Contrasting temporal trends in lung cancer incidence by socioeconomic status among women in New South Wales, Australia, 1985-2009

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Abstract

Objective We examined long-term trends in lung cancer incidence for women by socioeconomic groups in New South Wales (NSW), Australia.

Methods Data on lung cancer incidence for women were extracted from the NSW Cancer Registry database. We divided the study cohort into five quintiles according to an area-based index of education and occupation (IEO) and calculated annual age-standardised incidence rates by IEO quintile for the period 1985-2009. The age-standardised incidence ratio (SIR) was estimated for IEO quintiles and 5-year period of diagnosis using the highest IEO quintile as the reference.

Results Overall, lung cancer incidence for women aged 25-69 years increased gradually from 19.8 per 100,000 in 1985 to 25.7 per 100,000 in 2009. The trends by IEO quintile were somewhat comparable from 1985 through to 1995, but from then on rates remained relatively stable for women residing in the highest quintile while increasing for women residing in the remaining four quintiles. Consequently, the SIR for all four of the lower IEO quintiles increased significantly over the 25-year period. For example, the SIR in the lowest IEO quintile increased from 1.16 (95% CI, 0.99-1.37) during 1985-1989 to 1.70 (95% CI, 1.50-1.93) during 2005-2009. The corresponding estimates for women aged 70 years or older showed no clear pattern of socioeconomic gradient.

Conclusion The increasing gap in lung cancer incidence between women in the highest socioeconomic group and all others suggests that there is a continued need for the broad implementation of tobacco control interventions, so that smoking prevalence is reduced across all segments of the population and the subsequent benefits are shared more equitably across all demographic groups.

Keywords: lung cancer, tobacco smoking, tobacco control, socioeconomic inequality, temporal trends, Australia

1. Introduction

Lung cancer is the leading cause of cancer death in Australia by a significant margin and has the fifth highest incidence [1]. Both the overall incidence of, and mortality from, lung cancer have declined in Australia over the last three decades [1], mainly due to the decrease in smoking prevalence [2] that has resulted from the implementation of successful tobacco control policies in Australia [3]. This observed reduction in lung cancer incidence is not, however, consistent across the whole population. In particular, while the incidence of lung cancer for Australian men has been declining since the mid-1980s, over the same period an upward trend in incidence was observed for Australian women [4, 5]. The upward trend for women is thought to reflect a later relative increase in smoking prevalence (which peaked at 33% in 1976 compared with 72% for men in 1945) and the time lag associated with lung cancer diagnosis [2]. Whether this increasing pattern in lung cancer incidence among Australian women is uniform across socioeconomic groups is unknown.

It is well known that there is a strong relationship between lung cancer incidence and tobacco use, with lung cancer trends closely mirroring generational trends in smoking prevalence [4, 5]. Research in Australia has shown that a social gradient exists in smoking prevalence and lung cancer rates, with an inverse relationship between socioeconomic status and smoking or lung cancer rates, meaning that lung cancer incidence tends to be higher for lower socioeconomic groups within a population [2]. International evidence has also shown that lung cancer incidence is associated with socioeconomic status based on education, occupation or income, with people of lower socioeconomic status having elevated rates of lung cancer [6]. While there have been previous Australian studies which have confirmed the pattern of lung cancer incidence tending to be higher in populations of lower socioeconomic status [4, 7], these estimates were based on only short periods of time (1987-1991 [7] and 2003-2007 [4]), and provided only a relative measure of socioeconomic inequality, comparing the rate for the highest socioeconomic group (top 20%) to that for the lowest socioeconomic group (bottom 20%). Our aim in this study was to build on this previous research by using data from a longer period of time and by using both relative and absolute measures of differences in lung cancer incidence.

Monitoring trends in lung cancer incidence rates by socioeconomic position is important for the development and promotion of evidence-based tobacco control policies. The aim of this study was to investigate lung cancer incidence rates across socioeconomic groups for New South Wales (NSW) women over the period 1985 to 2009 using data from a long-standing Australian population-based cancer registry and two measures of inequality.

