

# Lung cancer trend in England for the period of 2002 to 2011 and projections of future burden until 2020

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**Abstract.** Lung cancer is the most common cancer in the world, therefore creating a huge public health concern. The aim of this study is to determine the change in age-standardised incidence rate trend of lung cancer in England between 2002 and 2011 and use these findings to anticipate the potential burden of the disease by gender in the year 2020. Lung cancer incidence data (ICD-10 code C33-34) from 2002 and 2011 and mid-year population estimates for the same period were obtained from Office of National Statistics. Age-standardised incidence rates were calculated, by gender and region. Poisson regression analysis was used to describe the time incidence trend and projections were estimated up to year 2020. A total of 318,417 lung cancer cases were identified. Incidence rates decreased in men by an average annual percentage change (AAPC) of -1.0% and increased in women by +1.9%. Projection analysis showed that by year 2020, provided the rates remain the same, English women will have the same lung cancer incidence rates as their male counterparts. This study demonstrated that there would be 5,848 excess lung cancer cases by 2020 with female population accounting for 85% (4,996) of the excess cases. Therefore, in addition to the development of high quality preventive intervention strategies, future public health also needs to prioritise targets at the implementation phase, in a manner that engage women living in regions that have demonstrated very high AAPC values.

## Introduction

Despite decades of research and robust cancer preventive strategies, lung cancer remained the most common cancer since 1985 with a recorded 1.8 million new cases in 2012 (1). It has a

poor 5-year survival rate and is the commonest cause of cancer related mortality worldwide accounting for 1.6 million deaths annually, which is an estimate of one-in-five deaths from all cancers (2). In the United Kingdom (UK), 43,463 individuals (13% of all cancer cases) were diagnosed with lung cancer in 2011 and 35,371 lung cancer deaths (22% of all cancer deaths) were reported in 2012 (3). Five percent of adult lung cancer patients (4% of men and 7% of women) diagnosed in 2010-2011 in England and Wales are predicted to survive ten or more years (3).

Although the risk factors for lung cancer are multifactorial, tobacco smoking is still primarily responsible for the development of the disease (4,5). Throughout history, socioeconomic status has been identified to contribute to health disparities. Health behaviors such as smoking, lack of exercise and poor diet partly explain socioeconomic disparity in health (6). Socioeconomic gradient in lung cancer reflects differences in health behavior and exposure to occupational and environmental carcinogens, and air pollution among the various socioeconomic groups (7). The patterns in lung cancer incidence are influenced by exposure many years before diagnosis, which is unfortunately higher in socioeconomic deprived geographical areas (8).

Rising trends in lung cancer incidence have been observed internationally and also within the UK (9). Conducting periodic trend analysis has been found to be invaluable because studying historical data provides insights into the disease pattern, which is expedient for projection and future resource planning. The aim of this study is to present an analysis of incidence of lung cancer trends in England over the period 2002-2011, as well as project rates up to year 2020. In addition, we compared trends in comparable countries in the world.

## Methods and methods

Lung cancer cases were defined, according to the tenth revision of the International Classification of Diseases (ICD-10), by code C33-34. In the UK, it is obligatory for the National Health Service (NHS) to provide agreed core cancer registration dataset to regional cancer registries. New cancer registrations from the National Cancer Registration Service are submitted to the Office of National Statistics (ONS) for validation and data processing (for England and Wales), and are later compiled into the National Cancer Data Repository (10).

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Table I. Distribution of lung cancer cases by gender, age group, and region from 2002 to 2011.

Characteristics	Lung cancer cases (%) n=318,417	DASR	AAPC (%)
Gender			
Male	182,628 (57.4)	63.3	-1.0
Female	135,789 (42.6)	41.6	+1.9
All	318,417 (100)	52.5	+0.5
Male:Female	1.34:1 (134:100)	1.5:1 (3:2)	
Age group			
0-59	44,339 (13.9)	10.6	-0.5
60-69	81,606 (25.6)	164.3	+0.9
70-79	112,493 (35.3)	322.7	-0.3
80+	79,979 (25.1)	384.8	+2.6
Males			
0-59	24,296 (13.3)	11.8	-1.4
60-69	48,329 (26.5)	202.2	-1.5
70-79	66,362 (36.3)	412.2	-1.3
80+	43,641 (23.9)	532.3	+0.5
Females			
0-59	20,043 (14.8)	9.4	+0.4
60-69	33,277 (24.5)	126.5	+3.3
70-79	46,131 (34.0)	233.2	+0.6
80+	36,338 (26.8)	237.2	+4.8
Average incidence per year			
Male (range)	18,300 (18,056-19,200)		+0.3
Female (range)	13,600 (11,992-15,700)		+3.0

DASR, directly age standardised rate; AAPC, average annual percentage change.

