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# Reduced lung cancer deaths attributable to decreased tobacco use in Massachusetts

**Zubair Kabir · Gregory N. Connolly · Luke Clancy · Ahmedin Jemal · Howard K. Koh**

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**Abstract**
*Background* Approximately 88% of the lung cancer deaths in men and 71% in women occurring in the US are attributable to cigarette smoking, with almost 3,700 annual lung cancer deaths in Massachusetts. In the state, male lung cancer death rates are showing a per year annual decline following a peak in the early 1990s. Such recent declines could be mostly attributed to tobacco control efforts over the past 40 years.
*Method* This study predicts how many fewer lung cancer deaths have occurred in Massachusetts possibly attributable to tobacco control activities. The study employs the US National Cancer Institute's ''Joinpoint'' Regression Analysis Program (version 3.0) using statewide age-standardized (2000 US Standard Population) lung cancer death rates from 1931 to 2003 for each of the sexes. 95% confidence intervals (CI) were also calculated.
*Results* Modeled male lung cancer death rates stabilized from the calendar year 1977 onwards but showed significant decline from 1992 onwards, while females showed a deceleration in rising lung cancer rates from 1993 onwards. Therefore, based on their corresponding beta-coefficients (slope) and standard error for each of the two calendar years 19,665 (95% CI: 18,655; 20,765) fewer lung cancer deaths in males and 3,855 (95% CI: 3,630; 4,055) fewer lung cancer deaths in females were estimated to have occurred from 1977 to 1993 onwards, respectively, largely because of the anti-smoking interventions in the past.
*Conclusions* Reductions in tobacco smoking are a major factor in the decrease in lung cancer mortality rates. Sustained progress in tobacco control is essential.

**Keywords** Massachusetts · Lung cancer · Smoking · State-level

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## Introduction

During 1997–2001, smoking resulted in an estimated annual average of 259,494 deaths among men and 178,408 deaths among women in the United States (US) [1]. Of the 153,093 annual lung cancer deaths occurring in US about 88% in men and 71% in women are attributable to cigarette smoking [1]. Lung cancer death rates, particularly in males, peaked recently and showed a decreasing trend but regional and racial/ethnic variations do exist [2]. Since 88% of male lung cancer deaths are attributed to tobacco smoking, any decline or deceleration in the observed lung cancer death rates could be largely attributed to anti-smoking interventions in the past. However, it has been difficult to quantify the benefits of such large scale, preventive interventions.

A recent study for the entire US, based on a counterfactual approach, predicted a conservative estimate of at least 146,000 more lung cancer deaths in men during the period 1991–2003 had there been no anti-smoking interventions in the past [3]. Massachusetts reports almost 3,700 lung cancer deaths annually in most recent years [4]. We adopted a similar counterfactual approach to estimate how many fewer lung cancer deaths have occurred in Massachusetts because of long-term anti-smoking interventions.

## Methods

The US National Cancer Institute's (NCI) ''Joinpoint'' Regression Analysis Program (Version 3.0), a Windows-based statistical software can delineate exactly when significant changes in the direction of lung cancer death rates occur [5]. The software analyses can model data where several trend-lines are connected together at ''joinpoints.'' The software takes trend data (in this case age-standardized lung cancer mortality rates) and fits the simplest inflexion model allowable. The program starts with the minimum number of joinpoints (for example, 0 joinpoint which is a straight line) and tests whether more joinpoints are statistically significant and must be added to the model, thus enabling the user to test whether an apparent change in trend is statistically significant [6]. Statistical significance is assessed by use of two-sided $p = 0.05$. Such joinpoint analyses have been used extensively in recent cancer studies for examining temporal associations [7, 8].

This study uses modeled data to locate exactly where a significant inflexion (downward trend) first occurred. Each joinpoint estimates a beta-coefficient (the slope of the line). The beta-coefficients show the annual percent change in lung cancer death rates per year. This study used those beta-coefficients that showed the steepest slope for each of the sexes to predict expected lung cancer death rates, assuming no further declines in the observed lung cancer death rates from such significant inflexion points referring to a particular calendar year. The difference between this expected lung cancer rate and the observed rate gives the absolute counts of excess lung cancer deaths for each calendar year. The calculation assumes that rates increase or decrease at a constant rate over time, although the validity of this assumption has not been tested.

The statewide lung cancer death rates are age-standardized rates (2000 US Standard Population) from 1931 to 2003 for both sexes. The sources of such data and on the International Classification of Diseases (ICD) codes used are shown in Appendix 1. Ninty five percent CI for expected excess lung cancer deaths were also calculated based on the standard error of each of the beta-coefficients for males and females separately.

