Descriptive Study of Mesothelioma in the Australian Capital Territory

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Contents

Summary

The Australian Capital Territory (ACT) Government commissioned the Australian National University to undertake a study to improve understanding of the health risks of loose-fill asbestos insulation, which was installed in over 1,000 Canberra residences between 1968 and 1979. These residences are commonly referred to as "Mr Fluffy" houses. This report on the *Descriptive Study of Mesothelioma in the ACT* is the first component of the *ACT Asbestos Health Study*. It describes the trends in mesothelioma incidence in the ACT from 1982 to 2014 and compares them to the rest of Australia.

As background, breathing in asbestos—a naturally occurring fibre—is the main cause of mesothelioma, which is a form of cancer. Compared with other countries, Australia has high rates of mesothelioma; rates are particularly high in Western Australia (WA) due to the large number of people who were intensively exposed to asbestos in the mining town of Wittenoom. When comparing the rates of mesothelioma in the ACT to the rest of Australia data from WA are not included.

This descriptive study is based on mesothelioma cases diagnosed between 1982 and 2014 and reported to the ACT Cancer Registry. The data are most reliable from 1994, the year mandatory cancer reporting began in the ACT, up to 2011 ('finalised' data). Residential addresses at the time of diagnosis were linked to Mr Fluffy house addresses.

There were a total of 140 mesothelioma cases reported to the Registry between 1982 and 2014. Most cases (81%) were male and around one-third of the cases were diagnosed in people aged 65–74 years, with less than 5% aged less than 45 years. There was one case of mesothelioma diagnosed in a person living in a Mr Fluffy house at the time of diagnosis. The total number of mesothelioma cases increased from 9 in 1994–1996 (0.98 per 100,000 people per year) to 32 in 2009–2011 (2.95 per 100,000 people per year). Taking into account demographic changes in the ACT, mesothelioma rates increased 12% per three-year period between 1994 and 2011. However, there was considerable statistical uncertainty due to the small number of diagnosed patients. Overall, rates were lower in the ACT than the rest of Australia (excluding WA), but there is evidence to suggest that the rates may have increased faster in the ACT, at least in 2009-2011. Understanding these apparent differences would require a detailed historical knowledge of asbestos exposure in the different populations. However, the pattern in the ACT of higher mesothelioma incidence in males than females and rising incidence over time is generally consistent with national and international trends.

The limitations of this study include the small number of cases, as well as the inability to include people with unconfirmed mesothelioma and former ACT residents with mesothelioma who lived interstate at the time of their diagnosis. That one person was identified as living in a Mr Fluffy house at the time of diagnosis may be significant; however, more information is needed. The health risks associated with living in a Mr Fluffy house are the subject of further studies within the ACT Asbestos Health Study.

Background

This descriptive study of mesothelioma in the Australian Capital Territory (ACT) is the first of four components of the ACT Asbestos Health Study. The ACT Government commissioned the Australian National University (ANU) to conduct the ACT Asbestos Health Study to improve understanding of the health risks of living in a house containing loose-fill asbestos insulation.

Loose-fill asbestos insulation in the ACT

Between 1968 and 1979, a contractor commonly known as 'Mr Fluffy' insulated homes in the ACT, along with homes in southern NSW. The contractor blew asbestos in a ground raw form (loose-fill asbestos) into roof spaces.

Between 1988 and 1993, a Commonwealth Government audit visually checked some 65,000 houses in the ACT for the presence of loose-fill asbestos insulation. More than 1,000 houses were identified as containing this insulation and an extensive remediation program was undertaken, in which the loose-fill asbestos was removed from the roof spaces and efforts made to prevent any residual asbestos spreading inside the houses. Recently, there have been concerns about resident safety after asbestos fibres were found in living spaces of some remediated houses. In addition, there have been news media reports of at least one case of mesothelioma in a present or former resident of an affected residential property (ARP) and in an electrician who worked on ARPs, although exposure histories have not been verified.

In June 2014, the ACT government established The Asbestos Response Taskforce (http://www.act.gov.au/asbestos-response-taskforce) to respond to impacts of loose-fill asbestos insulation on affected residents and the broader ACT community. The Taskforce reports directly to the Chief Minister of the ACT and provides a single point of contact for ACT residents concerned about loose-fill asbestos insulation. The Taskforce provided guidance to the ACT Government on the long term management of this issue in the Territory and has subsequently administered the voluntary Buyback Program as well as providing wellbeing, financial and information support to those affected. The Taskforce is currently overseeing the Demolition Program of surrendered properties and continues its work in informing and engaging the community on this issue. The Taskforce is also recording contact details for those exposed to, or concerned about, loose-fill asbestos insulation in Canberra homes, including current and former home owners and tenants, tradespeople, real-estate and other professionals and members of the general community.

Domestic asbestos exposure and health

Asbestos is a naturally occurring silicate mineral that occurs in a variety of fibrous forms. The fibres have fire-resistant properties and have been used in building materials and for insulation, among other things. After World War II, asbestos cement products were commonly used as a building material in Australia, and until the 1960s, a quarter of all new homes were clad in asbestos cement. [1] From the 1970s, the use of asbestos was slowly

phased out in Australia, with asbestos products manufacture ceasing in 1987, and the sale, use and manufacture of asbestos products banned since 2003. [2]

The main forms of asbestos are chrysotile, actinolite, amosite and crocodilite, which vary in their propensity to cause disease in humans. Asbestos is a risk to health when fine fibres are inhaled. The risk to health increases with intensity and duration of exposure, and depends on the type of asbestos. [3, 4] Inhalation of asbestos fibres is the predominant cause of malignant mesothelioma and an important contributor to risk of lung, laryngeal and ovarian cancer in exposed people. Asbestos exposure can also cause non-malignant lung conditions such as asbestosis and plural plaques. [5, 6]

The association between exposure to asbestos and mesothelioma and other asbestos-related diseases has been well documented for people exposed in occupational settings. [7] However, the health impact of exposure to asbestos in non-occupational settings is less clear. [8] Non-occupational exposure can be categorised into 'neighbourhood or environmental' or 'domestic' exposure. Neighbourhood or environmental exposure occurs through exposure to naturally occurring asbestos fibres in the environment, and domestic exposure refers to exposure to asbestos fibres within the home, including through take home exposure from family members who work with asbestos (this is sometimes referred to as para-occupational exposure). [8] Non-occupational exposure has been suggested to explain up to 20% of mesotheliomas in developed countries. [9]

In Australia, the best documented studies of non-occupational exposure have been done on residents of Wittenoom in Western Australia (WA) where the urban environment was heavily contaminated with asbestos and many residents were either employed at the nearby crocidolite mine or mill or lived in the same house as a mine or mill employee. [10, 11] In a recent report from the Western Australian Mesothelioma Register, non-occupational exposure was estimated to account for 7% of mesothelioma cases in men (2% residence in Wittenoom, 4% home renovation and 1% other non-occupational exposure) and 44% in women (14% Wittenoom residence, 14% home renovation and 17% other) between 1960 and 2008. [12]