Information on new lung cancer registration and age-specific incidence data for this study were obtained from the cancer registration series published yearly by ONS. The ONS database records incidence by age band, region, gender, and ICD codes. Lung cancer incidences are reported as age-standardised per 100,000 population, allowing for better comparisons between groups in the study. Mid-year population estimates were used to calculate annual incidence rates for each calendar year of study. All cases with ICD C33-34 in England between 2002 and 2011 were included.

We also obtained age-standardised incidence data for 10 other countries from Europe, North America, Australia and Asia (Japan) from their respective cancer repositories. The selection of European countries to this study was purely based on population size and accessibility to validated data. Lung cancer incidence data for Russia, Italy, Spain, Poland and France were obtained from EUREG registry data from European Cancer Observatory (ECO) and for Germany, from the German Centre for Cancer Registry Data (ZfKD). Incidence data outside Europe were obtained for Australia, from the Australian Institute of Health and Welfare; for Canada, from Public Health Agency of Canada (Canada); for

Japan, from National Cancer Centre (Japan); and for USA, from National Cancer Institute (USA).

*Statistical methods.* Trends between groups were compared using age-standardised incidence rates. Cases were categorised into four age groups (0-59, 60-69, 70-79, and 80+) and nine English regions including London. Poisson regression models were used to examine time trends in the overall incidence of lung cancer and by age category, region of residence and gender in England between 2002 and 2011. The average annual percentage change (AAPC) was used to estimate the rate of change of incidence during the study period. AAPC is a useful tool in epidemiology because of its ability to summarise trend transitions within each grouped data and allow the use of a single value to describe the trend (11). Overall AAPC by gender was calculated for England, which was ranked against AAPC from the 10 countries mentioned above, in order to compare lung cancer trend in England with that seen elsewhere.

Age-standardised rates over the ten-year period were fitted into a mathematical model and the year variable extended by nine years to 2020. Model choice was largely based on whether the overall trend is decreasing or increasing (12) and the best

Table II. Ten-year regional statistics by gender.

Gender	England	North East	North West	Yorkshire and Humber	East Midlands	West Midlands	East of England	London	South East	South West
<b>Regional DASR</b>										
Males	63.3	87.1	77.4	73.6	64.5	64.2	56.4	56.7	53.0	55.7
Females	41.6	64.2	55.1	51.1	40.4	37.9	34.8	36.2	34.1	34.7
Overall	52.5	75.7	66.3	62.4	52.5	51.1	45.6	46.5	43.6	45.2
<b>New cases</b>										
Males	182,628	12,878	30,089	21,363	16,462	19,855	18,671	20,267	25,420	17,623
Females	135,789	10,919	24,572	16,938	11,374	13,146	13,027	14,932	18,529	12,352
Total	318,417	23,797	54,661	38,301	27,836	33,001	31,698	35,199	43,949	29,975
Percent	100	7.5	17.2	12.0	8.7	10.4	10.0	11.1	13.8	9.4
<b>Regional AAPC</b>										
Males	-0.7	-2.1	+0.4	-0.8	+0.6	-0.9	-0.8	-2.1	-0.8	+0.5
Females	+2.3	+2.3	+2.3	+2.5	+2.8	+1.6	+3.3	+1.1	+2.0	+4.1
Overall	+0.8	+0.1	+1.4	+0.9	+1.7	+0.4	+1.3	-0.5	+0.6	+2.3
DASR, Directly Age Standardised Rate; AAPC, Average Annual Percentage Change.										

fitting and biologically plausible models were used for both male and female incidence projection. Three models for lung cancer incidence were developed using three separate datasets: incidence (new registrations) data covering a forty-year period (1972-2011), twenty-year (1992-2011) age-standardised incidence rate data and, England projected population structure data (2012-2020). The first model (model 1) was developed using data from ONS new lung cancer registration collected over a forty-year period (1971-2011). The second model (model 2) highlighted the impact of the impending ageing population structure on future lung cancer incidence, since 9 out of 10 lung cancer cases are in 60+ age group and 4 in 10 cases in 75+ (13). Model 3 was developed to demonstrate the prospects of implementing a comprehensive tobacco control programme similar to the widely lauded California Tobacco Programme across the country. Such control programmes have the potential of reducing lung cancer incidence by ~14% over ten-year period (14). Furthermore, stratified analyses were conducted for men and women in order to explore gender differences in lung cancer trends. Analyses were considered to be statistically significant at p-value <0.05. Poisson regression was carried out using SAS 9.3 (SAS Institute, Cary, NC) but all other analyses were performed using Stata 13.1 (Stata Corp, College Station, TX, USA).