2. Methods

2.1. Data

Incidence data for women with first primary lung cancer (ICD-O3: C33-C34) [8] for the period 1972-2009 were available from the NSW Cancer Registry. Notification of cancer has been a statutory requirement for all NSW public and private hospitals, radiotherapy departments and nursing homes since 1972, and for pathology departments since 1985 [9]. The Registry generally has high standards of data completeness and quality, and the data are accepted by the International Agency for Research on Cancer for publication in Cancer Incidence in Five Continents (Volumes IV to X) [10]. The proportion of death certificate only (DCO) cases, an indicator of the quality of a cancer registry, is generally low (1.0% for 1993-1997 [11] and 0.9% for 2004-2008 [12]). While data are available from 1972 we chose to only use data from 1985 onwards because prior to 1985, when reporting by pathology laboratories became compulsory, the proportion of histologically verified cases was lower (47.9% in 1973 and 76.8% in 1984).

Cases diagnosed before the age of 25 were excluded, as diagnoses of lung cancer are rare in younger people. Cases diagnosed after age 69 years were also excluded from the primary analysis because socioeconomic inequality tends to diminish in relative terms for older age groups [13-15], and social gradients in health are generally less consistent for the older population than those for population groups of working age [13]. To define the upper bound of the age range for the primary analysis in this study we tried three alternative age thresholds, 65, 70, and 75 years, and found that the resulting patterns of socioeconomic variation were similar for the three age thresholds. We therefore used data for cases in the age range of 25 to 69 in the primary analysis for this study, and performed further analysis of the trends for those aged 70 years or older to also provide some insight into patterns across the whole age spectrum.

Lung cancer histological types were classified as previously defined by Lewis and colleagues [16] for small cell carcinoma, adenocarcinoma, and squamous cell carcinoma. Data for large cell lung cancer, however, were not separated into a unique histological type but instead were grouped with other specified/not otherwise specified carcinoma, as the incidence rates were low and there is some inconsistency in the classification of large cell carcinoma [4, 16].

Socioeconomic characteristics are not routinely collected by the Registry, so for this study we used an area-based “Index of Education and Occupation” (IEO) [17], derived from the 2001 Australian Bureau of Statistic’s Census of Population and Housing. The index has been extensively reviewed and validated using nine different methods and has been found to be highly correlated with the Index of Advantage/Disadvantage, which measures both socioeconomic advantage and disadvantage [17]. The IEO has been used as a socioeconomic measure in numerous previous studies of health outcomes in Australia [18-21]. A high score on this index indicates that the area has a larger proportion of residents with higher education qualifications and who are employed in higher skilled occupations compared to an area with a lower score. Cases were grouped into five quintiles based on their residential address (Local Government Area (LGA)) at the time of diagnosis, with quintile 1 being the group with the highest IEO scores and quintile 5 the lowest IEO scores.

The scores on this index are re-calculated every five years, and the ranking of an area may change across censuses. We used the index score based on the 2001 census data because it is difficult to match the population denominators exactly with the new cancer cases (numerators) because of LGA boundary changes (due to splits or amalgamations) over time. The Australian Bureau of Statistics' estimated mid-year NSW resident populations (for women) for the LGAs (collapsed into IEO quintiles) by 5 year age groups for 1985-2009 were used as population denominators.

2.2. Statistical analyses

Using the 2001 Australian standard population, annual age-standardised incidence rates (per 100,000) were calculated for the period 1985 to 2009, using direct standardisation, for the whole population and by IEO quintile.

We then divided the data into five 5-year periods, from 1985-1989 to 2005-2009, and calculated the age-standardised incidence ratio (SIR) stratified by period for each of the four lower IEO quintiles, using the highest IEO quintile as the reference group. This was done using the indirect method by dividing the observed number of lung cancer cases by the expected number in a specific IEO quintile. The expected numbers of new cases were determined based on the age-specific rates for the highest IEO quintile and the age distributions for each of the other four IEO quintiles. As the population in each IEO quintile (for which the SIR was calculated) is independent of that in the highest IEO quintile, the confidence intervals for the SIR were obtained using the exact method assuming a beta distribution, as described by Silcocks [22], which allows for error in the expected numbers and assumes no covariance between the observed and expected numbers.

To test whether there was a significant change over time in the variation in lung cancer incidence by IEO quintiles, a Poisson regression model was fitted with age groups, IEO quintile (one linear term) and period of diagnosis (one linear term). Significance of the association between IEO quintile and period of diagnosis was tested by adding to the model an interaction term between IEO quintile and period and then performing a likelihood ratio test for the nested models, with a *P*-value < 0.05 indicating statistical significance.

