular, it was important to know whether the occurrence of testicular cancer in fire fighters was limited to Wellington or more widespread, and whether it continued into the 1990s. Given this prior hypothesis, it is striking that testicular cancer was the only cancer for which the cohort produced convincing evidence of an elevated incidence rate. This elevated rate was evident even when the original Wellington cluster was excluded from the analysis, and continued into the 1990s The elevated risk appears not to have been confined to Wellington fire fighters, but may have been limited to the North Island. Based on the confidence interval and *p*-value, the elevated incidence in the 1990s seems unlikely to have been due to chance. There was some evidence of an exposure-response relationship, particularly when the exposure was limited to service as a paid fire fighter (Table 8).

Studies have produced evidence of two other cancer risks elevated in New Zealand fire fighters. These were for laryngeal cancer and kidney cancer. Our study produced no evidence that New Zealand fire fighters are at particular risk for either of these cancers. A study of occupational cancer risk for kidney cancers reported to the New Zealand Cancer Registry during 1978 to 1986 obtained a relative risk estimate for being a fire fighter of 3.51 (95% CI: 2.09-3.52).[10] Our study found only two kidney cancers across the entire follow-up period (SIR = 0.57, 95% CI: 0.1-2.1).

Another study of occupational associations with male cancer registered with the New Zealand Cancer Registry during 1972-84 found that fire fighters had an increased risk for laryngeal cancer.[11] Four cases were observed in men aged 15-64 years (SIR = 1074, 95% CI: 2.79-27.76). No cases of laryngeal cancer were found in the present study.

Studies of fire fighters overseas have produced inconsistent results. However, after reviewing the literature, Howe and Burch considered that there was some evidence for an association between fire fighting and brain tumours, malignant melanoma, and multiple myeloma.[1] The present study found no cases of multiple myeloma. However, there were small excesses, within the bounds of chance, of brain cancer and malignant melanoma (Table 4). The SIRs increased slightly when the analysis was confined to the period 1990-1996 (Table 7).

Guidotti, after reviewing the literature, considered there was strong evidence for an association between fire fighting and genitourinary cancer, including cancers of the kidney and bladder.[2] In the present study there was a deficit of kidney cancer and the number of bladder cancers was about what would have been expected.

Golden et al., in a further review, considered that there was evidence linking employment as a fire fighter with leukaemia, non-Hodgkins lymphoma, multiple myeloma and cancers of the brain and bladder.[3] They felt that weaker evidence linked fire fighting with increased risks of rectal, colon, stomach, and prostate cancers, and melanoma. With the possible exception of melanoma, the present study supplies little support for any of these associations.

The question arises whether the apparently elevated risk of testicular cancer in this study could be due to bias or confounding. There are two main types of bias that affect epidemiologic studies: selection bias and information bias. Since the cohort involved all paid New Zealand fire fighters and the follow-up rate was very good for cohorts of this type, it seems improbable that we could, somehow, have selected in favour of fire fighters more likely to be affected by testicular cancer. However, there are other possibilities. These are related to the high level of awareness of testicular cancer within the New Zealand Fire Service, engendered by the previous testicular cancer cluster investigation. First, it is conceivable that fire fighters are checking themselves more regularly and testicular cancers may be being detected at an earlier stage than would otherwise be the case. This could raise the SIR for this cancer. However, such an effect would be transitory, as the cancers would all eventually be diagnosed anyway once they had grown to a certain size. Secondly, it could be that the publicity has led to more complete notification to the Cancer Registry of incident testicular cancers in fire fighters than of testicular cancer cases diagnosed in the general male population. However, to account for the elevated risk in the 1990-96 period, testicular cancer cases in fire fighters would need to be nearly three times as likely to be notified as in the general population. An effect of this magnitude seems unlikely.