## Results

A total of 318,417 lung cancer cases were extracted from ONS during the study period and more males were diagnosed with lung cancer (57.4%) than females (42.6%). Lung cancer age-standardised rates were also higher in men than in women in all age groups and the overall rate ratio between male and female was 3:2, respectively (Table I).

As expected, rates increased directly with increasing age and the greatest percentage change was seen in the 80+ group (+2.6%). Although the bulk of the cases seen in the 10-year study were observed in the 70-79 age-group, a total of 35.3% of all cases, this age group showed a remarkable decrease in AAPC by -0.3%. Regionally, London was the only region that showed a decrease in overall trend in the last ten years (Table II), which mirrors England's smoking prevalence data showing the region to have the lowest prevalence of smoking (15), as well as the largest percentage decrease in smoking prevalence between 2002 and 2011 (Table III).

Analysis showed significant decline in age-standardised rates of lung cancer in males in all age groups, from 2002 to 2011 with an AAPC of -1.0%. In contrast, the age-standardised rates of lung cancer in females increased steadily in all age groups over the same period with an overall AAPC of +1.9% (Table I and Fig. 1). The greatest change seen in women was an increase of +4.8% in the 80+ age group followed by those in 60-69 age group with an AAPC of +3.3% (Table I). Overall, lung cancer trend increased by +0.5% in England and our projections to 2020 revealed that incidence rates in men would continue to fall from the current 57.2 per 100,000 to 39.8 per 100,000 in 2020 whilst rates in women will increase from the current value of 38.7 to 40.3 per 100,000 using a very modest model ( $R^2=0.69$ ) (Fig. 2). Actually, the best fitting model ( $R^2=0.91$ ) predicted age-standardised rate of 50.5 per 100,000 in women by 2020.

Table III. Prevalence of Smoking in England in numbers and average annual percentage change (AAPC) in bracket from 2002-2011.

Region	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Overall AAPC
North East	27 (-6.9)	28 (3.7)	29 (3.6)	29 (0.0)	25 (13.8)	22 (12.0)	21 (-4.5)	22 (4.8)	21 (-4.5)	21 (-4.8)	-2.8
North West	28 (-3.4)	30 (7.1)	28 (-6.7)	24 (14.3)	25 (4.2)	23 (8.0)	23 (0.0)	23 (0.0)	22 (-4.3)	22 (-4.5)	-3.0
Yorkshire and Humber	27 (-6.9)	25 (7.4)	28 (12.0)	25 (10.7)	23 (-8.0)	22 (-4.3)	25 (13.6)	22 (12.0)	23 (4.5)	23 (-8.7)	-2.3
East Midlands	24 (14.3)	27 (12.)	27 (0.0)	25 (-7.4)	20 (20.0)	19 (-5.0)	20 (5.3)	19 (-5.0)	16 (15.8)	16 (18.0)	-2.2
West Midlands	23 (-4.2)	25 (8.7)	23 (-8.0)	22 (-4.3)	22 (0.0)	23 (4.5)	20 (13.0)	22 (10.0)	21 (4.5)	21 (-4.8)	-2.8
East of England	25 (-3.8)	24 (0.0)	24 (-4.0)	23 (-4.2)	19 (17.4)	18 (-5.3)	19 (5.6)	19 (0.0)	19 (0.0)	19 (0.0)	-2.1
London	24 (11.1)	24 (0.0)	22 (-8.3)	22 (0.0)	21 (-4.5)	19 (-9.5)	19 (0.0)	22 (15.8)	17 (22.7)	17 (-5.9)	-4.9
South East	26 (8.3)	24 (7.7)	22 (-8.3)	22 (0.0)	20 (-9.1)	19 (-5.0)	20 (5.3)	19 (-5.0)	19 (0.0)	19 (0.0)	-1.8
South West	25 (4.2)	25 (4.0)	23 (-4.2)	25 (8.7)	23 (-8.0)	21 (-8.7)	21 (0.0)	18 (-14.3)	17 (-5.6)	17 (5.9)	-2.4