There is a lack of published literature on health effects of domestic exposure to asbestos-containing products. [2, 8] The literature on domestic exposure has mainly reported on exposure to fibres released from bonded products (generally asbestos cement) through deterioration or during the course of renovation, or through para-occupational exposure of family members. Australian researchers have raised concerns about home renovation exposure as a cause of mesothelioma. [12] In a recent survey of Australian householders, almost a quarter of respondents had done "do-it-yourself" renovations. [13] With an estimated one-third of all homes built in Australia containing some asbestos product [14] and the deterioration of older, weathered asbestos products and the need for renovation in older homes, the likelihood of exposure could be quite high if safety precautions are not taken. Tradespeople and residents may be exposed to fibres during the process of

demolition or maintenance of houses, out-buildings and fences, for example. The process of renovation or demolition of asbestos cement-clad buildings measurably increases the exposure to asbestos fibres for workers. [15] Studies have also revealed that, while tradespeople and home renovators have been aware that they were working with asbestos containing materials, they do not always take safety precautions. [13, 16] In WA, 5% of mesothelioma cases (87/1631) were attributed to asbestos exposure during home maintenance and renovation, with an increasing proportion of such cases recently. [12]

Asbestos-based home insulation, specifically, has been recognized as a health concern for residents living in houses containing this material, and for tradespeople who may have worked in the houses, but there is a lack of scientific data that quantifies the health risks in this context. [17]

Mesothelioma

Because of the very strong causal association between asbestos exposure and mesothelioma, mesothelioma incidence is often used as a marker of asbestos exposure sufficient to cause asbestos-related diseases. [18] Inhalation of asbestos fibres is the predominant cause of malignant mesothelioma, with approximately 70 to 80 percent of cases of pleural mesothelioma being associated with documented asbestos exposure. [5, 18, 19] Although short-duration or low-level asbestos exposures have been linked to the development of mesothelioma, it usually takes intense, repeated exposures to asbestos for mesothelioma to develop, with the risk increasing with increasing exposure. [5, 19]

Mesothelioma is cancer of the mesothelium, a protective membrane that lines the walls of, and organs in, the chest and the abdomen. Three out of every four cases of mesothelioma disease begin in the pleural mesothelium, which forms the outer lining of the lungs and the inner lining of the chest wall. Mesothelioma can also begin in the abdominal cavity and around the heart. Mesothelioma symptoms commonly do not appear until 20 to 50 years after initial asbestos exposure. Symptoms usually include chest pain, shortness of breath and cough. Systemic symptoms such as fatigue and weight loss may also be present, particularly in patients with advanced disease. Often by the time mesothelioma is diagnosed, the disease is well advanced. [3, 5]

Mesothelioma in Australia: Incidence, survival and mortality rates

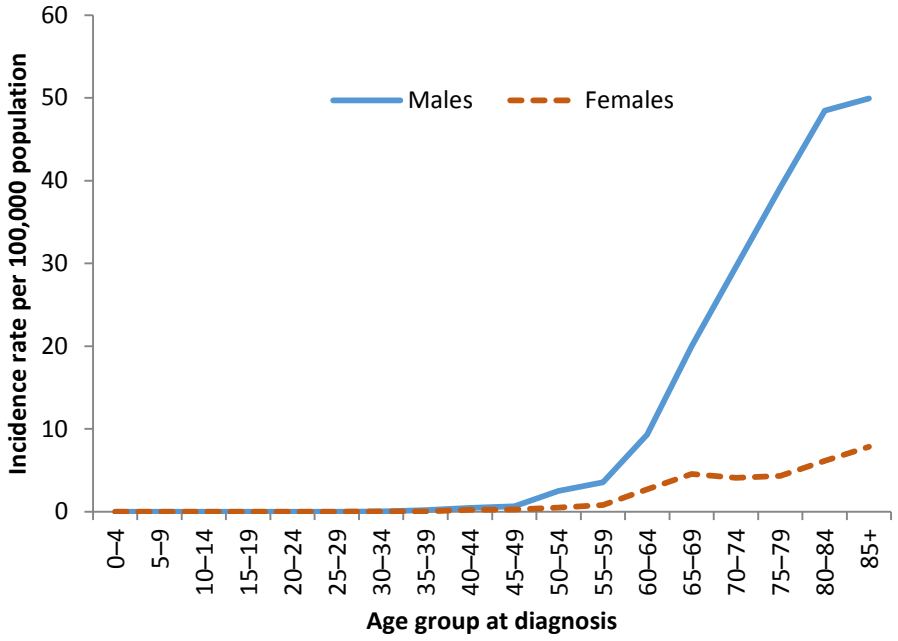
Australia has one of the highest incidence rates of malignant mesothelioma in the world. [18] In Australia in 2011, the rate of mesothelioma was 3.1 per 100,000 persons,[1] with rates higher in males (5.2 per 100,000) than females (1.0 per 100,000). After taking into account age, men were approximately six times more likely to develop mesothelioma than women, the 2011 age-standardised incidence rates being 5.1 and 0.9 per 100,000, respectively. [20]

[1]Throughout the report, incidence rates were estimated per 100,000 persons per year (100,000 person-years), but for simplicity are often expressed as per 100,000 persons. See “Terminology used in this report” for more information on incidence rate and person-years.

Mesothelioma incidence rates in Australia have increased over time. Based on cancer registrations, the age-standardised incidence rate was 1.2 per 100,000 persons in 1982, increasing to 2.8 per 100,000 persons in 2011. [20] While mesothelioma rates have peaked in some countries, [18] it is not certain whether rates have yet peaked in Australia. [21]

Mesothelioma incidence rates increase with age (see Figure 1). In 2011, incidence was very low for men and women under the age of 50, with only 2% of cases diagnosed by this age. In men, rates increased from 2.5 to 9.3 per 100,000 between the ages of 50-54 and 60-64 years, with a much steeper increase after that, peaking at 50 per 100,000 among men aged over 85 years. In women, the rate of diagnosis was relatively low in all age groups, with a small gradual increase after the age of 59 years, peaking at 7.9 per 100,000 among women aged over 85 years.

Figure 1. Crude incidence rates of mesothelioma in Australia for 2011, by age



Data source: Australian Institute of Health and Welfare, 2015. Australian Cancer Incidence and Mortality books

Mesothelioma incidence rates vary across Australia. Western Australia has a substantially higher rate than other states due to the large number of people exposed to asbestos in or from the asbestos mine and mill near the Pilbara town of Wittenoom. [22] Table 1 shows age-standardised incidence rates of new cases of mesothelioma for 2013 by sex and state or territory. To date there have been no published epidemiological studies comparing mesothelioma rates in the ACT to those for the rest of Australia.

