The impact of cigarette smoking on life expectancy between 1980 and 2010: a global perspective

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ABSTRACT

Introduction Tobacco smoking is among the leading causes of preventable mortality worldwide. We assessed the impact of smoking on life expectancy worldwide between 1980 and 2010.

Methods We retrieved cause-specific mortality data from the WHO Mortality Database by sex, year and age for 63 countries with high or moderate quality data (1980–2010). Using the time of the peak of the smoking epidemic by country, relative risks from the three waves of the Cancer Prevention Study were applied to calculate the smoking impact ratio and population attributable fraction. Finally, we estimated the potential gain in life expectancy at age 40 if smoking-related deaths in middle age (40–79 years) were eliminated.

Results Currently, tobacco smoking is related to approximately 20% of total adult mortality in the countries in this study (24% in men and 12% in women). If smoking-related deaths were eliminated, adult life expectancy would increase on average by 2.4 years in men (0.1 in Uzbekistan to 4.8 years in Hungary) and 1 year in women (0.1 in Kyrgyzstan to 2.9 years in the USA). The proportion of smoking-related mortality among men has declined in most countries, but has increased in the most populous country in the world, that is, China from 4.6% to 7.3%. Increases in the impact of tobacco on life expectancy were observed among women in high-income countries.

Conclusions Recent trends indicate a substantial rise in the population-level impact of tobacco smoking on life expectancy in women and in middle-income countries. High-quality local data are needed in most low-income countries.

INTRODUCTION

The toll of cigarette smoking on mortality continues to rise worldwide, and smoking is the largest cause of death in high-income countries. In 2010, almost 6 million people died from tobacco use and exposure to secondhand smoking; the annual number of tobacco-related deaths is expected to increase to 8.3 million by 2030,[1] and 80% of these deaths are projected to occur in low-income and middle-income countries (LMICs).[2] Among causes of death, lung cancer had the highest percentage of cases attributed to tobacco smoking worldwide (51%), followed by chronic obstructive pulmonary disease (COPD) (37%), upper-aerodigestive tract cancers (UADC, 34%) and cardiovascular diseases (CVDs) (11%).[3 4]

Several methods have been proposed to estimate smoking-related mortality,[3 5] but none seem adequate to analyse data from LMICs. The evolving relative risks for smokers, depending on the maturity of the smoking epidemic,[6 7] and cross-country variation in the distribution of cause-specific deaths[5] are some of the challenges in the application of these methods to data from LMICs.

This study aims to estimate the impact of smoking on life expectancy worldwide and the trends over time between 1980 and 2010. We propose a revision of the original method developed by Peto and colleagues that takes into account national accumulated exposure to smoking and smoking-related risk of dying, anchored to the country's position within the smoking epidemic continuum.[6] We validated the robustness of the results, comparing them with estimates obtained with the original Peto *et al*'s[3] method, as well as applying a lower excess mortality correction for all countries,[4] and finally using another model for developed countries.[5]

METHODS

Data sources: cause-specific mortality

Data on age-specific and sex-specific mortality by cause of death were extracted from the WHO Mortality Database between 1980 and 2010. Only 63 countries with data of high or moderate quality[8] were included in the analysis. The level of quality was based on the assessment of completeness, coverage and percentage of ill-defined causes of death. Countries included in the analysis are summarised in online supplementary table S1 that can be found in the online supplementary materials. Among the 63 countries, there are 2 in Africa, 15 in the Americas, 12 in Asia (13 regions with separate analysis for the Hong Kong Special Administrative Region separately from China), 32 in Europe and 2 in Oceania. We only included countries with a population of >1 million people and restricted data for adults aged 40–79 years, in order to avoid problems due to the low number of cases in the younger groups and misclassification of diseases among the elderly. Annual national age-specific and sex-specific population estimates were obtained from the United Nations Population Division.[9]

Statistical analysis

Lung cancer mortality can be converted into a smoking impact ratio (SIR),[10] which provides a proxy for the impact of the specific smoking history in that particular population compared to a reference population. Lung cancer mortality data were used because of their close relationship with smoking prevalence.[11] The SIR also avoids the need to estimate the prevalence of smoking and takes into account the smoking history of smokers (ie, duration, intensity, type of tobacco). For the majority of countries, we used Cancer Prevention Study (CPS) II for the reference estimate for non-smokers' lung cancer mortality rates. The use of coal as home fuel in poor ventilated dwellings has been reported to be a very important factor increasing lung cancer estimates in non-smokers.[12] We used the proposed correction factor by Ezzati and Lopez[10] to normalise the lung cancer mortality rates of non-smokers in the SIR in countries such as China,[13 14] where a proportion of lung cancer deaths is due to indoor air pollution. Hence, weighted non-smoker lung cancer mortality rates from China[14] were used instead for countries with a high prevalence of coal being used as home fuel (more than 70% of the total population).[15]