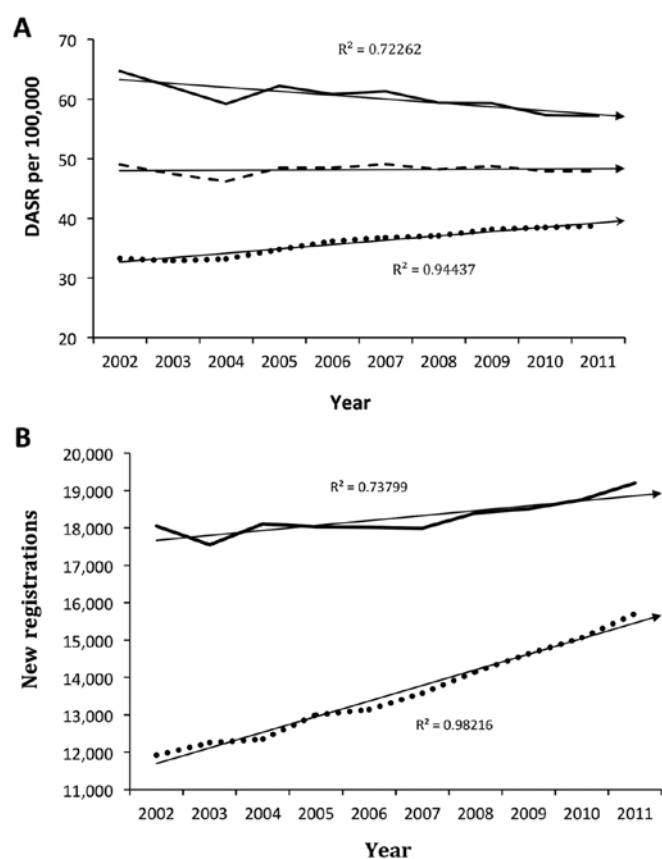


Figure 1. Trend of DASR (Directly Age-Standardised Rate) and New Registrations between 2002 and 2011. (A) Lung cancer trend using Age Standardise Rate (ASR) per 100,000. (B) Trend of new lung cancer registrations per year between 2002-2011. Solid line, trend in males; dotted lines, trend in females; dash lines, combined male and female trend.

While the decrease in lung cancer rates in men is consistent throughout this study, the lung cancer burden, defined as the total number of new registration per year, is nevertheless on the increase by an average of +0.3% per year in males; and by 3.0% per year in females. This higher rate of increase in females is responsible for narrowing the existing incidence gap between males and females, from a difference of 6,000 new registrations between men and women in 2002 to about

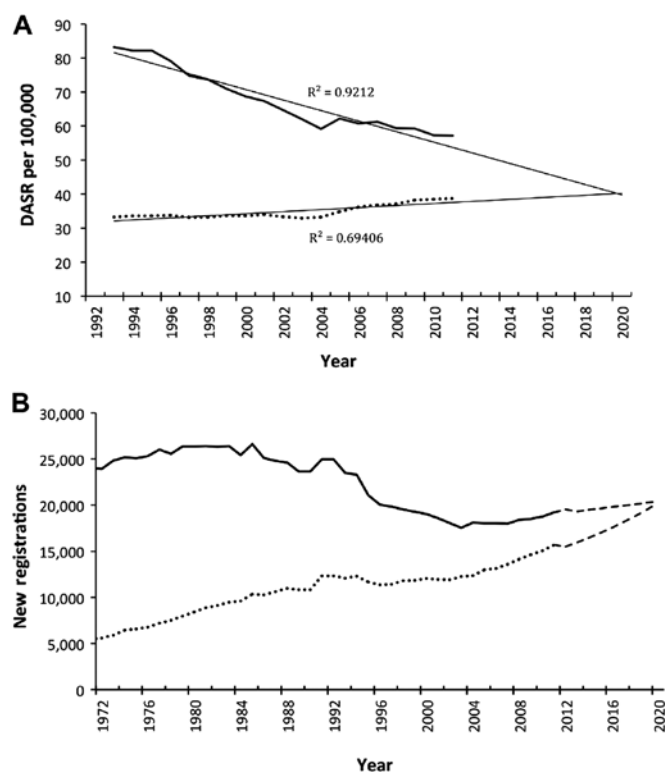


Figure 2. Projections of Lung Cancer DASR (Directly Age-Standardised Rate) and New Registrations by 2020 in England. (A) Twenty-year lung cancer DASR trend from 1992-2011 and projections to 2020. (B) Forty-year new lung cancer registrations trend between 1972-2011 and projections to 2020. Solid line, trend in males; dotted lines, trend in females; dash lines, projected registrations between 2012 and 2020.