Table 1. Age-standardised[a] mesothelioma incidence rates (per 100,000 population), by sex and state/territory,[b] 2013

Sex	NSW	Vic	Qld	WA	SA
Males	3.2	3.0	4.5	8.3	4.3
Females	0.6	0.9	0.9	1.4	n.p.
Persons	**1.8**	**1.8**	**2.6**	**3.9**	**2.5**

[a] Age-standardised to the 2001 Australian population

[b] Incidence rates not published (n.p.) for Tasmania, ACT and Northern Territory due to small numbers

Source: Australian Mesothelioma Registry 3rd Annual Report [22]

On average, the life expectancy for those diagnosed with mesothelioma is nine months, with few surviving longer than two years. [22] For the period 2006–2010, five-year relative survival rates were among the lowest of all cancers in Australia, at 5% for men and 10% for women (see Table 2). This compares to five-year relative survival rates of all cancers combined of 65% (men) and 67% (women). [23] In 2012, where the cause of death was ascertained in those diagnosed with mesothelioma, mesothelioma was the cause of death in 96% of cases. [22] Due to the low survival rate, the age-specific death rates show a similar pattern to those for incidence rates. [20]

Table 2. Summary of relative survival (RS) from mesothelioma, Australia 2006–2010

	1-year relative survival		5-year relative survival		10-year relative survival	
Cancer	**RS (%)**	**95% CI**	**RS (%)**	**95% CI**	**RS (%)**	**95% CI**
Mesothelioma						
Males	43.6	40.9–46.4	5.3	4.3–6.4	2.4	1.7–3.3
Females	47.6	41.4–53.6	10.2	7.4–13.4	4.1	2.5–6.5
Persons	**44.3**	**41.8–46.8**	**6.2**	**5.2–7.2**	**2.8**	**2.1–3.6**

CI=confidence interval

Source: AIHW. Cancer Series Number 69, Cancer survival and prevalence in Australia [23].

Objectives of the study and hypotheses

The objectives of this study were to describe patterns and trends in the rates of mesothelioma in the ACT from 1982 to 2014 and compare mesothelioma rates in the ACT with those for the rest of Australia (excluding WA).

The specific hypotheses tested were:

1. Mesothelioma rates in the ACT are higher in men than women.
2. Mesothelioma rates in the ACT have increased over time.
3. Mesothelioma rates in the ACT do not differ from those reported for the rest of Australia (excluding WA).

Method

We undertook a descriptive analysis of mesothelioma cases registered in the ACT between 1982 and 2014, the years for which ACT Cancer Registry data were available. This analysis included calculation of mesothelioma rates in relation to sociodemographic variables, examination of trends over time and comparisons of rates to those for the rest of Australia (excluding WA). Western Australia was excluded from the comparison because rates in WA are substantially higher than elsewhere in Australia due to the large number of cases associated with asbestos mining and milling at Wittenoom.

Data sources

ACT Cancer Registry

The study used de-identified ACT Cancer Registry data supplied by ACT Health. The ACT Cancer Registry is a population-based registry that maintains a record of all cases of cancer (malignant neoplasm) diagnosed in ACT residents. Registry data date back to 1982 but reporting has been mandatory only since 1994, with all public and private pathology laboratories, hospitals and nursing homes in the ACT required by law to notify the ACT Cancer Registry of diagnoses of cancer.

The time from diagnosis of mesothelioma to registration is usually around three to five months, but can range from a few days to a few years,[2] thus some people who have been diagnosed with mesothelioma in the ACT before the end of 2014 may not have been registered at the time of extraction of data for this report (30 April 2015). Pathology laboratories generally send notifications to the ACT Cancer Registry on a weekly or fortnightly basis. Hospitals notify less often and notification frequency depends on the number of cancer patients they have. For example, Canberra Hospital provides an electronic

[2]When a person's death certificate is the only place where a diagnosis of mesothelioma is mentioned, it may take several years to identify and register them as being a case of mesothelioma. Such delays have been common in recent years because access to the national and state and territory cause of death unit record file has been delayed by data governance issues. The information from the cause of death unit record file enables registries to identify cases by cause of death (e.g. mesothelioma). However there were no diagnoses in the ACT Cancer Registry extraction (30 April 2015) made on the basis of death certificate only.

notification monthly, whereas a small private hospital may notify every three to six months. Data up to and including 2009 is considered finalised ACT Cancer Registry data, which includes notifications from hospitals, pathology laboratories and nursing homes, as well as any death-certificate-only cases (to 2007), notified from cause of death files. The data from 2010 to 2014 includes pathology reports received from pathology notifiers, which are fast tracked, and notifications from hospitals, which may be incomplete due to delays in reporting.[3]

The Registry contains a range of information including demographic characteristics of the patient at the time of diagnosis (age, sex and address), clinical details about the cancer and, if a person has died, date of death, which is provided to the ACT Cancer Registry by the ACT Register of Births, Deaths and Marriages each month (see Appendix Table 1 for details). Cancer type is coded according to the International Classifications of Diseases for Oncology, Third edition (ICD-O3), with morphology (pathology) codes used to extract the mesothelioma cases for this study.

Other data sources

Mesothelioma data for the rest of Australia (aggregated by age, sex and year) were sourced from the Australian Cancer Database, which is publicly available data from the Australian Institute of Health and Welfare website. [20] These data were available for 1982 to 2011.[4] We obtained WA mesothelioma data (1982–2011) by making a standard data request to the WA Cancer Registry (http://www.health.wa.gov.au/wacr/home). For calculation of rates (i.e. numbers of cases per 100,000 population), population counts by age, sex and year were obtained from Australian Bureau of Statistics published estimates. [24-26]

In addition, addresses of where people lived at the time of diagnosis (as recorded in the ACT Cancer Registry), were linked to the ACT Asbestos Response Taskforce register of ARPs to determine whether or not patients were residents of ARPs at the time of cancer diagnosis. This linkage was performed by ACT Health and only de-identified data from it were supplied to the researchers.

Study data

Cases

The study included all cases of mesothelioma diagnosed between 1 Jan 1982 and 31 December 2014 and that were recorded in the ACT Cancer Registry as of 30 April 2015.

[3]The information on reporting of cancer in the ACT was obtained through communications with the ACT Cancer Registry, Epidemiology Section, ACT Health Directorate.

[4]Note 34.3% and 34.7% of the total number of new cases of cancer in Australia for 2010 and 2011, respectively, are based on estimates made by the AIHW. This is because the 2010 and 2011 incidence data for NSW and the ACT were not available for inclusion in the 2011 version of the Australian Cancer Database. [20]

Variables

Variables in the analyses included: *sex* (male, female); *age group*, based on age at diagnosis (categorised as <25, 25–34, 35–44, 45–54, 55–64, 65–74, 75–84 and ≥85 years); and *period*, based on year of diagnosis (grouped into three-yearly intervals, from 1982–84 to 2012–2014). We also examined the distribution of cases by *area-level SES,* which was based on the Socio-Economic Indexes for Areas (SEIFA) Index of Relative Socioeconomic Disadvantage (IRSD) [27]; the score was derived from postcode of residence, and categorised into ACT-population-based tertiles using the most recent version of the SEIFA (2011). *Survival time* was calculated as the number of days between date of diagnosis and date of death (categorised as <1 year, 1–<2 years, 2–<5 years, and ≥5 years).