## Results

Figure 1 shows that male lung cancer death rates leveled from 1977 to 1992 and then it starts to decline. In contrast, females showed a constant increase in rates by 1.5% per year from 1975 to 1993 but a slower increase of 0.2% per year was observed from 1993 onwards (Fig. 2).

Figure 3 predicts the expected lung cancer death rates in men from 1977 onwards had there been no decline in the current rates based on the beta-coefficient (slope) for the joinpoint year 1977 (=2.01). In other words, the male lung cancer death rates were increasing by 2% per year from 1944 to 1977 and then leveled. From 1992, we see a significant annual decrease in male lung cancer death rates by 1.5%. Therefore, assuming the steepest slope of 2% annual increase to have continued unabated from 1977 onwards, the annual expected lung cancer death rates were calculated based on the corresponding annual observed rates for each year. Consequently, an estimated 19,665 (95% CI: 18,655; 20,765) more lung cancer deaths would have occurred in males between 1977 and 2003. Likewise, for females 3,855 (95% CI: 3,630; 4,055) more lung cancer deaths were projected to have occurred between 1993 and 2003.

In total, 23,520 more lung cancer deaths would have occurred in Massachusetts from 1977 onwards had the observed trends continued. However, if 88% of male lung cancer deaths and 71% of female lung cancer deaths were assumed to be attributable to smoking exposure alone, then 17,305 and 2,735 excess lung cancer deaths would have occurred in males and females, respectively, totaling to 20,040 excess deaths.

Figure 4 is a graphic representation of total pack-year per-capita cigarette consumption versus lung cancer death rates in both sexes over the past 50 years in Massachusetts. It is quite obvious that when cigarette consumption peaked in the early 1960s lung cancer death rates in males peaked nearly 20 years later, suggesting a lag period. In addition, the significant downward slope in tobacco consumption in the early 1980s also coincides with a dramatic reduction in lung cancer death rates in males from the early 1990s onwards. However, such peaks do not apply to female lung cancer death rates.

Table 1 shows that there was more than a 12-fold increase in total lung cancer death rates between 1931 and 2003, with females showing a 15-fold increase. Although a relative decrease of 6% did occur in overall lung cancer death rates in the most recent decade, female lung cancer death rates still showed an overall increase of almost 3%. Table 1 also shows that if male lung cancer death rates continued rising unabated from 1977 onwards (following the pattern in Fig. 1) then a total of approximately 3,745 lung cancer deaths would have been expected in the year 2003 instead of the observed 1,931 deaths. Likewise, for females the expected total lung cancer deaths in 2003 would have been approximately 2,435 instead of the observed 1,818 deaths had the 1993 death rate patterns continued unabated (as shown in Fig. 2).

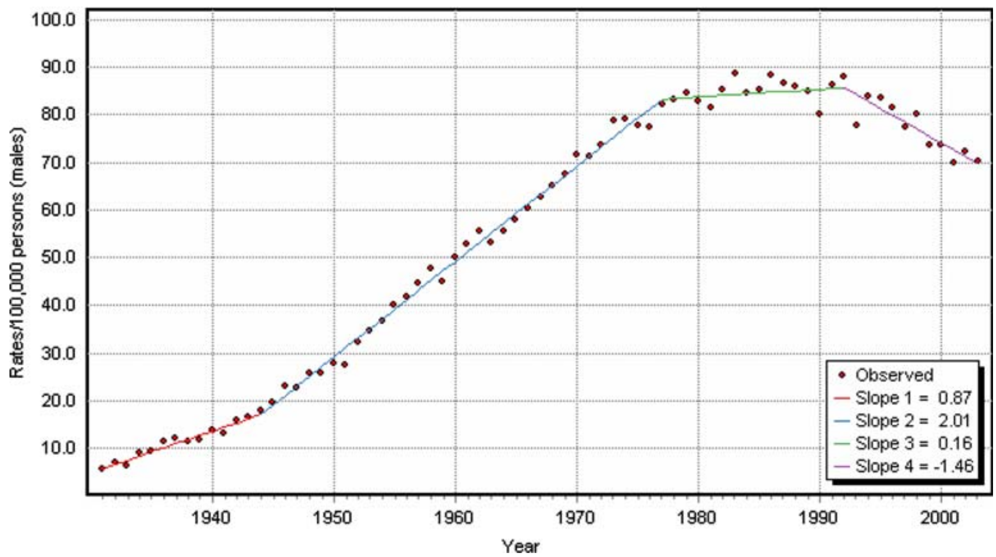


**Fig. 1** Joinpoint analysis of male lung cancer death rates, 1931–2003 (age-standardized to 2000 US Standard Population). Slope 1: 1931–1944, slope 2: 1944–1977, slope 3: 1977–1992, slope 4: 1992–2003