To further illustrate the impact of variation in lung cancer incidence between IEO quintiles, we calculated the “excess” numbers of lung cancers diagnosed as being the difference between the observed and expected numbers of cases for IEO quintiles 2-5. A chi-square test was then used to determine if the proportions of the observed cases considered to be “excess” were significantly different over time.

As the association between socioeconomic groups and incidence of lung cancer may be affected by changes in histological types that have occurred over time, we repeated the primary analysis stratified by major histological types. A Poisson regression model was fitted with age groups, IEO quintile, period of diagnosis, and histological types. Significance of the association between IEO quintile and period of diagnosis was determined by a likelihood ratio test as previously described.

3. Results

Between 1985 and 2009 there were 9,840 women aged 25-69 diagnosed with first primary lung cancer in NSW, Australia. Annual age-standardised incidence rates in NSW for the period 1985-2009 are presented in Figure 1 for women aged 25-69 years and 70 years or older separately. For women aged 25-69 years, the overall incidence rates increased gradually over the 25 year period. Trends by IEO quintile (Figure 1) were more or less comparable between 1985 and 1995 although there were some fluctuations due to small numbers, and started diverging after 1999. Overall, the patterns in trends were mixed, with rates relatively stable for the highest IEO quintile (quintile 1) while increasing for the remaining four quintiles. This pattern is supported by the results from the indirect standardisation, shown in Figure 2, which used aggregated 5-year data rather than annual data. The corresponding estimates for women aged 70 years or older showed inconsistent patterns of variation by socioeconomic groups over time. Compared to the incidence rate for all cases aged 70 or older, the lowest quintile had lower or average rates until 2002, while the highest quintile had more or less average rates in the first 15 years (1985-1999), but then from 2001 to 2009 had lower rates than the other quintiles.

The age-standardised incidence ratios for lung cancer by period of diagnosis and IEO quintile in women aged 25-69 years are shown in Figure 2. The variation by IEO quintile was somewhat unclear in 1985-1989, although higher SIRs were seen for IEO quintiles 2-5 compared with IEO quintile 1 (p=0.02). From 1990-1994, however, the pattern started becoming clearer, with women in IEO quintiles 2-5 having a higher risk of lung cancer (p=0.0001). Overall, the gap in lung cancer incidence across IEO quintiles increased significantly (p=0.003 for the interaction term) over time. For each histological type, the variation in incidence by socioeconomic groups seems to be becoming wider over time (Figure 3). The interaction term for IEO quintile and period of diagnosis remained significant (p=0.0007) after considering the effect of histology type. The association was less pronounced for the incidence of adenocarcinoma than for the other histological types.

Table 1 shows the “excess” numbers of lung cancers diagnosed (the difference between the observed and expected numbers of cases for IEO quintiles 2-5) over five time periods (1985-2009) in NSW women aged 25-69 years, if incidence rates across the whole population were equivalent to that of the highest IEO quintile (which makes up 20% of the whole population). Both the total numbers of new cases and the number of “excess” cases diagnosed increased over time, and the proportion of “excess” cases increased significantly (p<0.001) from 8.0% in 1985-1989 to 30.3% in 2005-2009. This indicates that in the most recent period, “excess” cases of lung cancer made up over 30% of all lung cancers diagnosed among women aged 25-69 years. If we extrapolate this proportion to the national population, there were 2709 “excess” lung cancer cases diagnosed among Australian women aged 25-69 years during 2005-2009, which is equivalent to more than 540 cases per year.

4. Discussion

This study is, to our knowledge, the first to show that while there has been an overall increase in lung cancer incidence for women (aged 25-69 years) resident in NSW over the past 25 years, this increase is not apparent across all socioeconomic groups. Although the overall lung cancer incidence rate has increased by about 30% in relative terms since 1985, the highest socioeconomic quintile (top 20% of the population) showed a relatively stable trend over time. An increase in incidence was observed among those women living in areas of lower socioeconomic status, with the highest increase (55%) seen for the lowest ranked socioeconomic quintile. As a result, socioeconomic inequalities in lung cancer among women in NSW increased significantly over time in both relative and absolute terms.