The relative risks (RRs) of dying for smokers compared with non-smokers according to each cause of death, sex and age group were derived from the CPS-I, CPS-II and CPS-Contemporary Cohorts. The RR of dying for smokers compared with non-smokers has evolved differently for each cause of death due to differences in the time required to change risk following increased or reduced exposure to tobacco smoking. For example, the RR from CVD increases slightly for both men and women, while the RR of dying from COPD increases steeply even after the mortality peak of the smoking epidemic.[7 16] In general, using RR as reported by the CPS-II study group in the 1980s would lead to overestimation or underestimation of the percentage of smoking-related deaths for countries in different stages of the smoking epidemic than the USA during the 1980s.[16] Therefore, we allowed for changes in the SIR and the corresponding RR using the smoker's lung cancer mortality rates and the RRs of the three different CPS waves.[7] Annual adjustment was done relative to the country-specific and sex-specific peak of lung cancer mortality rate, using CPS-II as the reference peak for men, and CPS-Contemporary Cohorts as the reference peak for women.

Separate analyses were performed for lung cancer (LC), UADC, other cancers (OC), COPD, other respiratory diseases, CVD and other medical causes. We assumed that smoking has no impact on cirrhosis; infectious and parasitic diseases excluding tuberculosis; maternal and perinatal conditions, neuropsychiatric conditions; congenital anomalies and external causes (injuries and accidents).

The proportion of deaths attributable to accumulated exposure to tobacco smoke was estimated using the population attributable fraction (PAF):

$$\mathrm{PAF_i} = \mathrm{SIR_i} \times \frac{\mathrm{RR_i} - 1}{1 + \mathrm{SIR_i}(\mathrm{RR_i} - 1)}$$

where i refers to each category of sex, 5-year age group for adults aged 40 to 79 years and cause of death. To avoid the effects of confounding from other risk factors, we applied the same reduction of 50% from the original indirect method[3] to excess mortality related to tobacco smoking for all causes related to smoking except for lung cancer. In order to measure the impact of tobacco smoking on life expectancy, we calculated the potential gain in life expectancy (at age 40) by elimination of smoking-related deaths. In other words, we estimated the loss of life years that could be attributed to tobacco smoking. To have estimates of the impact of tobacco for the last age group, we applied the PAF from the age group 74–79 to the age group 80+. The loss of life years was estimated using a cause-deleted life table method[17] applied to the UN life tables.

RESULTS

Total deaths attributable to tobacco smoking

Online supplementary table S2 in the online supplementary materials shows the average PAF of total mortality associated with smoking in adults aged 40–79 years for each period and country, by sex. Countries with the highest PAFs in 2000–2010 (>26%) were concentrated in Europe, including countries from eastern (Poland, Hungary, Russia, Kazakhstan), western (the Netherlands, Belgium), southern (Croatia) and northern (Belarus, Estonia) Europe. For men, Poland had the highest PAF with 31.1% of total mortality due to smoking. Almost three quarters of the countries have experienced a significant decrease in the proportion of smoking-related deaths over the most recent years, ranging from −13.8% in Azerbaijan to −0.2% in Hungary. The remaining countries have shown stabilisation of the trends, although a substantial rise was observed in China (PAF: 4.6% to 7.3%).

In women, the highest PAFs in 2000–2010 (>15%) were concentrated in North America (USA, Canada), Europe (Denmark, Hungary and the UK) and in Cuba with the maximum level in Denmark, that is, 19.2% of total mortality in women aged 40–79. The majority of countries around the world had lower PAFs (<5%), and in 5 countries <1% of total mortality was attributable to smoking, mostly in Central Asian countries. Women experienced recent increases in their PAF in almost three quarters of all countries (with significant changes ranging from 0.7% to 15.8%). One of the highest increases in the most recent period was observed in China (1.1% to 6.1% between 1980 and 2000).