Analysis

Crude rates and proportions

For each three-year period, we calculated the number of mesothelioma cases, the total person-years of observation, and the crude mesothelioma incidence rate per 100,000 person-years with exact 95% confidence intervals (CIs);[5] we reported the crude rates separately for males and females, as well as for total persons. In addition, based on survival time, we calculated the proportion dying within 1, 2 and 2–5 years, and the proportion surviving ≥5 years; we restricted this analysis to those with at least 5 years of follow-up (i.e. diagnosed on or before April 30 2010).[6]

Modelling

We performed a series of Poisson regression analyses to estimate the relative rates (RR) of mesothelioma in relation to sex and period within the ACT, and to estimate the rates of mesothelioma in the ACT relative to those for the rest of Australia (excluding WA). We used an indirect standardisation approach to adjust for age and sex due to the small numbers of cases. Prior to the modelling procedure, we calculated the expected cases in the ACT for each year using the age- and sex-specific rates for Australia (excluding WA) as the standard. We then regressed observed cases on the factors of interest (sex, period) using a log link, with the log of expected cases as an offset.

First, to estimate the average change over time in rates in the ACT, the observed cases were regressed on period, with period modelled as a continuous variable. We also included sex as a separate term in the model to estimate the RR for males compared to females (Model 1). Period was also modelled as a categorical variable, with the Wald test used to assess the significance of period in the model (Model 2). For these models, the expected cases were calculated using the age- and sex-specific rates for Australia (excluding WA) in 2000–2002 as the standard. It should be noted that the models assume homogeneity across strata (age-

[5] See "Terminology used in this report" for more information on person-years and confidence intervals.

[6] Note that this is based on absolute survival time, which is not the same as *relative survival* (see "Terminology used in this report" for more information).

sex groups) of the ratios of rates in the different subgroups of the factors under study (sex and period) and in the reference population; [28] while this may be a reasonable assumption, there was insufficient power to test it.

Second, we compared mesothelioma rates in the ACT to those for the rest of Australia (excluding WA). To do this we undertook a similar analysis to the first model, but we used the age- and sex-specific rates for Australia (excluding WA) in a given period as the standard to generate the expected cases. We ran an intercept-only model to estimate the average RR for mesothelioma in the ACT compared to the rate for the rest of Australia (Model 3). We then compared trends over time in the ACT to those for the rest of Australia by regressing observed cases on period entered as a continuous variable (Model 4) and then as a categorical variable (Model 5).

The main analyses were undertaken using data for 1994 to 2011. We did this because reporting of cancer diagnoses was not mandatory in the ACT prior to 1994, and the 2012–2014 data were not yet finalised. We conducted a sensitivity analyses by re-running the models using data for 1994 to 2008, thus excluding data for 2009–2011, the period containing estimated data for NSW and possibly incomplete data for the ACT. We also performed supplementary analyses, re-running all models for the entire period for which Registry data were available (1982–2014); however, these results should be interpreted cautiously due to the ascertainment issues outlined earlier.

All models were tested for goodness of fit, using the Pearson chi-squared test. Where Poisson models fitted poorly (found to be the case only in the supplementary analyses), alternative count models, including negative binomial regression were considered. Model coefficients were exponentiated, with estimates reported as RRs (point estimates with 95% CIs). All analyses were performed using Stata version 14 (StataCorp).

Ethics and funding

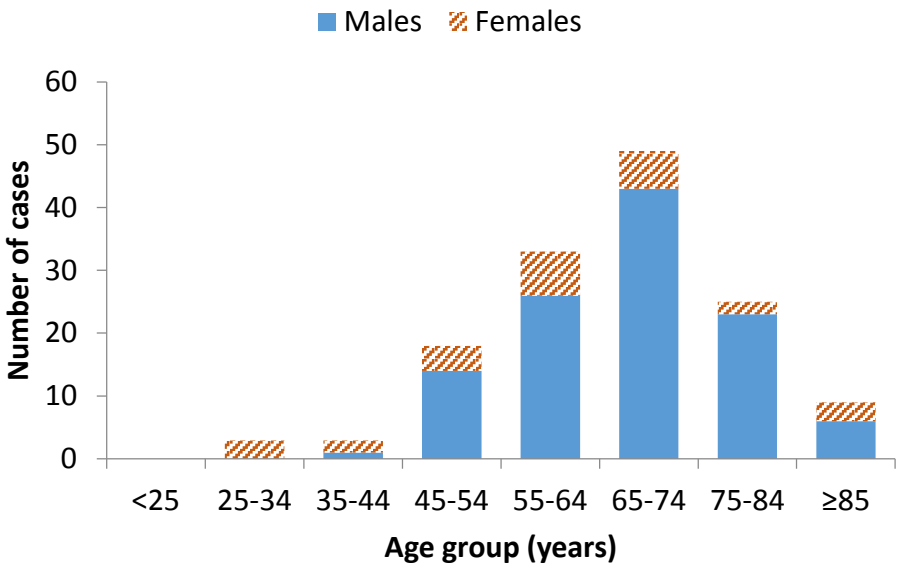
This project was approved by the ACT Health Human Research Ethics Committee (ETH.11.14.330,) and the ANU Human Research Ethics Committee (Protocol no. 2014/808). The ACT government provided funding for this study under the ACT Asbestos Health Study.

Results

Crude data

There were 140 mesothelioma cases reported to the ACT Cancer Registry between 1982 and 2014, 81% male (113 cases) and 19% female (27 cases) (Appendix Table 2). Around one-third of the cases (35%, 49 cases) were diagnosed at age 65–74 years, a quarter (24%, 33 cases) in those aged 55–64 years, with less than 5% (6 cases) diagnosed in people younger than 45, none in those aged <25 years (Figure 2). The cases were evenly distributed across tertiles of SES (data not shown). There was one case of mesothelioma diagnosed in a person recorded as being resident at an ARP at the time of diagnosis (in 2012–2014).

Figure 2. Number of mesothelioma cases in the ACT (1982–2014), by age group and sex



Crude mesothelioma rates are reported by period and sex in Table 3, with the periods where data are most likely to be complete—1994–1996 to 2009–2011—highlighted. Between 1994–1996 and 2009–2011, the number of cases and the crude incidence rates increased, from a total of 9 cases in 1994–1996, a rate of 0.98 (95% CI: 0.45–1.86) per 100,000 person-years, to 32 cases in 2009–2011, a rate of 2.95 (95% CI: 2.02–4.17) per 100,000 person-years. The rates increased in both males and females, but were substantially higher in males; in 2009–2011 the rates were 5.19 (95% CI: 3.45–7.51) per 100,000 person-years among males and 0.73 (95% CI: 0.20–1.88) per 100,000 person-years among females.