3,500 in 2011 (Fig. 1). Historically this gap was wider by about 18,000 back in 1972 (Fig. 2). Our projections, which incorporated the impact of expected population structure in England (model 2), showed that this existing gap between men and women would cease to exist by 2020 and women will then begin to have higher number of new lung cancer registrations per year subsequently (Fig. 3).

We also observed that although the North West recorded the largest number of new cases over the 10 years in both males and females (30,089 and 24,572 new cases, respectively), the

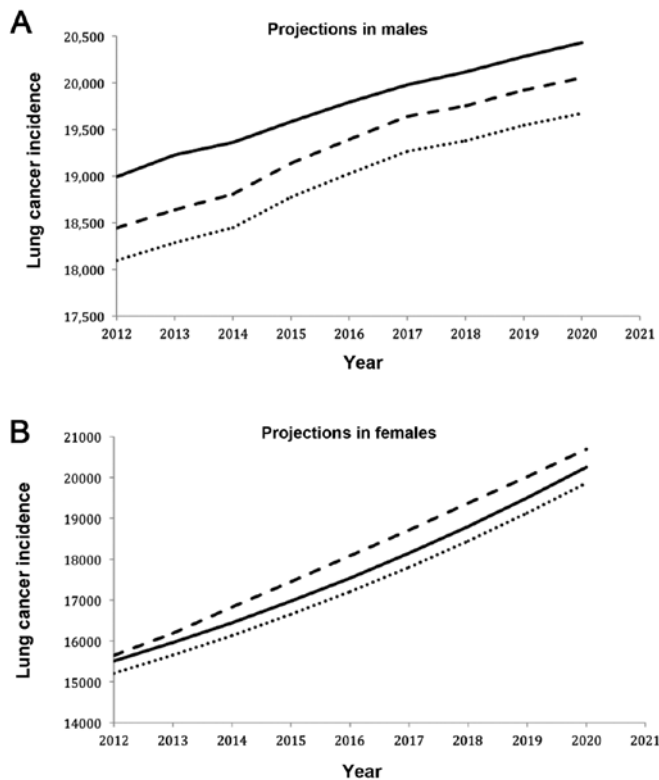


Figure 3. Projected lung cancer burden by gender. (A) Projected lung cancer in males. (B) Projected lung cancer in females. Model 1 (solid line), projections from historical lung cancer incidence (burden) per year; model 2 (dash lines) developed from projected rate and impact of ageing; model 3 (dotted lines) model demonstrating impact of comprehensive Tobacco Control Programme across the country.

North East region had the highest incidence rates in both males and females (87.1 and 64.2, respectively) (Table II). Rates varied differently in all the regions over the last 10 years, with a decrease in AAPC seen in men in all the regions except in East Midlands (+0.6%), South West (+0.5%) and North West (+0.4%). North East and London regions both have AAPC that is less than the England average (AAPC) for men. Regional trends in females varied between +1.1 and +4.1%, indicating an increase in female lung cancer incidence trend in all regions in England from 2002 to 2011. South West region had the highest rate of growth in female lung cancer incidence with an AAPC of +4.1 and London had the least (+1.1). The overall DASR (Directly Age-Standardised Rate) ratio between England worst (North East) and England best (South East) region is 1.7.

Further regional analyses showed London to have significantly lower than England average trend in both men and women (Fig. 4), which could be attributed to the low smoking prevalence in that region. London currently has the lowest prevalence of smoking (15) and their smoking data also showed the largest regional percentage decrease (-4.9%) in smoking prevalence between 2002 and 2011. London was the only region that demonstrated an overall trend (AAPC) decrease in lung cancer in the last ten years (Table II). Finally, analysis of lung cancer data from other countries revealed that Japan had the largest increase over the 10-year study in males (+1.6%) and France (+8.0%) in females. The largest decrease in men was seen in Italy (-4.6%) and Russian Federation in women (-1.3%) (Fig. 5).

