Appendix

The new indirect method to estimate smoking-attributable mortality is fully developed by Preston, Glei and Wilmoth in their 2010 paper[1-2] and relies on the strength of the relationship between cigarette smoking and lung cancer mortality. Lung cancer mortality acts as a proxy for damage from smoking and is used to estimate the impact of smoking on mortality from all other causes of death. The high proportion of lung cancer deaths that are attributable to smoking, along with evidence that changes in lung cancer risk result primarily from the history of smoking behavior, supports the validity of this assumption.[1]

In the first stage of the indirect estimation method, age-, sex- and year-specific lung cancer death rates are used to predict age-sex-year-specific mortality from all other causes of death. Controls for country fixed effects, age and time dummies, as well as interactions between country and year, lung cancer mortality and year and lung cancer mortality and age are included. The coefficients from this model (in this paper we use the coefficients published in Preston et al (Table 1)[2]), along with estimates of the expected lung cancer death rate among non-smokers (in high income countries typically associated with passive smoking and radon exposure), are then used to estimate the overall fraction of deaths attributable to smoking. Preston, Glei and Wilmoth estimated this model using data from 21 developed countries for the period 1950 through 2007. They have demonstrated that the results produced are very similar to estimates produced using the Peto-Lopez method.[1]

As a check for model validity, Preston, Glei and Wilmoth predicted mortality from four groups of causes using lung cancer mortality. As expected, strong relationships were observed between lung cancer mortality and both smoking-related cancers and respiratory diseases, while a weak relationship was observed between lung cancer mortality and external causes (accidents, homicide and suicide), a category for which smoking should be unrelated to mortality. The authors also assessed the robustness of the results to alternative model specifications.[1]

To apply this method, we first estimate the fraction of deaths due to lung cancer in a specific sex-age-education group that is attributable to smoking, A_L, as follows:

$$A_L = \frac{M_L - \lambda_L^N}{M_L} \qquad (1)$$

where M_L is the observed sex-age-education-specific lung cancer death rate and λ_L^N is the expected sex- and age-specific lung cancer death rate among non-smokers, which is taken from the Cancer Prevention Study II (CPS-II). These rates are similar to death rates from lung cancer observed among non-smokers in other industrialized countries.[1]

Second, we estimate the fraction of deaths from all other causes besides lung cancer in a specific sex-age-education group that is attributable to smoking, A_O, as follows:

$$A_O = 1 - e^{-\beta_L (M_L - \lambda_L^N)} \qquad (2)$$

where β_L are the age- and sex-specific model coefficients published in Preston, Glei and Wilmoth and M_L and λ_L^N are as defined above.[2] In cases where $M_L - \lambda_L^N$ is negative, the fraction of deaths attributable to smoking is set to 0.

The overall attributable fraction of deaths from all causes that is due to smoking, A, is then calculated as:

$$A = \frac{A_L D_L + A_O D_O}{D} \qquad (3)$$

for each sex-age-education group, where D_L is the observed number of deaths from lung cancer, D_o is the observed number of deaths from all other causes, and D is the observed number of deaths from all causes combined. Thus, the fraction of all deaths above age 50 that is attributable to smoking, A_{50+}, is:

$$A_{50+} = \frac{\sum_{i=50-54}^{85+} A_i D_i}{\sum_{i=50-54}^{85+} D_i} = \frac{\sum_{i=50-54}^{85+} A_i D_i}{D_{50+}} \quad (4)$$

95% confidence intervals for the estimates of the smoking-attributable fractions are produced using the delta method. The variance estimates for A_{50+} incorporate random variation in the observed death rates and variation in the estimated regression coefficients.

To translate smoking-attributable mortality by age into implications for life expectancy at age 50, we obtain adjusted age-specific death rates (i.e., death rates from which smoking-attributable mortality is removed), m_i^{-s}, as follows:

$$m_i^{-s} = m_i(1 - A_i) \quad (5)$$

where i = 50-54, 55-59, …, 80-84, 85+ and m_i is the sex-age-education-specific death rate from all causes combined. We then use standard life table procedures to calculate life expectancy at age 50 by sex and education level with and without the inclusion of smoking-attributable deaths to determine the extent to which smoking contributes to educational differentials in life expectancy at age 50 and whether this contribution has changed over time.

The central assumption of this model is that lung cancer mortality accurately proxies the impact of smoking damage on mortality from other causes. This method may be less reliable in populations in which factors other than smoking have a strong impact on lung cancer mortality, such as air pollution in China, or in developing country contexts.[1] See discussion for a more detailed evaluation of model assumptions as they relate to the context of this study.

References

1. Preston SH, Glei DA, Wilmoth JR. A new method for estimating smoking-attributable mortality in high-income countries. *Int J Epidemiol* 2010;39:430–8.

2. Preston SH, Glei DA, Wilmoth JR. Contribution of smoking to international differences in life expectancy. In: Crimmins EM, Preston SH, Cohen B, eds. International Differences in Mortality at Older Ages. Dimensions and Sources. Washington, DC: The National Academies Press 2010:105–131.