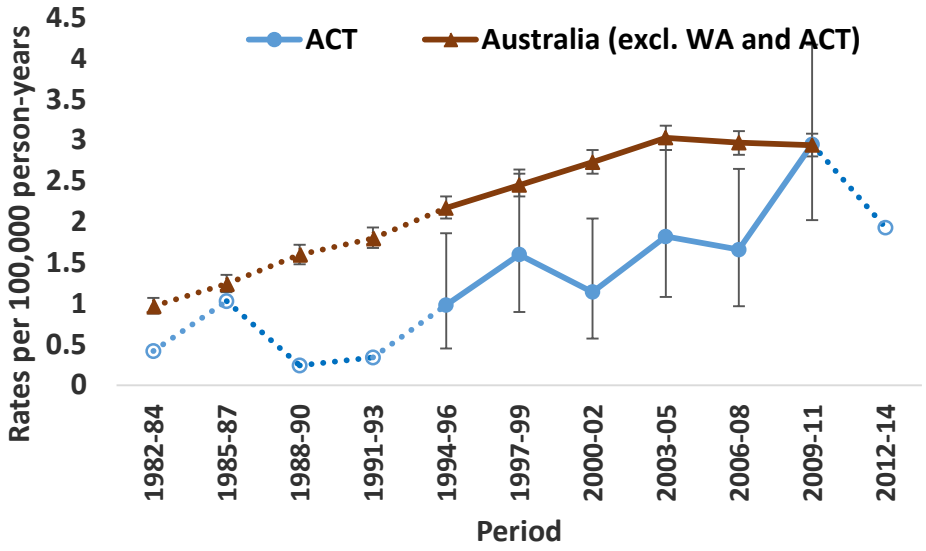
Table 3. Crude mesothelioma rates (per 100,000 person-years (PY)) by sex and period, ACT, 1982 to 2014

	Males			Females			Total persons		
Period	No	PY	Rate	No	PY	Rate	No	PY	Rate (95% CI)
1982–84	1	358,274	0.28	2	358,866	0.56	3	717,140	0.42 (0.09–1.22)
1985–87	3	387,892	0.77	5	387,884	1.29	8	775,776	1.03 (0.45–2.03)
1988–90	1	414,973	0.24	1	415,799	0.24	2	830,772	0.24 (0.03–0.87)
1991–93	3	441,282	0.68	0	442,678	0	3	883,960	0.34 (0.07–0.99)
1994–96	9	455,933	1.97	0	461,728	0	9	917,661	0.98 (0.45–1.86)
1997–99	12	464,086	2.59	3	472,150	0.64	15	936,236	1.60 (0.90–2.64)
2000–02	10	475,619	2.10	1	487,781	0.21	11	963,400	1.14 (0.57–2.04)
2003–05	16	487,887	3.28	2	499,809	0.40	18	987,696	1.82 (1.08–2.88)
2006–08	13	508,161	2.56	4	518,021	0.77	17	1,02,6182	1.66 (0.97–2.65)
2009–11	28	539,181	5.19	4	545,355	0.73	32	1,084,536	2.95 (2.02–4.17)
2012–14	17	568,003	2.99	5	574,196	0.87	22	1,142,199	1.93 (1.21–2.92)
Totals	**113**	**5,101,291**	**2.22**	**27**	**5,164,267**	**0.52**	**140**	**10,265,558**	**1.36 (1.15–1.61)**

Notes. 1. The periods in which data were most likely to be complete—between 1994–96 and 2009–11—are highlighted. 2. 95% CI = 95% confidence interval.

The crude incidence rates for the rest of Australia (excluding WA), also increased over the same period (Figure 3), with rates of 2.17 (95% CI: 2.04–2.31) per 100,000 person-years in 1994–1996 rising to an estimated 2.94 (95% CI: 2.80–3.08) per 100,000 person-years in 2009–2011. In 2009–2011 the rates were estimated to be 4.78 (95% CI: 4.53–5.03) per 100,000 person-years for males and 1.12 (95% CI: 1.00–1.25) per 100,000 person-years for females.

Figure 3. Crude rates of mesothelioma in the ACT and the rest of Australia (excluding WA) by period (with 95% confidence intervals), both sexes, 1982 to 2014



Note: Closed circles and solid lines indicate periods where data are most likely to be complete

Regarding survival, after excluding one case with an invalid date of death and all cases diagnosed after April 30, 2010 (i.e. those with less than five years of follow-up, n=40), almost half of those registered (44/99, 44%) had died within one year of diagnosis, with 17% (17/99) surviving five years or more (Table 4). However, it is recognised that not all deaths may have been captured at the time of data extraction, so survival may be over-estimated.

Table 4. Survival: Time between diagnosis and death among cases in the ACT Cancer Registry with at least 5 years of follow-up

Survival time	No	%	Cumulative %	
			Died	Survived
< 1 year	44	44.4	44.4	55.6
1-<2 years	27	27.3	71.7	28.3
2-<5 years	11	11.1	82.8	17.2
≥ 5 years	17	17.2		
Totals	99	100.0		

Model results

Between 1994 and 2011, mesothelioma rates in the ACT were 6.29 (95% CI: 3.58–11.05) times higher in males than females (Model 1, Table 5). Rates increased over time, on average by 12% per three-year period (RR= 1.12, 95% CI 0.99–1.26; Model 1, Table 5). However, the 95% confidence interval reflects considerable statistical uncertainty in this estimate. When period was modelled as a categorical variable (Model 2, Table 5), there was little consistent evidence that adjusted mesothelioma incidence in the ACT increased with time; incidence in 2009–2011, however, may have been higher than in earlier periods. When data for 2009–2011 were excluded from this analysis, the RR for sex changed little, but the RR for period fell to 1.02 (95% CI: 0.86–1.21) (see sensitivity analyses, Model 1, Appendix Table 4). The latter indicates strong dependence of the RR of 1.12 (Model 1, Table 5) on the higher rate of mesothelioma observed in 2009–2011. While this might indicate a recent increase in mesothelioma rates in the ACT, substantial period by period fluctuations in mesothelioma incidence in the ACT have been common and there may yet be a "correction" in 2012–2014 (Figure 3).

Mesothelioma rates were lower on average in the ACT than in the rest of Australia (excluding WA) between 1994 and 2011 (RR= 0.84; 95% CI: 0.69–1.02, Model 3, Table 5). However, the analysis comparing trends over time during this period provided evidence that incidence of mesothelioma increased at a 12% per three-year period higher rate in the ACT than it did in the rest of Australia (excluding WA) (RR=1.12, 95% CI 0.99–1.27, Model 4, Table 5). Again, it is important to note the statistical uncertainty in these results, as shown by the 95% confidence intervals. With data from 2009–2011 excluded from the analyses (see sensitivity analyses, Appendix Table 4), ACT rates were also on average lower than the rest of Australia (RR=0.73; 95% CI: 0.58–0.92). However, the RR for period was 1.00 (95% CI: 0.84–1.19), meaning there was no apparent difference in the change in rates over time between the ACT and the rest of Australia for the period from 1994 to 2008.