These findings are generally consistent with the few previous studies that have examined risk of lung cancer by socioeconomic groups in Australia [4, 7]. Smith et al (1996) found a clear gradient in the association between lung cancer and socioeconomic status, with significantly higher rates among women living in lower socioeconomic urban areas in NSW during the period 1987-1991 [7]. A more recent publication also reported that the incidence rates of lung cancer decreased with increasing socioeconomic status in Australia, with women in the lowest socioeconomic quintile being 1.2 times more likely to be diagnosed with lung cancer than their counterparts in the highest socioeconomic quintile during the period 2003-2007 [4]. Our study builds on these previous results by examining long-term trends by socioeconomic groups to show that over the last 25 years an increase in lung cancer incidence was observed for women in all socioeconomic groups except those in the highest 20%, for whom rates decreased.

The observed socioeconomic inequalities in lung cancer incidence probably largely reflect the historical and continued differences in tobacco smoking behaviours across socioeconomic population groups [23]. In an analysis of data on tobacco smoking in Victoria, Australia, Germain et al found that over the period 1984-2008 smoking prevalence was consistently higher for those living in areas of lower socioeconomic status [24], which almost certainly led to higher lung cancer incidence. More importantly, the gap between groups became significantly wider, as the highest socioeconomic status group had a greater decrease in smoking prevalence (59%) than that observed in areas of lower socioeconomic status (50%) [24]. More recent data also indicate that this socioeconomic inequality in smoking prevalence has continued [25]. National data showed that over the period 1998-2013 there was a significant linear decline in regular smoking within each education group among women, but the magnitude of the decrease was higher among those with tertiary qualifications (from 17% to 7%) than those who did not complete senior high school (from 27% to 17%) [25]. Furthermore, among the younger population (18-39 years old), those who did not complete senior high school were significantly more likely to become regular smokers [25] and were less likely to quit smoking [26] than those with higher levels of education. Differences in smoking prevalence between education levels have therefore become increasingly pronounced with time [25], thus it is likely that socioeconomic inequalities in lung cancer incidence for women will continue for some time [27].

Passive exposure to tobacco smoke is another important risk factor for lung cancer, especially for women [28], and previous Australian research has found that those from lower socioeconomic groups are at higher risk of being exposed to environmental tobacco smoke [29]. Other factors that may also contribute to the differences in lung cancer incidence by socioeconomic group include occupational exposure (to asbestos, radon and ionising radiation) [28] and environmental exposures [30]. However, the contributions from these factors is likely to be small, as the vast majority of lung cancer cases are attributable to personal and passive tobacco smoking [4, 31].

Our study also looked at the incidence of the various histological types of lung cancer and their associations with socioeconomic status, with the results confirming those from many previous studies [32-34]. We observed a less pronounced association between the incidence of adenocarcinoma and IEO quintile than for the other histological types (Figure 3). This is likely to be because adenocarcinoma is less strongly linked to tobacco smoking history than the other histological types of lung cancer [35, 36]. This, combined with the data showing that people living in areas of lower socioeconomic status consistently have higher smoking rates [24, 25], provides further evidence that associations between lung cancer incidence and socioeconomic status are likely to be the result of different patterns in smoking behaviours.

While it is possible that our finding of a widening socioeconomic inequality in lung cancer from 1985 to 2009 is caused by the way inequality is measured, we believe our methods ensure that this is unlikely. Following the advice from Harper et al [32] that multiple measures are needed to provide a clear picture of health disparity, in this study we used two complementary measures of disparity, one absolute (difference) and the other relative (ratio). While the relative measure is the preferred measure in epidemiology because it provides an estimate of the magnitude of the effect [37], the absolute measure indicates the magnitude of the problem, and quantifies the public health significance of the problem [33]. We found that both measures estimated the effect in the same direction. The overall consistency of these results suggests that our findings are reliable.

The use of aggregated area-level data to classify individual cases according to socioeconomic status is a potential limitation of this study. However several international studies have demonstrated the value of using area-based socioeconomic measures in evaluating health inequalities [21, 35, 36], and evidence from Australia has indicated that such area-based measures may in fact be of more use than individual level measures in studies of inequality in smoking related health outcomes, as it has been shown that the interventions and policies that influence neighbourhood characteristics are closely related to the prevalence of smoking in that area [38]. Additionally, we allocated each case to the IEO quintile based on the 2001 census due to the difficulty in matching the population data with cancer cases caused by the LGA boundary changes over time as mentioned in the Methods section, although some LGAs may have moved to another quintile between 1986 and 2006. However, supportive evidence from previous studies showed that socioeconomic inequalities in lung cancer have been found in Australia in all other census periods between 1985 and 2009, which were all in line with our findings of significant variation by socioeconomic group in all periods between 1985-1989 and 2005-2009 (1986 [39], 1991 [7], 1996 [39], 2006 [4]). Furthermore, the observed association between lung cancer incidence and socioeconomic status might have been biased if the data used were not valid and consistent over time. However, the two important data quality measures from the Cancer Registry indicate that the data used are of high quality, with a low proportion of DCO cases and a high proportion of histologically confirmed cases. Finally, variation in the detection of lung cancer between population groups may have biased our results, although a recent systematic review of socioeconomic inequalities in lung cancer suggests that this is unlikely [40] and the only Australian study [41] included in the review found no significant differences in lung cancer detection by socioeconomic groups. That our data showed that the proportion of DCO cases is very similar across socioeconomic groups further supports this.