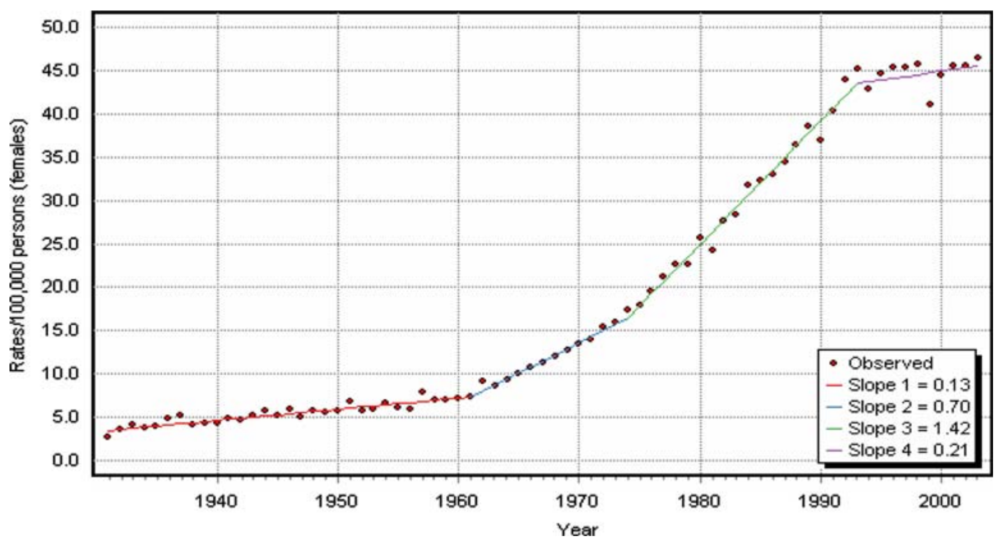


**Fig. 2** Joinpoint analysis of female lung cancer death rates in Massachusetts, 1931–2003 (age-standardized to 2000 US Standard Population). Slope 1: 1931–1961, slope 2: 1961–1974, slope 3: 1974–1993, slope 4: 1993–2003

## Discussion

An estimated 23,520 fewer lung cancer deaths from 1977 onwards most likely attributable to tobacco control represents a substantial health gain in Massachusetts. Due to a very strong association of lung cancer with tobacco smoking, any observed decline or slowing in lung cancer death rates is more likely attributable to anti-smoking interventions over the past 40 years or so. We assume the role of tobacco control activities far outweighs the contributions of lung cancer treatment during this time frame. Figure 4 shows that when the per-capita cigarette consumption peaked in the early 1960s, the male lung cancer death rates started to peak almost after 20 years, in the early 1980s, suggesting a lag period for lung cancer induction period. Such observations may also be due to underlying secular trends or in part because of some other factors such as improved air quality or reduced occupational carcinogenic exposures. However, contributions from such changes are unlikely to be nearly as substantial as declining tobacco consumption to explain the observed trends in this study.

This study has caveats. The study does not address how many fewer lung cancer deaths are attributed to specific anti-smoking interventions or to specific components of a tobacco control program. The assumption of this study is solely based on the strong attributable risk of lung cancer and tobacco smoking. Therefore, the estimated fewer lung cancer deaths are largely a general reflection of the beneficial impacts of any form of anti-smoking effort in the past. Such efforts include: (1) heightened public awareness of the ill-effects of smoking following landmark publications in the early 1950s associating lung cancer with tobacco smoking, (2) the 1964 Surgeon's General Report,