Results from analyses that included data for the entire period of Registry data (1982–2014), generally showed similar patterns to those of the main analyses, but with less statistical uncertainty due to increased power (see supplementary analyses, Appendix Table 4). However, these results need to be interpreted cautiously due to the data quality issues outlined earlier and the fact the models (Poisson as well as alternative count models) generally did not fit these data well. In particular, caution should be applied in interpreting the decrease in rates in the 2012–2014 period compared to the previous period, as it was unlikely that the registrations for 2012–2014 were complete.

Table 5. Main analyses: Poisson regression model results for mesothelioma incidence, 1994–2011

	RR[1]	95% CI
A. Comparisons within the ACT		
Model 1		
Period	1.12	0.99–1.26
Sex		
Females	1.00	
Males	6.29	3.58–11.05
Model 2		
Period[2]		
1994–96	1.07	0.44–2.58
1997–99	1.56	0.72–3.39
2000–02	1.00	
2003–05	1.47	0.70–3.12
2006–08	1.26	0.59–2.69
2009–11	2.17	1.09–4.30
B. Comparisons with the rest of Australia (excluding WA)		
Model 3		
Rest of Australia, excluding WA	1.00	
ACT (constant)	0.84	0.69–1.02
Model 4		
Period	1.12	0.99–1.27
Model 5		
Period[3]		
1994–96	1.18	0.49–2.84
1997–99	1.62	0.74–3.52
2000–02	1.00	
2003–05	1.42	0.67–3.00
2006–08	1.29	0.60–2.75
2009–11	2.32	1.17–4.59

Notes.

1. RR=relative rate
2. p-value for Wald test = 0.1745
3. p-value for Wald test = 0.1224

Discussion

Summary of the main findings

Rates of mesothelioma have increased over time in the ACT, but remain relatively low, with 2.95 per 100,000 people diagnosed with the disease each year in 2009–2011. Between 1982 and 2014, approximately one-third of mesothelioma cases were diagnosed in people aged 65–74 years, with less than 5% in those aged less than 45 years. There was one case identified from the ACT Cancer Registry where the person was living in a Mr Fluffy house at the time of diagnosis.

Taking into account demographic changes in the ACT, mesothelioma rates increased on average by 12% per three-year period between 1994 and 2011, with rates around six-fold higher in men than women. There is some evidence that rates increased more in the ACT than the rest of Australia between 1994 and 2011, although there is considerable uncertainty around the estimated 12% greater increase. Moreover, the greater increase in the ACT than in the rest of Australia (WA excluded) appeared confined to the period 2009–2011 when ACT rates became similar to those in the rest of Australia (excluding WA). While there was an apparent decrease in rates in the most recent period under study (2012–2014), it is not possible to reach a conclusion on this point because ACT cancer data are unlikely to be complete for this period.

Limitations of the study

There are several limitations that need to be borne in mind when interpreting the results of this study. Because of the small number of cases, there is considerable statistical uncertainty in the results. In particular, the study was underpowered to confidently estimate trends over time. The modelling procedure used to test trends over time in the ACT relied on assumptions of proportional rate ratios; while this may be a reasonable assumption to make, there was insufficient power to test it. The models used in the supplementary analyses (including data from 1982 to 2014) did not fit the data well. There may also be some bias due to possible under-ascertainment of cases. This would particularly relate to analyses that include data before 1994, the period before mandatory reporting; it may also affect results based on data from the most recent reporting periods, due to the time lag between diagnosis and registration. It is important to also note that the ACT Registry data do not include people with unconfirmed mesothelioma, nor cases involving former ACT residents who lived interstate at the time of their diagnosis; it may include people who only recently moved to the ACT. Similar issues also apply to the data for the rest of Australia. In addition, the data included in the Australian Cancer Database for the years 2010 and 2011 include both estimated (NSW and ACT) and actual (other states) cases.

Interpretation of results

The substantially higher rates of mesothelioma in men than women was expected, given the incidence is known to be higher in men, in Australia and internationally. [19, 20, 22] The magnitude of the increased risk for men in the ACT was similar to that reported for national

mesothelioma statistics. [20, 22] As elsewhere, this probably reflects the higher occupational exposure to asbestos among men, which is the predominant exposure type among those diagnosed with mesothelioma. [22]

That the rate of mesothelioma increased in the ACT over time, at least up to 2009–2011, is generally consistent with national and international trends. [18, 19, 21] Most countries have now banned asbestos products. Manufacture of asbestos products ceased in Australia in 1987 and the sale, use and manufacture of asbestos products have been banned since 2003. The trends in mesothelioma incidence generally reflect the widespread use of asbestos since the 1940s and the long lag time (20 to 50 years) expected between exposure and the development of mesothelioma. [2, 21] Given this lag, it will be important to assess mesothelioma rates in the ACT into the future.

While it is possible that the rates have increased more in the ACT than the rest of Australia (excluding WA), it is not at all certain that this is so and, if it is so, the increase may have all occurred in 2009–2011. Explaining this difference, if it exists, would be difficult to do with any certainty. Exposure to asbestos at ARPs is one of several possible explanations, which also include: other sources of non-occupational exposure to asbestos (e.g. in other buildings in which asbestos was used as an insulating material); occupational exposure to asbestos; and possible artefact due to change over time in the accuracy of medical diagnosis of mesothelioma and ascertainment of cases (which is likely to have changed between 1993 and 1994 at least).

That one person was identified as living in a Mr Fluffy house at the time of diagnosis may be significant. However, more information is needed about the time during which this person lived in an ARP and, even with that information, causation could be at most inferred, not established. Furthermore, there are likely to be people diagnosed with mesothelioma who lived in a Mr Fluffy house but who had moved by the time of the diagnosis, so the Register will not record these people as being in an ARP. The health risks associated with living in a Mr Fluffy house are the subject of further studies within the ACT Asbestos Health Study, which may provide more evidence regarding the relationship between ARPs and mesothelioma risk.

Terminology used in this report

Affected residential property (ARP): An ARP is a property in the ACT that was insulated with loose-fill asbestos insulation, between 1968 and 1979. As of July 2015, there were 1,022 ARPs registered with the Asbestos Response Taskforce. The number of ACT homes that had the insulation is thought to be around 1,100—this includes homes that had been demolished before the Taskforce list of ARPs was established or that were burnt in the bush fires in 2003.

Confidence interval (CI): Expresses the degree of statistical uncertainty in a result. The 95% confidence interval can be interpreted to mean that one can be 95% confident that the true value of the estimate lies within that interval (see also *point estimate*).

Incidence rate: The number of new cases of disease per head of population in a specified period of time. In this study, it is the number of new mesothelioma cases diagnosed per 100,000 population during one year (i.e. new cases per 100,000 person-years). A **crude rate** is the incidence rate, unadjusted for any other factors, such as age. An **age-adjusted rate** minimises the effects of differences in age composition in comparing rates for different populations (see also *standardisation*).

Indirect standardisation: Used to validly compare rates in two populations where, for example, the age-specific rates in the study population (in this study, the ACT) are not available or are based on small numbers of cases (as is in this study). The specific rates in the standard population (in this study, the age- and sex-specific rates for Australia excluding WA and the ACT) are applied to the study population (in this study, the ACT), to calculate an expected number of cases in the study population, with which the observed number is compared in a standardised incidence ratio (see also *standardisation* and *standardised incidence ratio*).