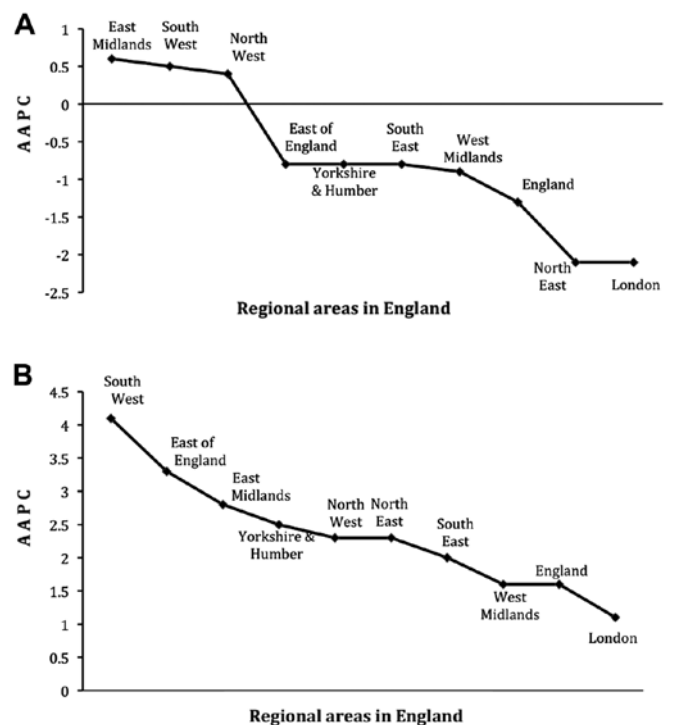


Figure 4. Ten-year regional lung cancer trend in England. (A) Ten-year AAPC (average annual percentage change) by England regions in males. (B) Ten-year AAPC by England regions in females.

## Discussion

This study showed that overall lung cancer incidence in England increased per year by an average of +0.4% between 2002 and 2011. Historically, men have always had higher lung cancer incidence rates than women across the country, with an incidence ratio as high as 6:1 documented between males and female, respectively in 1950s (16). However, the gender gap is closing due to decreasing rates in men and increasing rates in women, in spite of the decreasing prevalence of smoking. The current overall male to female incidence ratio demonstrated in this study was 3:2, but our projections showed the rate ratio will be 1:1 by 2020.

The overall trend in women increased by an average of +1.9, which seemed rather modest, but subgroup analysis revealed that some age-groups had AAPC values as high as +4.7 (80+) and +3.3 (60-69) during the period of study (Table I). If 9 out of 10 lung cancer cases occur at age of 60+ (13), understanding the increasing rate in women over 60 becomes very vital because it would lead to a significant lung cancer burden with an increasing ageing population in England. The projected models in Fig. 3 showed an impending lung cancer burden in England especially in women. For instance, if the current incidence rate is not halted, as describes by model 2, there would be 5,848 excess lung cancer cases in 2020 (when compared with the 2011 figures), with the female population accounting for 85.4% (4,996) of the excess cases. We also demonstrated that in spite of the projected decrease in incidence rates in men, there would still be an excess of 852 lung cancer cases by 2020, mainly caused by the projected increase in male population over 60+.

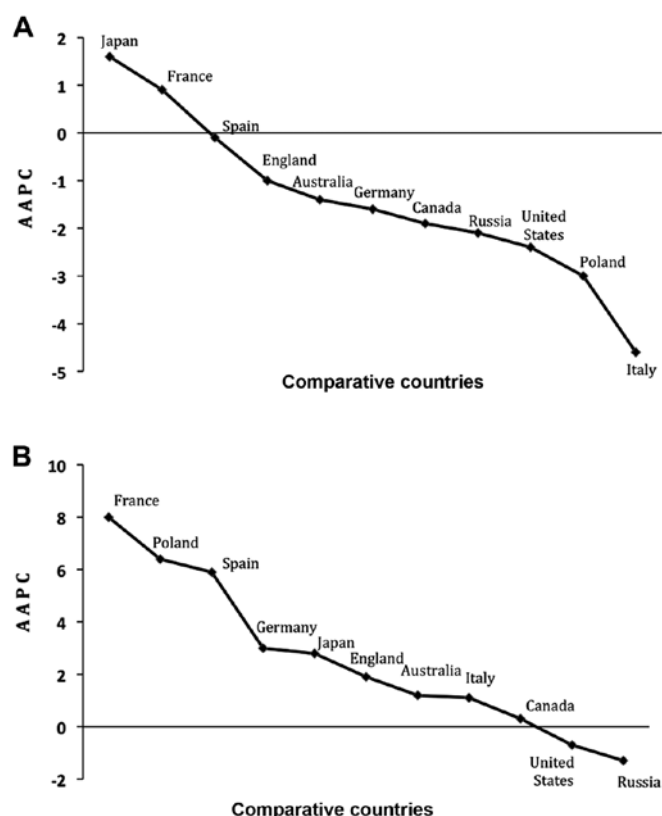


Figure 5. International lung cancer trend by gender. (A) Ten-year AAPC by country in males. (B) Ten-year AAPC (average annual percentage change) by country in females.

