# The Impact of the 2004 Irish Workplace Smoking Ban on Lung Cancer Incidence and Mortality

Theodore L. Caputi and Dr. Zubair Kabir
School of Public Health, College of Medicine & Health, University College Cork, Cork, Republic of Ireland

## Background

Ireland has become a global leader in tobacco control practices designed to reduce smoking prevalence and second-hand smoke exposure. This strategy has been successful, reducing the smoking prevalence from 29% to 18% in the past 15 years (1).

In 2004, Ireland became the first country globally to institute a comprehensive smoking ban in all workplaces, including restaurants, bars, and pubs (2).

Previous research supports that comprehensive smoking bans are an effective tobacco control strategy:

- Improved bar-worker respiratory function (4)
- Reduced self-reported second-hand smoke and respiratory symptoms among bar workers (5)
- Reduced hospital admissions due to acute coronary syndrome and acute pulmonary disease (7,8)
- Reduced mortality due to cardiovascular, cerebrovascular, and respiratory disease (9)
- Reduced proportion of babies born small-for-gestational age (10)

Possible counter-effects of smoke-free legislation (e.g., declines in bar revenues) are either negligible or non-existent. (12-14).

## Smoking Bans and Lung Cancer

Despite the intuition that a smoking ban may impact lung cancer incidence and mortality, only two previous studies have explicitly measured lung cancer (hospital admissions and mortality) before and after a smoking ban.

The authors of the first study (27) cautioned against interpreting this finding as an effect of the ban, given the long latency period for lung cancer relative to the short follow-up period of the study (two years after the ban).

The second study (28) examined municipal smoke-free ordinances that were implemented at different times (ranging from 2004-2013). The authors stated they may not have had sufficient follow-up data for several of the municipalities.

## Research Question

**What was the effect of the 2004 Irish Workplace Smoking Ban on lung cancer incidence and mortality when compared to a counter-factual scenario?**

## Methods – Study Design

Quasi-experimental interrupted time-series study based upon Poisson regression, using the pre-ban period as historical controls

## Methods – Data Sources

**National Cancer Registry Ireland:** Aggregated cancer incidence from 1994 to 2014. The NCRI captures the near universe of cancer incidence in Ireland.

**Irish Central Statistics Office:**
- Quarterly cancer mortality data from 1994 to 2015
- Irish population data by age and sex

**Health Service Executive:** Cigarette smoking prevalence data by age and sex from 2002 to 2018.

## Methods – Confounders

Lung cancer incidence and mortality was adjusted by annualized percentage of smokers in Ireland. Previous studies indicate Irish smoking prevalence was not impacted by the smoking ban, so smoking prevalence is unlikely to be a mediator between the smoking ban and lung cancer incidence and mortality.

## Methods – Statistical Analysis

One-sample interrupted time-series analysis was conducted using Poisson regression. That is, for each year-age-sex combination, the number of mortality and incidence cases within that group was regressed against an indicator for pre- vs. post-interruption, with an offset for the total population of the age-sex group.

"Modelled interruption" points 0, 1, 2, 3, 4, 5, and 6 years after the 2004 ban were tested using a forward stepwise regression, and the most significant break point (measured by the absolute value of the t-statistic) was used as the interruption. 2010 was chosen as the interruption for lung cancer incidence, and 2006 was chosen as the interruption for lung cancer mortality.

A Durbin-Watson statistic revealed significant autocorrelation in both the incidence and mortality data, and so significant lag time effects were included in each model (a 2-year lag for incidence; 1-, 2-, and 3- year lags for mortality).

$$\ln(E(Y_{t,s,a})) = \beta_0 + \beta_1 T_{t,s,a} + \beta_2 X_{t,s,a} + \beta_3 X_{t,s,a} T_{t,s,a} + \beta_4 C_{t,s,a} + \epsilon_{t,s,a}$$

$$\epsilon_{t,s,a} = \rho \epsilon_{t-Q,s,a} + u_{t,s,a}$$

$t$ -- year
$s$ -- sex
$a$ -- age group
$Y_t$ -- aggregated annual rate (either incidence or mortality)
$T_t$ -- years since the beginning of the study period (1994)
$X_t$ -- whether the observation is before/after the intervention
$C_t$ -- a matrix of time-varying confounders
$\beta$'s -- parameter estimates
$\epsilon$ -- error term

To detect effect modification, segmented regression analyses were conducted based upon age group and sex.

For each analysis, risk ratios and 95% confidence intervals for both immediate effects ($\beta_2$) and gradual effects ($\beta_3$) were reported by exponentiating the Poisson regression coefficients and confidence intervals.