Mesothelioma case definition: A diagnosis of mesothelioma between 1 Jan 1982 and 31 Dec 2014 and recorded in the ACT Cancer Registry as of 30 April 2015.

Person-years (py): The product of the population size (p) and the number of years that the population is observed (y). For example, the py for 2009 = p in 2009 x 1. The py for 2009-2011 = (p in 2009 x 1) + (p in 2010 x 1) + (p in 2011) x 1).

Point estimate: A single value that is the "best estimate" of a population parameter (such as a crude rate or a relative rate in the population). It should be interpreted alongside the confidence interval (see also *confidence interval*).

Poisson regression: A statistical analysis method used to model incidence rates.

Relative rate (RR): The ratio of two rates.

Relative survival: A net survival measure representing cancer survival in the absence of other causes of death. Relative survival is defined as the ratio of the proportion of observed

survivors in a cohort of cancer patients to the proportion of expected survivors in a comparable set of cancer free individuals.

Standardisation: A set of techniques, based on weighted averaging, to remove as much as possible the effects of age, sex or other factors when comparing rates for two or more populations.

Standardised incidence ratio [SIR]: The ratio of the incident number of cases in the study population (in this study, the ACT) to the incident number that would be expected if the study population had the same specific incident rates as the standard population (in this study, the rest of Australia, excluding WA).

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Appendix tables

Appendix Table 1. ACT Cancer Registry Dictionary[1]

Variable	Description/Notes	Codes
Age at diagnosis (years)		
Sex		1 – Male 2 – Female
Country of Birth		Codes are according to the Standard Australian Classification of Countries (SACC) issued by the Australian Bureau of Statistics – see link below
AHS of residence at diagnosis	Area Health Service of residence at diagnosis	All records are Australian Capital Territory
Postcode of residence at diagnosis		4 digit Australia Post code with preceding zeros.
SSLA of residence at diagnosis	State and Statistical Local Area of residence at diagnosis	Codes are according to the Australian Standard Geographical Classification (ASGC) issued by the Australian Bureau of Statistics – see link below
Date of diagnosis	The month and year in which the diagnosis was made	MMYYYY
ICD Cancer type	The type of cancer according to the reporting categories for cancer	Coded using International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification (ICD-10-AM)
ICD-0-3 Topography Code	The site of the cancer	Coded according to the WHO International Classification of Diseases for Oncology (third edition) – see link below
ICD-0-3 Morphology Code	Morphology codes are only recorded for malignant neoplasms and insitu breast and melanoma cases	Coded according to the WHO International Classification of Diseases for Oncology (third edition) – see link below
Best Basis of Diagnosis		0 – Cytology including FNA, smears, washing, sputum 1 – Clinical/imaging/biochemical 2 – Histopathology performed 3 – Confirmed by post mortem (obsolete code) 4 – Found at post mortem 5 – Death certificate only 6 – Histopathology sighted at CCR

Variable	Description/Notes	Codes
Degree of spread		1 – Localised to tissue of origin 2 – Regional spread – adjacent organs and/or regional lymph nodes 3 – Distant metastases 9 – Unknown **OTHER** - Invalid data
Thickness of melanomas	Thickness of skin melanomas in mm	
Size of breast cancer	Size in mm	
Date of death	The month and year of death for persons diagnosed with cancer who have since died	MMYYYY
ICD-0-3 Cause of death	The cause of death according to the reporting categories for causes of death (for cancer deaths only)	Cancer deaths coded according to the WHO International Classification of Diseases for Oncology (third edition) – see link below.

Useful links:

Country of birth: http://www.abs.gov.au/ausstats/abs@.nsf/mf/1269.0

State and Statistical Local Area: http://www.abs.gov.au/ausstats/abs@.nsf/mf/1216.0

WHO International Classification of Diseases for Oncology: http://www.who.int/classifications/icd/adaptations/oncology/en/

[1]Table adapted from table in "ACT Cancer Registry [ACT Government, Health Directorate]"; available at <http://www.cherel.org.au/data-dictionaries>

Appendix Table 2. Crude data: number of mesothelioma cases and person-years (PY) by sex, age group and year, ACT, 1982 to 2014

	Age group (years)																	
	<25		25–34		35–44		45–54		55–64		65–74		75–84		≥85		TOTAL	
Period	Cases	PY	Cases	PY	Cases	PY	Cases	PY	Cases	PY	Cases	PY	Cases	PY	Cases	PY	Cases	PY
MALES																		
1982–84	0	166,054	0	66,099	0	56,106	0	33,352	1	23,152	0	9,994	0	3,052	0	465	1	358,274
1985–87	0	173,774	0	69,130	0	65,368	1	37,591	1	25,463	1	12,015	0	3,956	0	595	3	387,892
1988–90	0	179,870	0	73,187	0	71,614	0	43,321	0	26,727	1	14,586	0	4,867	0	801	1	414,973
1991–93	0	188,165	0	75,114	0	73,476	0	52,105	2	28,069	1	17,259	0	6,095	0	999	3	441,282
1994–96	0	187,124	0	76,160	1	73,069	1	60,600	4	30,974	2	19,401	1	7,269	0	1,336	9	455,933
1997–99	0	180,956	0	76,369	0	73,140	3	66,480	0	35,200	7	20,824	1	9,445	1	1,672	12	464,086
2000–02	0	178,500	0	77,138	0	73,388	5	68,814	2	41,421	2	22,478	1	11,700	0	2,180	10	475,619
2003–05	0	179,560	0	78,781	0	73,414	2	67,765	4	48,154	7	24,063	3	13,431	0	2,719	16	487,887
2006–08	0	182,603	0	82,503	0	75,892	2	68,954	2	53,352	4	26,668	5	14,464	0	3,725	13	508,161
2009–11	0	190,974	0	90,488	0	79,376	0	70,637	8	57,030	13	30,717	6	15,319	1	4,640	28	539,181
2012–14	0	195,280	0	98,654	0	83,693	0	72,631	2	58,327	5	36,730	6	17,025	4	5,663	17	568,003
Subtotals	**0**	**2,002,860**	**0**	**863,623**	**1**	**798,536**	**14**	**642,250**	**26**	**427,869**	**43**	**234,735**	**23**	**106,623**	**6**	**24,795**	**113**	**5,101,291**
FEMALES																		
1982–84	0	161,288	1	68,876	1	54,858	0	31,043	0	23,435	0	12,589	0	5,305	0	1,472	2	358,866
1985–87	0	169,346	1	70,589	0	64,672	2	35,101	0	25,013	2	14,774	0	6,558	0	1,831	5	387,884
1988–90	0	175,943	0	73,450	0	72,075	0	41,243	0	25,451	0	17,523	1	7,986	0	2,128	1	415,799
1991–93	0	181,805	0	76,213	0	75,333	0	49,773	0	27,067	0	20,251	0	9,694	0	2,542	0	442,678
1994–96	0	180,934	0	77,526	0	76,912	0	59,530	0	29,985	0	22,195	0	11,438	0	3,208	0	461,728
1997–99	0	173,586	0	78,281	0	77,035	0	67,771	0	34,405	2	23,009	0	14,036	1	4,027	3	472,150
2000–02	0	172,678	0	78,372	0	77,386	0	72,282	1	41,153	0	24,181	0	16,462	0	5,267	1	487,781
2003–05	0	172,626	0	79,207	0	76,370	1	72,673	1	48,844	0	25,898	0	18,035	0	6,156	2	499,809
2006–08	0	174,432	0	82,431	0	77,562	1	73,403	0	55,254	1	28,822	0	18,771	2	7,346	4	518,021
2009–11	0	180,931	0	88,966	1	80,428	0	74,342	3	59,457	0	32,802	0	19,514	0	8,915	4	545,355
2012–14	0	185,262	1	97,696	0	83,631	0	75,363	2	61,675	1	39,339	1	20,889	0	10,341	5	574,196
Subtotals	**0**	**1,928,831**	**3**	**871,607**	**2**	**816,262**	**4**	**652,524**	**7**	**431,739**	**6**	**261,383**	**2**	**148,688**	**3**	**53,233**	**27**	**5,164,267**
Totals	**0**	**3,931,691**	**3**	**1,735,230**	**3**	**1,614,798**	**18**	**1,294,774**	**33**	**859,608**	**49**	**496,118**	**25**	**255,311**	**9**	**78,028**	**140**	**10,265,558**