Identifying socioeconomic inequalities in lung cancer and describing the possible reasons for them is only the first step. The substantial socioeconomic differences in lung cancer incidence that we observed suggests that while Australia has had successful and sustained tobacco control policies in place since the early 1970s, these may not be equally effective across all population groups [42]. The reasons for this are likely to be highly complex, however previous research has indicated that those living in higher socioeconomic areas may be more responsive to public health campaigns, more likely to use effective resources for quitting smoking and to have more restrictive home/work environments in terms of smoking [43]. While effective tobacco control interventions [24] explained the majority of the overall decrease in smoking prevalence in Australia [44], the effects of recently implemented tobacco control interventions, price increases (first, 25% in 2010, then 12.5% annually from 2013 to 2016) and plain packaging (introduced in 2012), will not yet be reflected in the lung cancer incidence observed in this study. However, we do expect that these interventions, and the additional planned increases in the cost of tobacco [45], are likely to result in a reversal of the long-term increasing trend in lung cancer incidence at the population level in the near future. In addition to reducing smoking prevalence for the whole population, with broad application these effective interventions also have the potential to reduce socioeconomic disparities in smoking prevalence [2, 46, 47], and thus may lead to a reduction in lung cancer inequalities in the future.

Using population-based lung cancer incidence data for the period 1985-2009 for women aged 25-69 years residing in NSW, we found that lung cancer incidence rates are widening in both relative and absolute terms between women in the highest socioeconomic group and all others. This underscores a continued need for broad implementation of tobacco control interventions so that the benefits of a reduction in smoking prevalence are shared more equitably across all demographic groups. Our findings could inform future research and tobacco control policies targeting persons with low socioeconomic status in Australia.

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Ethical approval: This study involves analysis of routinely collected data and the records were de-identified (name, address, date of birth had been removed) before being provided to the research team. For this type of study formal consent is not required. The NSW

Population and Health Services Research Ethics Committee approved the use of the data from the NSW Cancer Registry (reference number: 2009/03/139).

Conflict of interest: The authors declare that they have no conflicts of interest.

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Table 1 Number of "excess" lung cancer cases diagnosed for women aged 25-69 years during 1985-2009 in NSW, Australia

Period of diagnosis	Number diagnosed in NSW	"Excess" number in NSW*	Proportion "excess" (%)	Number diagnosed Australia[&]	"Excess" number in Australia
1985-1989	1553	124	8.0	4829	387
1990-1994	1672	236	14.1	5499	777
1995-1999	1860	290	15.6	6031	942
2000-2004	2095	417	19.9	6966	1387
2005-2009	2660	807	30.3	8933	2709

* If rates for all population groups were equivalent to that for the highest IEO quintile (20% of the whole population).
[&] Data source: Australian Cancer Incidence and Mortality (ACIM) books from http://www.aihw.gov.au/acim-books/ accessed 10 November 2015.

$p<0.001$ from χ^2 test of no change in the proportion of "excess" cases over time.

Figure captions

Figure 1 Annual age-standardised* incidence rate for lung cancer for women by age group (25-69 years, 70 years or older), and by IEO** quintile in NSW, Australia 1985-2009

* standardised to 2001 Australian standard population.