Implementing a comprehensive tobacco control that is based on the six policies identified by the World Bank has the potential of reducing incidence. An example is the California Tobacco Control programme which utilised these policies and saw a 61% decrease per capita cigarette consumption compared to just 41% across USA, during the same time period (1989-90 and 2006-07). Within 10 years (1988-1997), California recorded a decrease in lung cancer incidence by 1.9% per year ( $p < 0.01$ ). The overall incidence rate decreased by 14.0% in California and by 2.7% in non-California regions during the 10-year period (14). Our model 3 provides picture of lung cancer if a similar tobacco control programme was implemented across England, with the potential of reducing lung cancer incidence (new registrations) in males by 371 cases per year and in females by 340 cases per year. Effective tobacco control will reduce incidence by an overall 6,400 cases (3,340 in men and 3,060 in women) over the projected 9-year period.

Throughout this study, we saw a statistically significant trend increase in women partly explained by the steady rise in female smoking prevalence after the Second World War through to the early 1980s when smoking prevalence realistically started to decline (17,18). Smoking is the most significant risk factor in the development of lung cancer (19,20) and the presence of lag time between exposure to smoking and onset of lung cancer of ~20-35 years is why we are still experience a steady rate increase in women (21).

However, recent studies showed that smoking alone cannot account for the relatively high AAPC currently seen in

females (22). These studies identified genetic factors that make women more susceptible to developing lung cancer, smoking patterns in women involving deeper inhalation and effects of oestrogen on tumor metabolism (23,24), all contribute to the increasing trend in women. Zang and Wynder described the relative risk of developing lung cancer in women to be ~1.5-fold higher than in men, despite men having greater number of cigarette pack-years (25).

We also established that regional inequalities still exists across England with higher incidence rates seen in the northern parts of the country and lower rates in the south creating a North-South divide (Table II and Fig. 6). For more than half a century, the northern part of England is known for its high deprivation, unemployment and higher smoking prevalence (26,27) and Quinn *et al* showed that in the most deprived region in England, lung cancer incidence was 2.5 and 3.0 times those in affluent areas in both males and females, respectively (20). Trends in males decreased across all the regions except in East-Midlands (+0.6), South-West (+0.5) and North-West (+0.4) regions. While trend increased in females in all the regions, South-West (+4.1), East of England (+3.3) and East-Midlands (+2.8) were the top 3 hotspots for female trend in England. The ratio between England worst region (North East) and England best region (South East) is 1.6 and 1.9 in both males and females, respectively (Table II).

Finally, benchmarking England data against 10 different countries was necessary to evaluate the impact of existing lung cancer preventive measures in England. Overall, trend seen in these countries is similar to that observed in England with only a few exceptions. For instance, all countries demonstrated a decreasing trend in men except in Japan where the trend is on the increase (+1.6). Similarly, the trend in women is on the increase in all the countries except in Russia and the USA where incidence decreased by -1.3 and -0.7, respectively. Although lung cancer incidence trend in males is decreasing in England but when compared with other countries, we concluded that there is room for improvement. Seven countries achieved better 10-year AAPC than England, whilst 5 countries had better AAPC in females (Fig. 5). Only 2 countries (USA and Russia) showed decreasing trend in both males and females and while the success seen in USA could be attributable to the wide-ranging smoking cessation programmes and lobbying in that country (28,29), that seen in Russia remains unclear. A possible explanation for the decreasing rates in Russia could be the low average life expectancy of 66 years recorded during our study period, whereas the average age of diagnosis for lung cancer is 70 years (30,31).

The strengths of this study include the large number of lung cancer cases and the use of ONS data, which minimises the chances of missing information on lung cancer incidence. However, the result of this study must be considered in the light of a number of limitations. First, it was practically impossible to stratify and depict trend by race, smoking and other important risk factors (as the data are not available). Secondly, we did not have access to stage or grade specific incident data, which would have allowed us to explore trend according to histological subtypes.