An identical analysis was conducted with incidence and mortality of brain cancer as the dependent variable. Brain cancer is unrelated to smoking (either active or passive) and so there should be no impact of the smoking ban on brain cancer incidence or mortality.

The total number of cases avoided from the smoking ban was calculated by subtracting the observed number of cases from the number of cases predicted over the post-interruption time period using the pre-interruption slope and intercept. A 95% confidence interval was computed through bootstrapping.

## Results

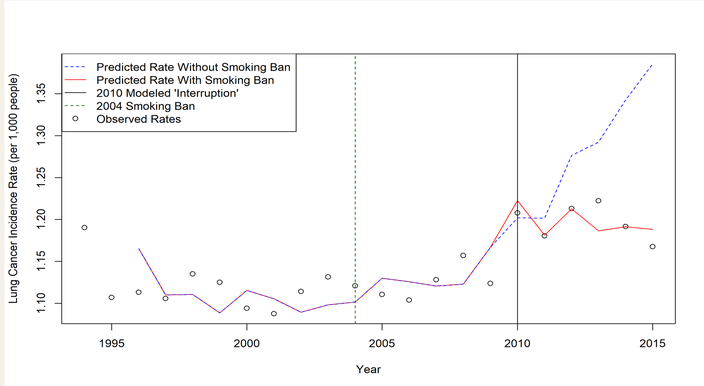
**The 2004 Irish Smoking Ban significantly reduced the incidence and mortality of lung cancer in Ireland.**

Compared to modelled counterfactual:

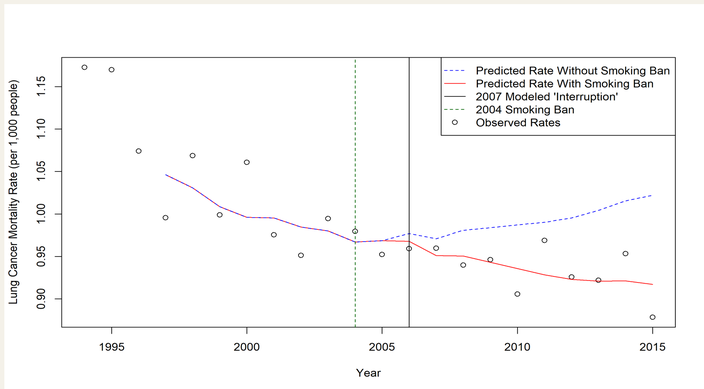
- **3%** (95%CI 2-5) **decrease in lung cancer incidence**
- **209** (95%CI 155-274) **fewer lung cancer cases/year**
- **1%** (95%CI 0-2) **decrease in lung cancer mortality**
- **122** (95%CI 104-143) **fewer lung cancer deaths/year**

Significant results **not** found for brain cancer.

## Results (cont'd)




**Lung Cancer Incidence with and without the Smoking Ban**




**Lung Cancer Mortality with and without the Smoking Ban**

## Limitations and Validity

- One-sample interrupted time series leaves the possibility that an external event, occurring at the interruption, could confound the effect. If that event reduced smoking, the effect is overstated (and vice versa).
- Thorough review of tobacco control landscape, we could not find something that could plausibly explain the decrease
- Brain cancer validity test mitigates the possibility that a broader public health/cancer event could explain the effect

## Conclusion

The Irish Workplace Smoking Ban significantly reduced the incidence and mortality of lung cancer in Ireland, averting over 200 cases and over 100 deaths each year. Still, twenty-four US states and 11 European Union countries do not yet have comprehensive smoking bans (15-16). This study can be added to the arsenal of studies that support the adoption (or retention) of comprehensive smoking bans.

Future research, potentially including individual-level data, are essential to fully understand the biological and policy implications of a comprehensive smoke-free policy.

## Acknowledgements

We would like to thank the Ireland Environmental Protection Agency, Ireland Health Services Executive, National Cancer Registry Ireland, and the Central Statistics Office of Ireland for access to air quality, smoking prevalence, cancer incidence, and cancer mortality data (respectively). This project would not have been possible without the assistance of those institutions and the hard work of their employees.

This dissertation is dedicated to all patients, survivors, and victims of cancer. Hopefully, this work will be used to improve tobacco control policy so that fewer individuals and families will have to suffer through the hardships of cancer. .

## Contact Information

**Theodore L. Caputi**

1050 Massachusetts Ave.
Cambridge, MA 02139
United States of America

Tel: +1 267 312 8471
tcaputi@gmail.com
www.theodorecaputi.com

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