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Modelling lung cancer mortality rates from smoking prevalence: Fill in the gap

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ABSTRACT

Background: The objective of this study is to estimate the gap between smoking prevalence and lung cancer mortality and provide predictions of lung cancer mortality based on previous smoking prevalence.
Materials and methods: We used data from the Spanish National Health Surveys (2003, 2006 and 2011) to obtain information about tobacco use and data from the Spanish National Statistics Institute to obtain cancer mortality rates from 1980 to 2013. We calculated the cross-correlation among the historical series of smoking prevalence and lung cancer mortality rate (LCMR) to estimate the most likely time gap between both series. We also predicted the magnitude and timing of the LCMR peak.
Results: All cross-correlations were statistically significant and positive (all above 0.8). For men, the most likely gap ranges from 20 to 34 years. The age-adjusted LCMR increased by 3.2 deaths per 100,000 people for every 1 unit increase in the smoking prevalence 29 years earlier. The highest rate for men was observed in 1995 (55.6 deaths). For women, the most likely gap ranges from 10 to 37 years. The age-adjusted LCMR increased by 0.28 deaths per 100,000 people for every 1 unit increase in the smoking prevalence 32 years earlier. The maximum rate is expected to occur in 2026 (10.3 deaths).
Conclusion: The time series of prevalence of tobacco smoking explains the mortality from lung cancer with a distance (or gap) of around 30 years. According to the lagged smoking prevalence, the lung cancer mortality among men is declining while in women continues to rise (maximum expected in 2026).
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1. Introduction

Tobacco smoking is the leading cause of preventable deaths in developed countries [1]. Particularly, tobacco use is responsible of 71% of lung cancer mortality [2]. Lung cancer is usually detected at advanced stages and, once detected, the survival expectance is poor. The gap between tobacco use and the development of lung cancer disease is of up to 3 or 4 decades [3]. Therefore, knowledge of tobacco use over time can help to predict morbidity and mortality of diseases related to tobacco smoking. The MPOWER strategy suggests the monitoring of smoking trends as an essential tool for tobacco control. Whilst historical series of smoking prevalence rates are available only for some developed countries [4], their reconstruction based on health surveys is reliable and valid [5–7]. On the other hand, mortality from lung cancer has been studied over the years, and thanks to the completeness and reliability of death registers it allows to monitor time trends in lung cancer mortality [8,9].

Few studies [7] have systematically evaluated the time gap between the two aforementioned series and how this gap can predict future mortality rates. Therefore, we propose to explore the cross-correlation between smoking prevalence and lung cancer mortality rates in order to better model the future lung cancer

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mortality rates, using data from a nationally representative survey and universal vital statistics in Spain.

2. Material and methods

2.1. Data

Smoking data were obtained from the three 2003, 2006 and 2011 waves of the Spanish National Health Survey. All surveys included information on smoking status, age at smoking initiation (for current and former smokers) and age at smoking cessation (for former smokers). We then reconstructed the smoking prevalence for each year from 1940 to 2011, stratified by age and sex, as detailed in previous studies [7,10].

Lung cancer mortality data from 1980 to 2013 were available from the National Statistics Institute (INE). Annual population data for the denominator were also available during the study period from the INE. This information was aggregated by sex and age groups. From these data we calculated from 1980 to 2013 the crude mortality rate, the standardized mortality rate (using the standard population of the World Health Organization [11]) and age-specific mortality rates for lung cancer; all the rates calculated in deaths per 100,000 people.

The objective of our statistical analysis was, first, to estimate the most likely gap between the smoking prevalence and the lung cancer mortality rates; and second, to use this most likely gap to predict future lung cancer mortality rates, assuming the same previous trend of smoking prevalence, and the year with the maximum mortality rate.

2.2. Estimating the most likely time gap between smoking prevalence and lung cancer mortality rates

We calculated the cross-correlation between the time series of smoking prevalence and lung cancer mortality rates and its corresponding 95% confidence interval (CI). The cross-correlation is a standard method of estimating the degree to which two series are correlated. The cross-correlation, similar to the Pearson correlation, measures the correlation between two time series after applying a lag (k) to one of them. For two time series x, y and a lag of k units of time, the cross-correlation is calculated as:

$$\frac{\sum(x_i)(y_{i-k})}{\sqrt{\sum(x_i-\bar{x})^2}\sqrt{\sum(y_{i-k}-\bar{y})^2}}$$

In our case, we applied a lag of k years (0–40) to the lung cancer mortality rate series. Thus, the lung cancer mortality rate in a given year (e.g.: 2010) was matched with the smoking prevalence k years before (e.g.: 1980 for a k = 30 year lag). Then, we calculated the correlation between the two series and estimated the most likely gap between the smoking prevalence series and the lung cancer mortality rate series by choosing the lag that maximizes this cross-correlation. Therefore, our parameter of interest in the modeling is k.