** IEO stands for Index of Education and Occupation.

Figure 2 Age-standardised incidence ratio (SIR) for lung cancer by IEO* quintile in NSW women aged 25-69 years, 1985-2009

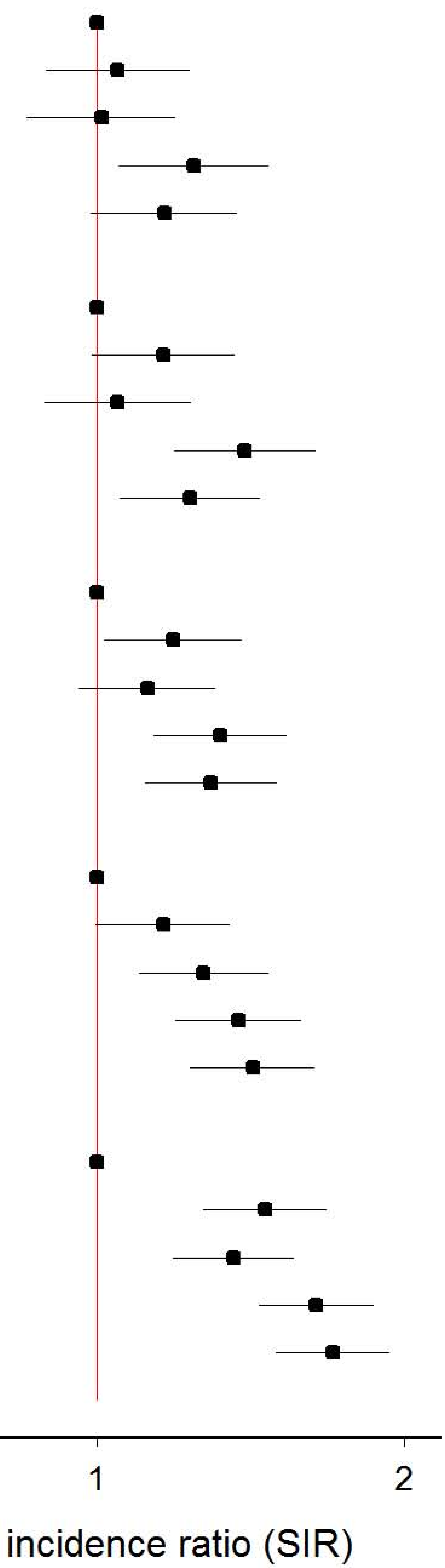
* IEO stands for Index of Education and Occupation.

Figure 3 Age-standardised incidence ratio (SIR) for lung cancer by histological type and IEO* quintile in NSW women aged 25-69 years, 1985-2009

* IEO stands for Index of Education and Occupation.