Information bias would be possible if, for some reason, fire fighters were more likely to be erroneously diagnosed as having testicular cancer than were other males in the New Zealand population. All the fire fighters with testicular cancer in this study had histological classifications consistent with testicular cancer. Irrespective of this, it seems unlikely that fire fighters would be threefold overdiagnosed relative to all other males.

Confounding would be possible if there were a risk factor for testicular cancer that was correlated with employment as a fire fighter, but not incurred as a consequence of being a fire fighter. If such a risk factor exists it is not clear what it could be.

In contrast to the cancer incidence data, the mortality analysis was, on the face of it, reassuring. The overall mortality rate was lower than expected, both in the cohort as a whole and in the analyses using shorter time periods. None of the individual causes of death were associated with convincing evidence of elevated risks. A generally reduced mortality rate in fire fighters, due to the so-called healthy worker effect, is to be expected. This is a well-established phenomenon in occupational cohorts, particularly for occupations that require a reasonable level of fitness and good health. The healthy worker effect operates through two main processes. First, there is an initial medical screening procedure before one can become a fire fighter. This selects out the less healthy and the unfit. Secondly, those who are less healthy will tend not to remain long in the occupation. Thus, a priori, it is reasonable to expect that fire fighters as a group will have a lower mortality rate.

The healthy worker effect has been a consistent finding in virtually all mortality studies of fire fighters carried out overseas.[8,14,15,16,17,18,19,20,21,22,23,24] In most cases, the effect has been somewhat less than that found in the present study. Relative risk estimates (such as SMRs) for all cause mortality have generally been in the region 0.80-0.95, whereas this study produced estimates ranging from 0.33 to 0.69 (Table 11). However, this study is not unique with its finding of a strong healthy worker effect. A recent study of Paris fire fighters obtained an SMR for all cause mortality of 0.52 (95% CI: 0.35-0.75).[25] There are at least two possible reasons why the mortality rate that we measured might be particularly low relative to most other studies. Firstly, it may be that people applying to join the New Zealand Fire Service have to meet more stringent health and fitness entry criteria than is the case in other countries where fire fighter mortality studies have been carried out (mainly the United States, Canada, Australia, Scandinavia). Secondly, there is the possibility that errors in recording of key identifier data may be such that matching between the names and birth dates on our cohort database with those in the mortality database may be incomplete. The process by which this matching takes place may be less than totally effective, particularly if there are errors in the recording of names and birth dates in either database, or in both. If so, deaths recorded by the NZHIS may contribute to the calculation of the expected number of deaths, but not be recognised as contributing to the observed number of deaths. This would lead to underestimation of relative risks. We note that the SMRs for consecutive five-year periods steadily increase (Table 11). This could be due to the healthy worker effect wearing off as the cohort gets older on average, or it could be due to a greater frequency of errors in the earlier recorded data.

At this stage, the true reason for the low mortality rates remains unclear, but may be due to either or both of the above reasons. However, it is worth noting that a number of deaths were recorded in the UFBA fire fighter database, and others in the WINZ data as the reason why payment of some benefits was terminated. Of 33 deaths recorded in the

UFBA database, NZHIS mortality data were not found for four. It is possible that the UFBA database contains information on deaths that occurred overseas. WINZ advised us of 43 deaths, all of which were found on the NZHIS mortality database. Considering this information, it seems likely that identification of deaths in the cohort was fairly complete and the low SMR may have been due to a strong healthy worker effect. Whatever the case, it is most probable that the fire fighter cohort did not have a high mortality rate. For the cohort to have had an actual mortality rate that corresponded to the rate of the general male population, there would need to have been an extra 84 deaths not detected by the follow-up. A deficiency of that magnitude in identification of deaths seems unlikely.

In summary, with the exception of testicular cancer, there is no evidence that New Zealand fire fighters are at particular risk of cancer or early death. This is reassuring, but must be tempered with the fact that the total person-time experience of the cohort was not particularly large, and the number of cancers of any one type and deaths attributed to any one cause was not great. It is still possible that there may be cancer or mortality risks that would only become apparent if the cohort were followed over a longer period of time.