Cause-specific mortality related to smoking

Over the past three decades, we observed a shift in the distribution of the most common causes of deaths that were related to smoking: although CVD deaths are the most common cause of deaths due to smoking in both sexes globally since the 1980s, its share over total deaths related to smoking has markedly decreased (43–35% in men and 61–50% in women). In contrast, lung cancer deaths related to smoking have proportionally grown over the same period of time, an observation that is seen in high-income countries (HICs) as well as in LMICs. At the beginning of the study period (c. 1980), CVD mortality represented half of the total deaths (50.8%) due to smoking in LMICs and 42.7% in HICs in men, and two-thirds (66.2%) in LMICs and 59.7% in HICs in women (see online supplementary materials). Lung cancer was the second cause of death among smoking-related deaths for men, at 17.2% in LMICs and 24.2% in HICs, respectively. At the end of the period (2000–2010), the share of CVDs in smoking-related deaths decreased to 44.6% and 36.9% in LMICs and HICs in men and to 54.9% and 44.2% in women, respectively, whereas the share of lung cancer mortality among men rose to 18.0% and 29.1% and to 14.3% and 28.8% among women, in LMICs and HICs, respectively.

Figure 1 shows the percentage of deaths that are attributable to smoking by cause of death and sex over time for a few countries from each world region under study. Among men, smoking is responsible for >80% of deaths from lung cancer in the majority of the countries except for China and Mexico. This is followed by COPD and UADC, with >50% of all deaths caused by smoking. Time trends of the percentage of smoking deaths for each cause of death showed a slight decrease in the majority of the countries, with the clear exception of China for all causes of death, and for COPD in several countries.

Among women, there were large variations in the estimated proportion of lung cancer death attributable to smoking, that is, 20% in Mexico and >80% in Denmark, the USA, Cuba and Hungary. Over the periods studied, there was a rising impact of smoking on cause-specific mortality except in Denmark, the