We calculated the gap for the crude, age-standardized and age-specific mortality rates because lifetime smoking (pack-years) and the different patterns of smoking vary by age and cohort and may affect the estimation of the gaps.

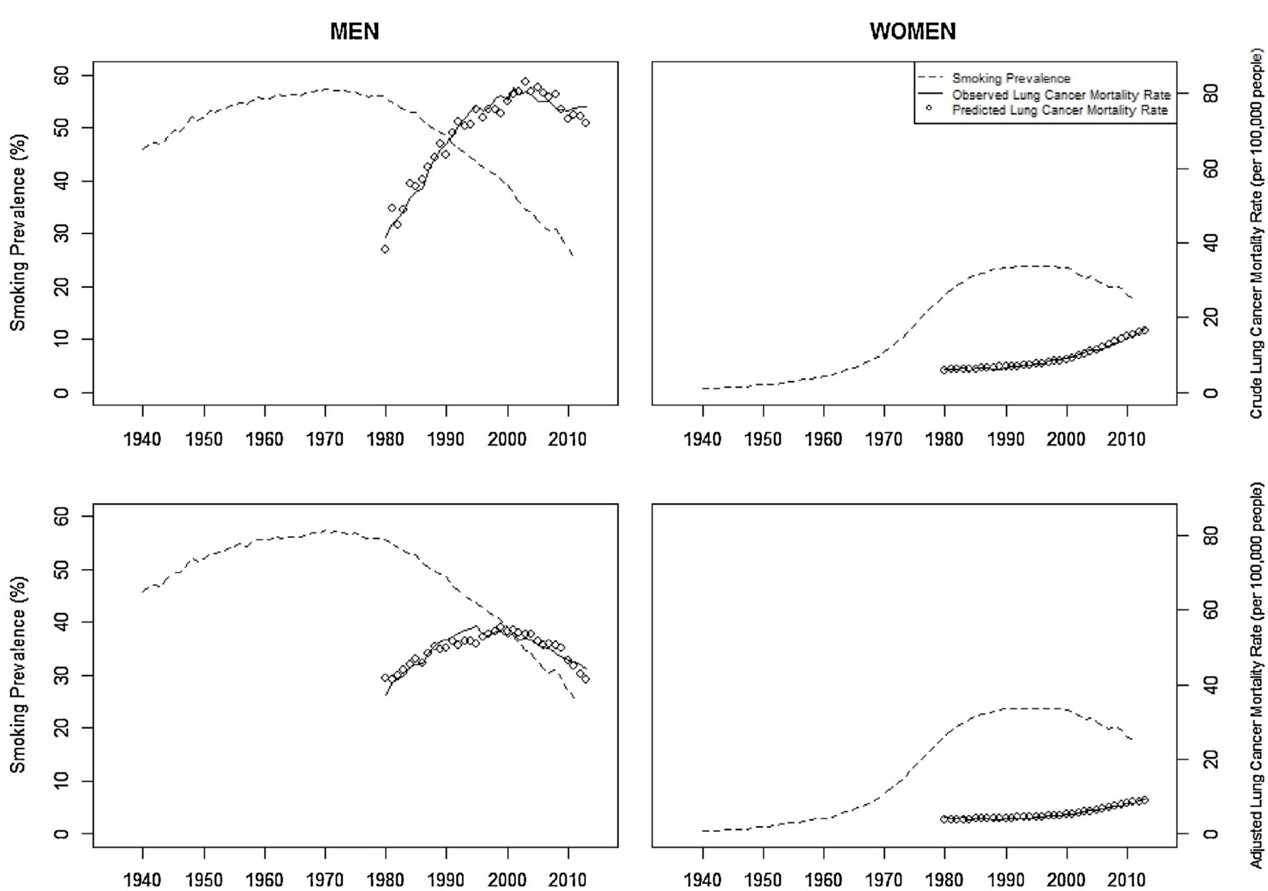

Fig. 1. Time series of smoking prevalence (1940–2011) and observed and predicted crude and adjusted lung cancer mortality rates (1980–2013) in Spain for men and women.

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