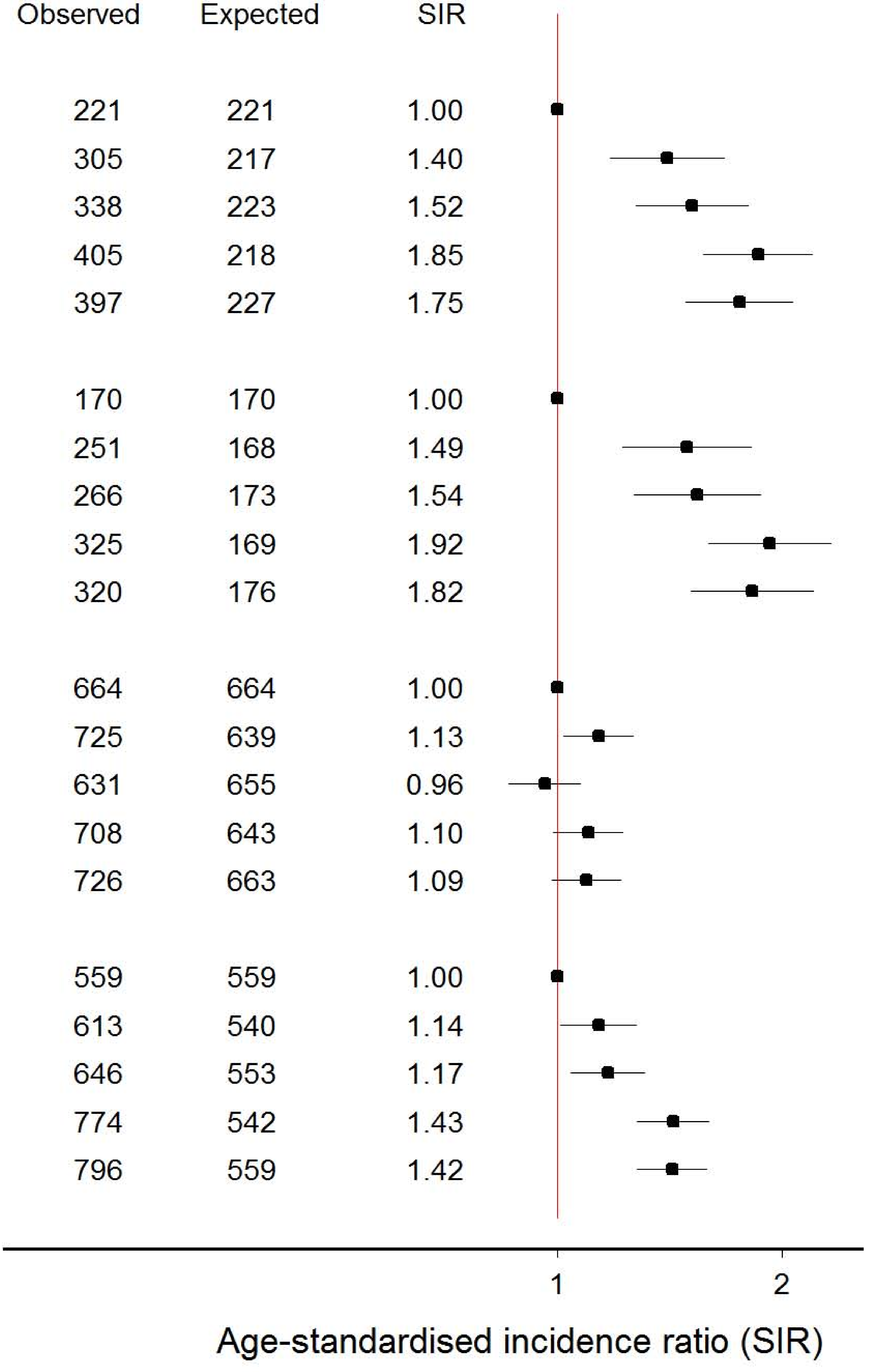
Aged 25-69 years
Aged 70 years or older
Rate per 100000
0
10
20
30
40
0
40
80
120
160
1985
1989
1993
1997
2001
2005
2009
Year
All
Highest IEO quintile
2nd quintile
3rd quintile
4th quintile
Lowest IEO quintile

	Number of cases: Observed	Number of cases: Expected	SIR
1985-1989			
Highest IEO quintile	312	312	1.00
2nd quintile	312	298	1.05
3rd quintile	290	287	1.01
4th quintile	317	255	1.24
Lowest IEO quintile	322	277	1.16
1990-1994			
Highest IEO quintile	293	293	1.00
2nd quintile	335	289	1.16
3rd quintile	304	290	1.05
4th quintile	382	274	1.40
Lowest IEO quintile	358	290	1.23
1995-1999			
Highest IEO quintile	310	310	1.00
2nd quintile	364	306	1.19
3rd quintile	355	317	1.12
4th quintile	412	312	1.32
Lowest IEO quintile	419	324	1.29
2000-2004			
Highest IEO quintile	332	332	1.00
2nd quintile	373	321	1.16
3rd quintile	427	336	1.27
4th quintile	472	343	1.38
Lowest IEO quintile	491	346	1.42
2005-2009			
Highest IEO quintile	367	367	1.00
2nd quintile	510	349	1.46
3rd quintile	505	371	1.36
4th quintile	629	384	1.64
Lowest IEO quintile	649	382	1.70



p-value=0.003 for interaction between IEO quintile and period

	Number of cases Observed	Expected	SIR
Small cell carcinoma			
Highest IEO quintile	221	221	1.00
2nd quintile	305	217	1.40
3rd quintile	338	223	1.52
4th quintile	405	218	1.85
Lowest IEO quintile	397	227	1.75
Squamous cell carcinoma			
Highest IEO quintile	170	170	1.00
2nd quintile	251	168	1.49
3rd quintile	266	173	1.54
4th quintile	325	169	1.92
Lowest IEO quintile	320	176	1.82
Adenocarcinoma			
Highest IEO quintile	664	664	1.00
2nd quintile	725	639	1.13
3rd quintile	631	655	0.96
4th quintile	708	643	1.10
Lowest IEO quintile	726	663	1.09
Other types			
Highest IEO quintile	559	559	1.00
2nd quintile	613	540	1.14
3rd quintile	646	553	1.17
4th quintile	774	542	1.43
Lowest IEO quintile	796	559	1.42



p-value=0.0001 for interaction between IEO quintile and histological subtype