In conclusion, as the UK is already laden with the challenges of a growing and ageing population, it is necessary to re-strategise and develop high-quality preventive

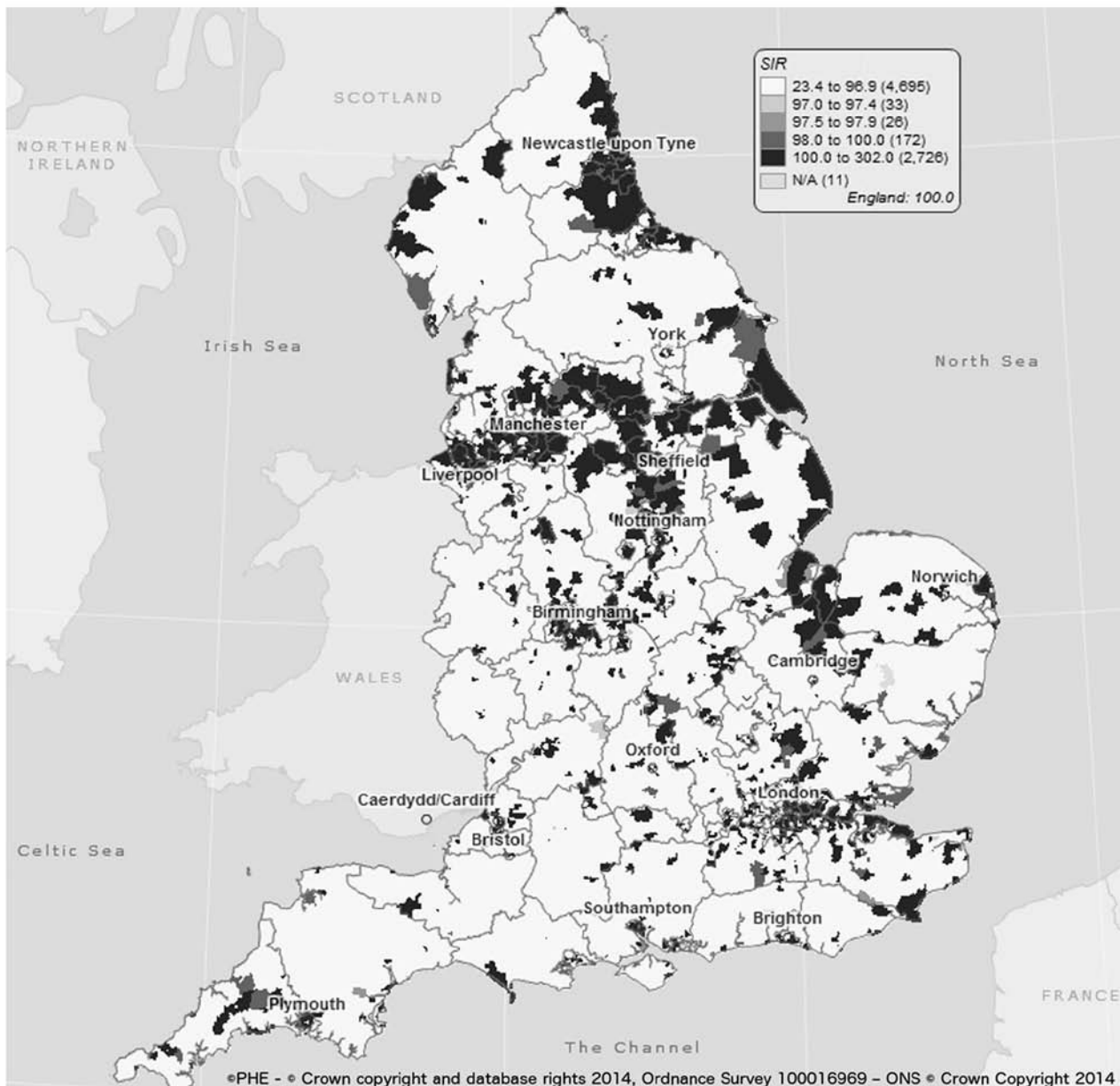


Figure 6. Lung cancer incidence map in England showing North South divide. This is the map of England with dark areas showing regions with lung cancer rates greater than England average. SIR, standardized incidence ratio.

interventions that will complement existing national tobacco control measures, especially in women living in regions that have demonstrated very high AAPC values (32). Utilising this targeted approach will achieve a considerable decline in age-adjusted lung cancer incidence rate similar to those seen in comparable countries such as USA (33). Our models showed that, unless a targeted and comprehensive preventive strategy is implemented, lung cancer rates in women will be on par or higher than that expected in their male counterparts in England by the year 2020.

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