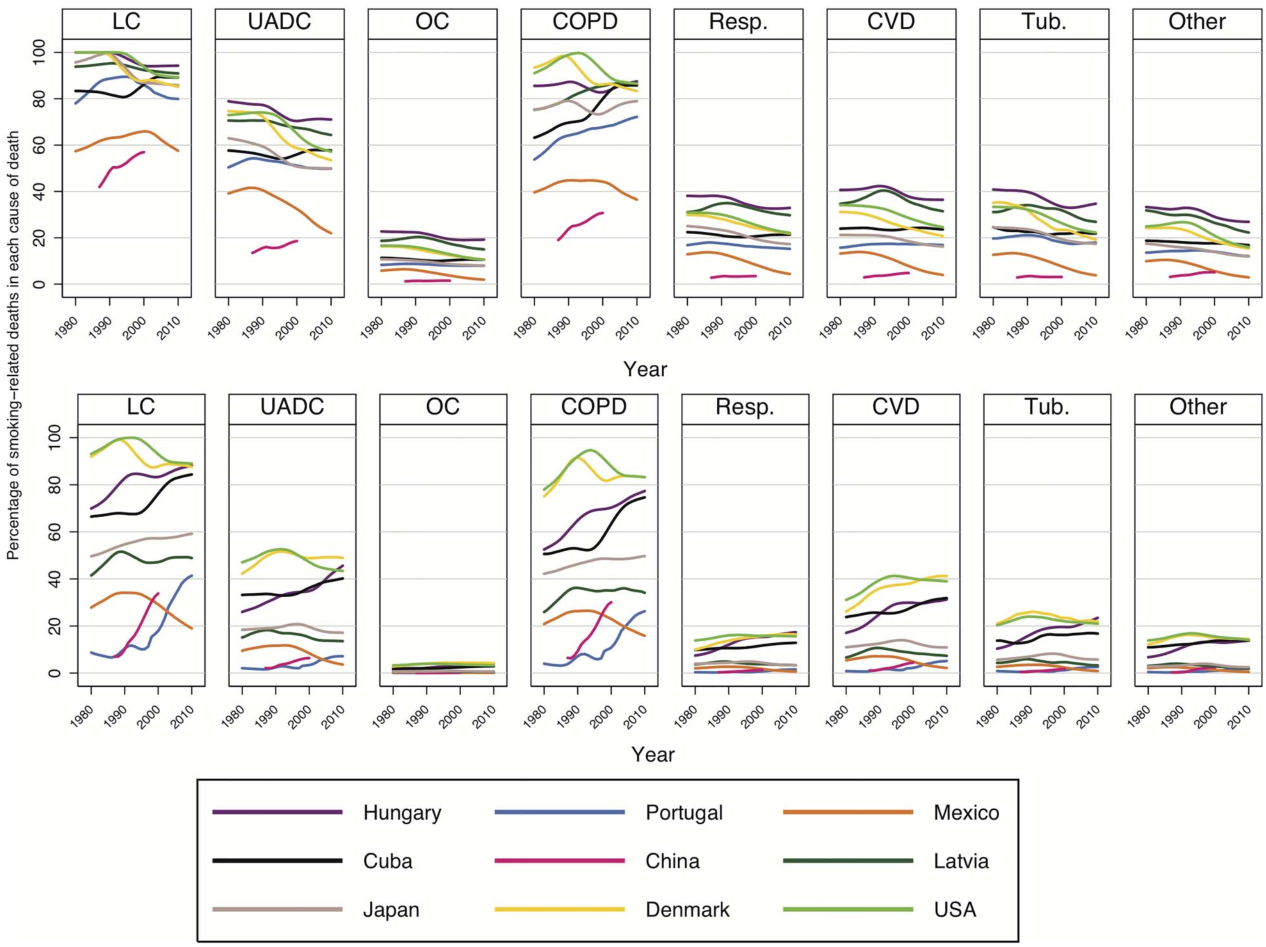

Figure 1 Average percentage of smoking-related deaths in each cause of death among men (top) and women (bottom) between 1980 and 2010. COPD, chronic obstructive pulmonary disease; CVD, cardiovascular disease; LC, lung cancer; OC, other cancers; Resp., respiratory disease; Tub, tuberculosis; UADC, upper-aerodigestive cancer.

USA and Mexico where a recent decrease was observed for all causes of death. Consistent decreases were observed for CVD deaths related to tobacco smoking among a larger group of countries.

Potential gain in life expectancy through elimination of tobacco smoking over time

The potential gain in life expectancy at age 40 after eliminating smoking-related mortality by country and sex is illustrated in figure 2 (see online supplementary tables for estimates for all countries). Currently, men could potentially gain 2.4 years on average if smoking-related deaths were to be eliminated. This varied widely by country and period, ranging from 5.7 years in Hungary (1990–1995) to 0.1 years in Guatemala (1980–1985). In the most recent period (2005–2010), Hungary had the largest number of life years to be gained when removing smoking-related deaths (4.8 years). Among men, countries on the left panel are characterised by a strong decreasing trend in potential gain of life expectancy if smoking-related deaths were eliminated, mainly observed in HICs in Europe and America, but also in South Africa. The second group pertains to countries where an increasing or stable trend was observed and mainly represented by countries from Asia and also a few Eastern-European countries. Finally, in the third group, a decreasing or stable trend predominates in countries with a low impact of smoking on life expectancy, concentrated in Latin American countries but also in Sweden. The impact of tobacco smoking-related mortality on life expectancy was less marked among women than among men with only 1 year of life expectancy gained after deleting smoking-related deaths, on average. The highest impact in the most recent year (2005–2010) was observed in the USA, with a potential gain in life expectancy of 2.9 years after removing smoking-related deaths. In figure 2, the majority of countries show an increasing impact of smoking-related deaths on women's life expectancy (even in countries with very low levels of smoking deaths). In only three countries, the USA, Singapore and Hong Kong, a decreasing trend was seen to come from relatively high levels, but decreases were also observed in countries with low impacts of smoking on mortality such as Mexico, Lithuania or Costa Rica.

DISCUSSION

In 2005–2010, tobacco smoking was responsible for 20% of total mortality of adults aged between 40 and 79 years (24% in men and 12% in women) in the countries included in this study, where the potential gain in life expectancy at age 40 was 2.4 years in men and 1 year in women, on average. Over the past three decades, decreases in smoking-related mortality among men in HICs have reduced the negative effect of smoking on life expectancy. Currently (2005–2010), the potential gains in life expectancy among men in HICs at age 40 after the elimination of smoking-related deaths are 2.7 years compared with the 3.6 years estimate 30 years previously. In LMICs, this decline occurred only recently at a much lower magnitude