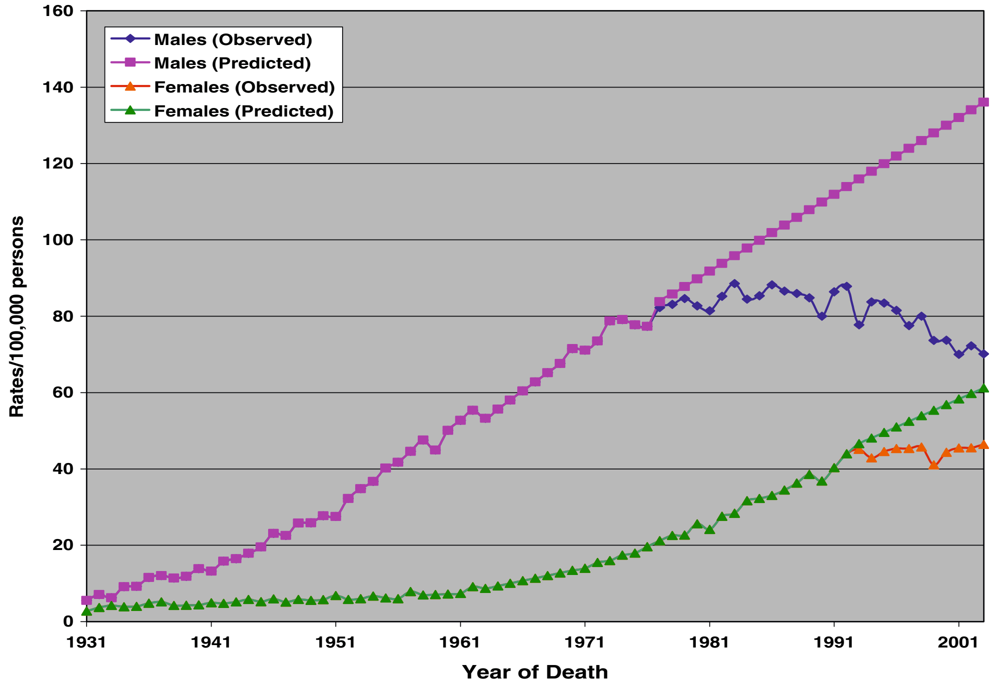


**Fig. 3** Observed and expected lung cancer death rates in both sexes in Massachusetts, 1931–2003. The expected lung cancer death rates in both sexes are based on the largest slopes

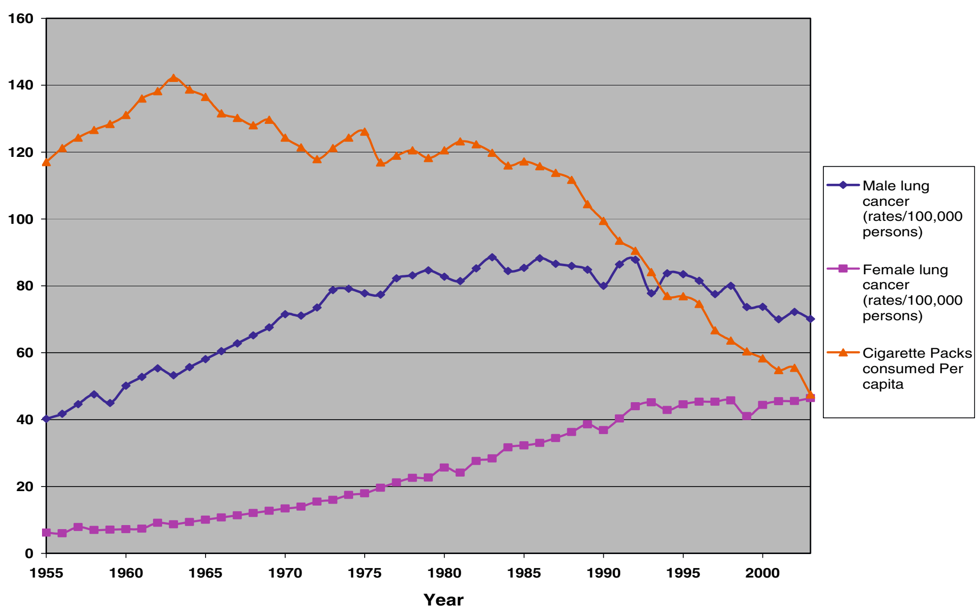


**Fig. 4** Annual cigarette packs consumed per-capita and annual lung cancer death rates in both sexes in Massachusetts, 1955–2003

(3) increased tobacco prices, including tax increases, (4) advocacy from health organizations, (5) increasing penetrance of smoke-free policies, governmental ordinances and regulations on advertisements and on tobacco products, (6) increased availability of cessation and counseling services, (7) increased counteradvertising, and (8) a comprehensive statewide Massachusetts Tobacco Control Program (MTCP), starting in 1993, which combined all the elements noted above [9]. Such anti-smoking interventions over the years should all have contributed to the recent decline in lung cancer death rates in Massachusetts.

Although it is relatively early for the MTCP to have a substantial impact on the recent lung cancer death rates, the California's Tobacco Control Program did show a 6% overall decline in lung cancer incidence within a decade [10]. Therefore, the significant slowing in female rates coupled with a steeper decline in male death rates after 1993 onwards could also in part be attributed to the MTCP. The MTCP started January 1993 [9]. Before then, no comprehensive statewide tobacco control efforts existed, although of course there were pockets of efforts from both volunteer health organizations and government programs.