Notes.

1. Data source for cases: ACT Cancer Registry, April 2015. Data for the periods before 1994 may not be complete given reporting was not mandatory until 1994; cases may also be missing after 1993, particularly in 2012–2014, due to lags between diagnosis and reporting. Periods where data are most likely to be complete—between 1994–96 and 2009–11—are highlighted.
2. For definition of person-years, refer to “Terminology used in this report”.

Appendix Table 3. Results of indirect standardisation: Observed and expected cases for the ACT by period, and associated standardised incidence ratios (SIR), using age-sex specific rates for the rest of Australia (excluding WA) as the standard

Period	Observed	Expected	SIR (95% CI)
A. Standard = Australia (excluding WA) in 2000-2002			
1982–84	3	8.54	0.35 (0.07–1.02)
1985–87	8	9.97	0.80 (0.34–1.58)
1988–90	2	11.48	0.17 (0.02–0.63)
1991–93	3	13.24	0.23 (0.04–0.66)
1994–96	9	15.07	0.60 (0.27–1.13)
1997–99	15	17.20	0.87 (0.48–1.43)
2000–02	11	19.66	0.56 (0.27–1.00)
2003–05	18	21.84	0.82 (0.48–1.30)
2006–08	17	24.07	0.71 (0.41–1.13)
2009–11	32	26.40	1.21 (0.82–1.71)
2012–14	22	29.35	0.75 (0.46–1.13)
B. Standard = Australia (excluding WA) in each period			
1982–84	3	4.37	0.69 (0.14–2.01)
1985–87	8	6.10	1.31 (0.56–2.58)
1988–90	2	8.37	0.24 (0.02–0.86)
1991–93	3	10.63	0.28 (0.05–0.82)
1994–96	9	13.65	0.66 (0.30–1.25)
1997–99	15	16.60	0.90 (0.50–1.49)
2000–02	11	19.66	0.56 (0.27–1.00)
2003–05	18	22.69	0.79 (0.47–1.25)
2006–08	17	23.62	0.72 (0.41–1.15)
2009–11	32	24.70	1.30 (0.88–1.82)

Notes.

1. In part A, the expected cases are calculated using the age- and sex-specific rates for Australia (excluding WA) in 2000–2002 as the standard—these are used in Models 1 and 2.
2. In part B, the expected cases are calculated using the age- and sex-specific rates for Australia (excluding WA) in each period as the standard—these are used in Models 3, 4 and 5.
3. Data for 2012–14 are not available for Australia so expected cases cannot be estimated in part B.

Appendix Table 4. Poisson regression model results: main, sensitivity and supplementary analyses

	Main (data: 1994–2011)		Sensitivity (data: 1994–2008)		Supplementary (data: 1982–2014)	
	RR	**95% CI**	**RR**	**95% CI**	**RR**	**95% CI**
A. Comparisons within the ACT						
Model 1						
Period	1.12	0.99–1.26	1.02	0.86–1.21	1.09	1.03–1.16
Sex						
Females	1.00	—	1.00		1.00	—
Males	6.29	3.58–11.05	6.00	3.07–11.72	4.19	2.75–6.37
Model 2						
Period	—	—	—	—		
1982–84	—	—	—	—	0.63	0.18–2.25
1985–87	—	—	—	—	1.43	0.58–3.57
1988–90	—	—	—	—	0.31	0.07–1.40
1991–93	—	—	—	—	0.40	0.11–1.45
1994–96	1.07	0.44–2.58	1.07	0.44–2.58	1.07	0.44–2.58
1997–99	1.56	0.72–3.39	1.56	0.72–3.39	1.56	0.72–3.39
2000–02	1.00	—	1.00	—	1.00	—
2003–05	1.47	0.70–3.12	1.47	0.70–3.12	1.47	0.70–3.12
2006–08	1.26	0.59–2.69	1.26	0.59–2.69	1.26	0.59–2.69
2009–11	2.17	1.09–4.30			2.17	1.09–4.30
2012–14					1.34	0.65–2.76
p-value for Wald test	0.1745		0.7548		.0343	
B. Comparisons with the rest of Australia (excluding WA)						
Model 3						
Rest of Aus., excluding WA	1.00	—	1.00	—	1.00	—
ACT (constant)	0.84	0.69–1.02	0.73	0.58–0.92	0.78	0.66-0.94
Model 4						
Period	1.12	0.99–1.27	1.00	0.84–1.19	1.09	1.01-1.17
Model 5						
Period						
1982–84	—	—	—	—	1.23	0.34–4.40
1985–87	—	—	—	—	2.34	0.94–5.83
1988–90	—	—	—	—	0.43	0.09–1.93
1991–93	—	—	—	—	0.50	0.14–1.81
1994–96	1.18	0.49–2.84	1.18	0.49–2.84	1.18	0.49–2.84
1997–99	1.62	0.74–3.52	1.62	0.74–3.52	1.62	0.74–3.52
2000–02	1.00	—	1.00	—	1.00	—
2003–05	1.42	0.67–3.00	1.42	0.67–3.00	1.42	0.67–3.00
2006–08	1.29	0.60–2.75	1.29	0.60–2.75	1.29	0.60–2.75
2009–11	2.32	1.17–4.59	2.32	1.17–4.59	2.32	1.17–4.59
p-value for Wald test	0.1224		0.1224		.0441	

Notes. 1. RR=relative rate. 2. Main analysis results are as reported in Table 5 of main text.