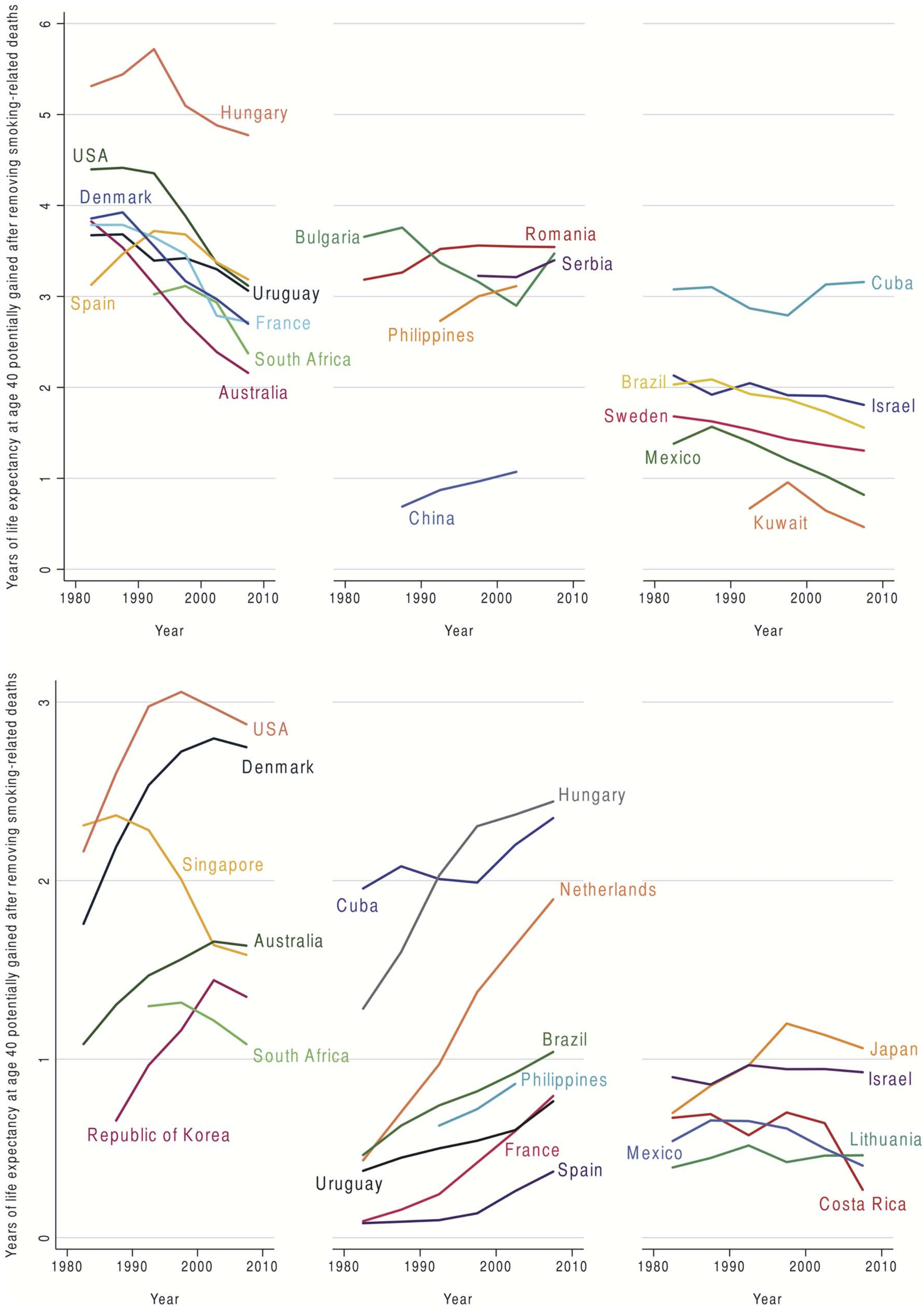

Figure 2 Gains in life expectancy at age 40 after deleting smoking-related deaths among men (top) and women (bottom) between 1980 and 2010.

(potential years gained by eliminating smoking-related deaths were 1.9 in 2005–2010 compared to 2.4 in 1980–1984)). In contrast, the continuing rise of smoking-related deaths among women in HICs has held back the expected increase in their life expectancy, that is, eliminating smoking-related deaths would extend women's life expectancy by 1.3 years in 2005–2010 (vs 0.9 years in 1980–1984). Over the past 30 years, the share of CVD deaths of all deaths related to smoking has decreased from

43% to 35% in men and 61 to 50% in women, whereas the share of lung cancer mortality due to smoking rose from 22% to 28% in men and from 15% to 24% among women. A similar phenomenon was observed in HICs and LMICs. Moreover, during the recent decades, the majority of countries have undergone a great reduction in adult mortality.[18] This might have contributed to the diminishing effect of smoking on total mortality in men in HICs.