**Table 1** Relative changes (%) in lung cancer death rates (100,000/persons) and absolute counts (numbers) by different calendar periods in Massachusetts

| Year | Male | | Female | | Total | |
|---|---|---|---|---|---|---|
| | Rates (observed) | Counts (observed) | Rates (observed) | Counts (observed) | Rates (observed) | Counts (observed) |
| 1931 | 5.54 | 85 | 2.77 | 47 | 4.05 | 132 |
| 1977[f] | 82.26 | 1,855 [a] | 21.21 | 675 | 45.45 | 2,530 |
| 1992[g] | 87.82 | 2,137 [b] | 43.95 | 1,512 | 60.88 | 3,649 |
| 1993[h] | 77.74 | 1,913 | 45.16 | 1,599 [c] | 57.83 | 3,512 |
| 2003 | 70.12 | 1,931 [d] | 46.41 | 1,818 [e] | 54.37 | 3,749 |
| Relative changes | | | | | | |
| 1931–2003 | +1,166% | | +1,575% | | +1,242% | |
| 1992–2003 | –11.5% | | +5.6% | | –10.7% | |
| 1993–2003 | –9.8% | | +2.8% | | –5.9% | |

[a] Expected lung cancer death counts = 1,889

[b] Expected lung cancer death counts = 2,772

[c] Expected lung cancer death counts = 1,654

[d] Expected lung cancer death counts = 3,746

[e] Expected lung cancer death counts = 2,433

[f] Year when male lung cancer death rates started to peak

[g] Year when male lung cancer death rates peaked, and thereafter decreased

[h] Year when female lung cancer death rates started to stabilize

A rigorous analysis is necessary to account for secular trends, and to determine how much of a decline in lung cancer in Massachusetts could be attributed to the Massachusetts Tobacco Control Program alone.

## Conclusions and future implications

In conclusion, this study offers insight into the potential importance of large preventive interventions that could have substantial beneficial impacts on disease outcomes. As such interventions did not have dramatic impacts on female lung cancer death rates, and therefore, more interventions should be targeted to this group. It may be the case that we have not yet seen the payoffs of tobacco control in reducing female lung cancer deaths. Lung cancer death rates do follow historical patterns of tobacco use and the tobacco control epidemic in women reached its peak about 20 years after it did in men.

Since 2002, funding for the Massachusetts Tobacco Control Program has been severely reduced, no doubt leading to the recent plateau in previously declining adult smoking rates between 2002 (18.1%) and 2005 (18.1%) [11]. Also, it would be interesting in the future to assess the differential impact of large scale tobacco control activities on socio-demographic sub-groups in the past 50 years. What is certain is that sustained progress in tobacco control is essential if we are to continue to make progress not only against lung cancer but also against all tobacco-related disease conditions.

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## Appendix 1: Sources of lung cancer and population data

(1) Mortality: 1930–1978, Annual Report on the Vital Statistics of Massachusetts
(2) Mortality: 1979–1988, CDC Wonder
(3) Mortality: 1989–1998, Mass CHIP database
(4) Population: 1930, 1940, Sixteenth Census of the United States (1940): Population, Volume II, Part 3
*For age groups 75–79, 80–84, and 85+ for 1930, see Source for 1980 population data*
(5) Population: 1950, A Report of the Seventeenth Decennial Census of the United States: Census of the Population: 1950, Volume II, Part 21
(6) Population: 1960, U.S. Census of Population: 1960, Massachusetts
(7) Population: 1970, 1970 Census of Population, Volume I, Part 23

(8) Population: 1980, 1980 Census of Population, Volume I, Chapter B, Part 23
(9) Population: 1990, 1990 Census of Population, General Population Characteristics, Massachusetts
(10) Population: non-census years: 1985–1997 (excluding 1990), Mass CHIP database
(11) Population: non-census years: 1931–1984 (excluding census years), (e.g., For the year 1931: 1930 + (((1931–1930)/10) × (1940–1930))

Notes on ICD codes from the Department of Public Health Massachusetts

Although the description for code 163 changes between 1957 and 1958, the description in the Detailed International List remains the same: ''Malignant neoplasm of lung and bronchus, unspecified...''Beginning in 1969, ICD 162 does not cite primary, secondary, or unspecified. The Massachusetts Department of Public Health no longer included ICD 163 from 1969 onwards. ICD 9 for lung cancer continued to be 162.

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