The reason for the excess risk of testicular cancer remain obscure. The possibility that it is a chance occurrence cannot be totally discounted, but seems unlikely. There is no obvious explanation from bias or confounding in the study, although such possibilities also cannot be completely dismissed. The question arises as to why, if the finding of testicular cancer is a real occupational risk of fire fighting as a profession, it has not been detected in studies carried out in other countries. There is a possible reason, related to the type and timing of most of the studies of cancer in fire fighters that have been carried out overseas. Firstly, of the studies done elsewhere most have investigated mortality only.[8,14,16,17,18,19,20,21,22,23,24,25] As testicular cancer can be very successfully treated nowadays, there are few fatal cases (only one occurred in this cohort). Therefore, unless they are very large, mortality studies are unlikely to detect a raised incidence of testicular cancer. Despite this, there have been some studies that have examined cancer incidence in fire fighters and it is important to consider why these generally did not detect a raised incidence of testicular cancer.[26,27,28,29]

A possible reason is the timing of the period of follow-up of these studies. Of the thirteen testicular cancers in New Zealand fire fighters that occurred during the period of our follow-up (including the two in the Wellington cluster not recorded by the Cancer Registry), twelve were registered in the years 1988 to 1996. Of the studies of cancer incidence in fire fighters carried out overseas, periods of follow-up were limited to the 1980s at latest. The two most recent periods of follow-up concluded in 1989.[28,29] It is conceivable, for example, that there might be a relatively new building material that produces a combustion product that is a testicular carcinogen, and which only relatively recently has begun to manifest itself in terms of an increased incidence of testicular cancer in fire fighters. Alternatively, there could be new fire fighting work practices or materials that carry an increased testicular cancer risk, whose effects have only recently become apparent. It is beyond the scope of this study to investigate such possibilities.

There are several areas of further investigation that could usefully be pursued, now and in the future, to clarify the findings of this study. These are:

1. Investigation of risk factors for testicular cancer within the fire fighting profession in New Zealand.
2. Investigation of whether the apparent increase in testicular cancer risk for fire fighters in New Zealand continues.
3. Investigation of whether testicular cancer risks for fire fighters are elevated in other countries.

The first of these investigations could be carried out now, within New Zealand. It would involve a comparison of the exposures of the known testicular cancer cases (since, perhaps, 1988) with the exposures of a suitable comparison group. The most appropriate epidemiological method to achieve this would be a nested case-control study. Each of the fire fighters with testicular cancer (the cases) would be matched with a control group comprised of, say, four or five other fire fighters without testicular cancer, but comparable in terms of age and work years. The control group would also be selected from the cohort using the data we already have. Both the case and control groups are "nested" in the cohort. Further cases and controls could be obtained if a surveillance system were instituted within the Fire Service to identify new testicular cancer cases. This would extend the time period of the study, but would be justified by the increase in statistical power arising from the greater number of study subjects. Information on exposures and experiences would be collected from both cases and controls, mainly by questionnaire. Analysis of the questionnaire data would be directed toward identifying factors more common in the experience of the cases than of the controls.

In addition to the case-control study, it would seem appropriate to continue to follow the fire fighter cohort, building on the work already done to collect follow-up and cancer and mortality data. For example, if the study were to be further followed up after, say, ten, or even five, years, the amount of person-time experience would be increased, and the ability to discriminate true risks appreciably extended.

Conclusions

On the basis of the results of this study, we conclude the following:

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

We recommend the following:

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.

1. 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.

2. 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.

3. 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.

Acknowledgements

The authors would like to thank the following people for their assistance with this study: Vince Arbuckle, Eni Toafa, Elizabeth Grieves, and Rod Nightingale (New Zealand Fire Service); Gordon Purdie and Tony Blakeley (Wellington School of Medicine); Don Roper (UFBA); Chris Lewis (NZHIS); and Kevin Hastings (WINZ).

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