Despite differences in methodologies, our estimates confirmed the continuous increase in smoking-attributable deaths among women and the recent decrease among men in HICs.[19 20] Since prospective studies in middle-income countries are scarce, comparisons with our results are difficult. A study in South Africa[21] estimated that 10% and 4% of total deaths between 1999 and 2007 in adult men and women (>35 years), respectively, were caused by tobacco smoking, whereas in our study these estimates were more than double (21.5% CI (20.8 to 22.6) in men and 9.2% CI (8.0 to 9.8) in women aged 40–79) in 2000–2010. Yet, Sitas and colleagues estimated the proportion of deaths related to tobacco smoking based on excess hazards among active smokers as compared to non-smokers (lifelong non-smokers and former smokers), making their results not comparable to ours. In our study, the equivalent prevalence measure is the SIR that captures the real impact of tobacco smoking from active smokers as well as former smokers on lung cancer mortality. Another study from China[22] reported 12% of total deaths in men aged 40 and over to be smoking-related in 2005 differing from the 7.3% (6.6; 8.4) estimated for 2000 in this study. However, this study uses a different age range and period study, as well as another methodology, for example, different adjustment for other risk factors such as indoor pollution, which can explain the difference from our results. Uncertainties regarding the estimates for smoking-related deaths in LMICs call for more local prospective studies in such countries.

Like other studies, our study shows that part of the existing discrepancy in life expectancies between sexes is related to sex differences in tobacco smoking.[23–26] The reduction in the life expectancy gap between sex ranges from 3 years in Russia (with a life expectancy gap of 9.8 years between sexes before excluding smoking deaths) to practically 0 years in Sweden (with a life expectancy gap of 3.7 years before excluding smoking deaths). In HICs such as Denmark, the USA or Sweden, the prevalence of smoking among women has been almost as high as among men, which explains the diminishing gap in life expectancy between sexes in these countries.[25 27 28] In Russia, where binge alcohol drinking is much higher in men, this may interact with smoking[29] and provide an additional explanation to the large gender gap in life expectancy. As for many countries in Latin America, tobacco smoking contributed little to explain the sex difference in life expectancies. Empowerment of women has been suggested as one of the drivers of increasing smoking prevalence in women in HICs.[30 31] It remains to be seen if empowerment of women in middle-income countries will lead to future convergence to men's prevalence of smoking.

Other social and economic factors have been strongly related to tobacco smoking, and this relationship differs according to the country's development level. Individuals in lower socioeconomic groups are more likely to smoke cigarettes in HICs,[32 33] while the reverse was observed in some LMICs.[34 35] The decrease in smoking-related deaths in HICs has been mainly driven by the reduction in smoking prevalence among the middle-income and high-income groups, which represent a large proportion of the population in these countries.[36] The increase in smoking prevalence and its impact on mortality in middle-income countries has been slow in part due to the smaller size of the high socioeconomic group which is able to purchase large quantities of cigarettes. In such countries, economic growth may increase the purchasing power of lower and middle socioeconomic groups. This, in addition to the low cigarette prices and shallow political commitment to control tobacco smoking, may hence increase smoking uptake and future smoking-related deaths in these subpopulations.[37–39]

Lung cancer, COPD and UADC are the main causes of death affected by smoking-related mortality. However, the proportion of smoking-related deaths in each of these disease categories varies depending on the country's position within the smoking epidemic continuum and the latency for each disease. In countries in the later stage of the smoking epidemic, 80% of lung cancer deaths in men are attributable to smoking, whereas only about 40% of lung cancer deaths were related to smoking in countries in the early stage. In contrast, the proportion of CVD deaths due to smoking remains rather stable throughout the countries. This might be related to the relatively small and stable effect sizes (RR). The composition of smokers and duration of the smoking epidemic in each country may also influence the distribution of smoking-related deaths. For example, in Japan, despite the high prevalence of smoking among men (around 60% in 1980),[40] only 20% of total mortality between ages 40 and 79 years was attributed to cigarette smoking 30 years later. This is probably caused by the recent start of the smoking epidemic as compared to other western countries and later age at smoking initiation in Japan.[41]

To the best of our knowledge, this is the first study to extend an available method of estimation of smoking-related deaths in developed countries to developing countries. The method is based on the original indirect method developed by Peto *et al*, but adjusts the estimation of the smoking prevalence and the use of RR to the timing of the smoking epidemic in each country to enable estimation of smoking-related deaths in countries where the impact of smoking on overall mortality is still low. After excluding countries with lower quality data to ensure robust final estimates, data quality remains variable in some years for some countries when the percentage of ill-defined codes is >20%. Various sensitivity analyses were performed to test the robustness of our final method (see online supplementary materials). Differences in the final PAFs as compared with the previous methods are minor for men in countries with lower levels of PAFs as well as for all PAFs in women. Larger differences were observed in estimates for men with higher PAFs, that is, up to 6.8 percentage points of difference with estimates produced using the original indirect method. The application of a different RR is the main reason behind this difference. Yet we believe that the use of varying RR conforms to the recent analysis describing the changing RR over the smoking epidemic continuum.[7] Applying a changing RR allows us a better adjustment to the different exposure times of each cause of death.[16]

The first limitation of this study is the assumption that lung cancer is mainly caused by tobacco smoking.[10 14] We adjusted for the impact of air pollution on lung cancer mortality in never-smokers in countries such as China,[4] but other known risk factors for lung cancer, namely asbestos, and other substances such as radon or chromium[42] were not controlled due to the absence of relevant information. In the case of other risk factors for lung cancer such as air pollution, its impact on the burden of lung cancer in non-smokers will be small.[43] Other tobacco-related causes of death, such as injuries caused by accidental fires or prenatal conditions due to smoking during pregnancy, were not included in this study and may cause an underestimation of the effect of smoking on total mortality, and hence life expectancy. Another source of underestimation is the reduction of 50% of excess mortality due to tobacco smoking, which in front of the most recent evidence might be too conservative, especially for most recent cohorts.[44] Furthermore, the fact that we restricted our analysis to deaths between 40 and 79 years ignores a large share of deaths among the older age groups, leaving aside a discussion on the impact of smoking among the oldest old. Nevertheless, the ongoing compression of mortality, especially in developed countries, is shifting total deaths to a later age and along with it smoking-related deaths.[45]

Finally, RRs are also determined by the intensity and duration of smokers.[46] Differences in the composition of light and heavy smokers could imply biases in the calculation of the SIR ratio, as well as using RRs that are unsatisfactory for some diseases. Further investigation based on the intensity and duration of smokers in each country could be a solution to improve the estimation of the impact of smoking on total mortality. Also, the absence of mortality data by cause of death from a majority of LMICs, especially in Africa and other populated Asian countries such as India or Indonesia, impedes assessing the level of smoking-related mortality and its impact on life expectancy for every region in the world.

CONCLUSION

During the past three decades, tobacco smoking continues to play an important role in determining the human's lifespan. Currently, the potential gain in life expectancy at age 40 by removing smoking-related deaths in men was 2.4 years; however, this varied widely by the countries and periods studied. In women, 1 year of life can be gained by removing current smoking-related death, yet the smoking epidemic has not reached its peak in almost all countries in this study. Smoking is expected to continue showing a negative impact in countries where the smoking epidemic has not subsided. This is true for women in the majority of the countries studied here and for men from countries where smoking-related mortality is still high or has not started to decline, which is not restricted to LMIC. Knowledge concerning countries' current position within the smoking epidemic continuum is of great importance in predicting the future evolution of smoking-related mortality and also in understanding the main causes of death associated with cigarette smoking.[47] Therefore, there is an urgent need for improved risk factor, disease and mortality surveillance data, especially in the LMICs,[48] in order to design effective interventions at the national and international levels to prevent the catastrophic expected impact of smoking on global health.

What this paper adds

- We propose a modification to the original method developed by Peto and colleagues that adjusts the reference population to the country's position within the smoking epidemic. This has enabled the estimation of time trends for 63 countries on the effect of tobacco smoking on total mortality and life expectancy, where 26 countries are from low-income and middle-income settings.
- Overall, we estimate that if the current tobacco-related deaths were eliminated, life expectancy would increase by 2.4 years for men and 1 year for women, on average.

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Contributors ER and IS designed the study and method. ER conducted the analysis of the data. ER and IS wrote the first draft of the paper. PJ and DF contributed to a critical review of the paper and revision of the final article. IS is the guarantor and provided approval to its final version and submission.

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