

Global trends of lung cancer mortality and smoking prevalence

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Abstract: Lung cancer killed approximately 1,590,000 persons in 2012 and currently is the leading cause of cancer death worldwide. There is large variation in mortality rates across the world in both males and females. This variation follows trend of smoking, as tobacco smoking is responsible for the majority of lung cancer cases. In this article, we present estimated worldwide lung cancer mortality rates in 2012 using the World Health Organization (WHO) GLOBOCAN 2012 and changes in the rates during recent decades in select countries using WHO Mortality Database. We also show smoking prevalence and trends globally and at the regional level. By region, the highest lung cancer mortality rates (per 100,000) in 2012 were in Central and Eastern Europe (47.6) and Eastern Asia (44.8) among males and in Northern America (23.5) and Northern Europe (19.1) among females; the lowest rates were in sub-Saharan Africa in both males (4.4) and females (2.2). The highest smoking prevalence among males is generally in Eastern and South-Eastern Asia and Eastern Europe, and among females is in European countries, followed by Oceania and Northern and Southern America. Many countries, notably high-income countries, have seen a considerable decrease in smoking prevalence in both males and females, but in many other countries there has been little decrease or even an increase in smoking prevalence. Consequently, depending on whether or when smoking prevalence has started to decline, the lung cancer mortality trend is a mixture of decreasing, stable, or increasing. Despite major achievements in tobacco control, with current smoking patterns lung cancer will remain a major cause of death worldwide for several decades. The main priority to reduce the burden of lung cancer is to implement or enforce effective tobacco control policies in order to reduce smoking prevalence in all countries and prevent an increase in smoking in sub-Saharan Africa and women in low- and middle-income countries (LMICs).

Keywords: Lung cancer; mortality; smoking; tobacco

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Introduction

Before the start of mass production of tobacco products in the late 19th century, lung cancer was a rare cancer (1). Currently, however, it is the leading cause of cancer deaths in males and the second leading cause in females globally (2). In 2012, lung cancer killed an estimated 1,098,700 men and 491,200 women worldwide, corresponding to 24% and 14% of all cancer deaths in males and females, respectively (2).

The most important cause of lung cancer is tobacco

smoking, although the proportion of lung cancer deaths attributable to smoking vary across populations, ranging from >80% in the United States (3) and France (4) to 61% in a pooled analysis of 21 Asian cohorts (5) and 40% in sub-Saharan Africa (6). Lung cancer is also caused by secondhand tobacco smoke, with an estimated 21,400 lung cancer deaths in non-smokers annually (7). Other risk factors for lung cancer include indoor air pollution because of unventilated combustion of coal in the household for heating and cooking (8); outdoor air pollution (9,10);

exposure to hazardous chemicals in some occupations, such as coal gasification and aluminum production (11); exposure to radiation from indoor radon released from soil and building materials (12); and exposure to asbestos, silica dust, and several elements, including arsenic (13). Most of the lung cancer deaths due to secondhand smoke and indoor air pollution occur in low- and middle-income countries (LMICs), particularly China (14,15).

In this article, we present estimated worldwide lung cancer mortality rates in 2012. We also show trends of lung cancer mortality during recent decades in select countries in various global regions. Trends in lung cancer mortality rates in a country generally follow historical trends in smoking prevalence, with the trend in lung cancer rates lagging 20-30 years. Therefore, we present contemporary regional smoking prevalence and recent trends in order to provide insights into future lung cancer trends. We do not provide detailed information about the risk factors other than smoking because, except for some specific populations, these risk factors are responsible for a relatively small proportion of lung cancer deaths worldwide (14) and because data on these risk factors are sparse.

Data sources

We used GLOBOCAN 2012 as calculated by the International Agency for Research on Cancer (IARC) to provide estimates of lung cancer mortality rates for all countries worldwide (16). Estimates are generally of higher quality in high-income countries because of higher coverage and quality of death registration (17). We examined temporal trends in lung cancer rates for select countries using the World Health Organization (WHO) Mortality Database (18). All rates were age-standardized to the 1960 Segi world standard population and expressed per 100,000 population (19). We present data for mortality only because there are no substantial differences between incidence and mortality rates and trends, even in economically developed countries, because of poor survival (20). We used the United Nations groupings (with the exception of Cyprus, which is included in Southern Europe for GLOBOCAN) for the classification of the world's regions (*Table 1*).

Data on smoking prevalence were obtained from *The Tobacco Atlas*, fifth edition (21), which used estimated data from the Institute for Health Metrics and Evaluation, University of Washington, United States (22), the WHO Report on the Global Tobacco Epidemic 2013 (23), and a national survey with more recent data that were not

included in the above sources (24).

Lung cancer mortality rates in 2012

Lung cancer is the leading cause of cancer death in 87 countries in men and 26 countries in women, with the latter largely confined to high income countries (2). There is large variation in mortality rates across the world in both males and females (*Figure 1*), with about 30-fold difference in both sexes.

Among males, the highest rates (per 100,000) worldwide are found in Hungary (66.6), Armenia (65.6), the Former Yugoslav Republic of Macedonia (63.5), and Serbia (61.8) (*Figure 2*), whereas the lowest rates are found in Nigeria, Tanzania, and Niger (all <1.0). In general, the highest mortality rates (per 100,000) in males by region were in Central and Eastern Europe (47.6) and Eastern Asia (44.8) and the lowest rates are found in Northern Africa (14.0), South-Central Asia (10.7), Central America (9.0), and sub-Saharan Africa (4.4), with the lowest rate in Western Africa (1.5 per 100,000).

Among females, the highest lung cancer mortality rates (per 100,000) in 2012 worldwide were found in North Korea (30.7), Denmark (28.4), Hungary (26.6), and Canada (25.1) (*Figure 3*). By region, the highest estimated lung cancer mortality rates (per 100,000) in 2012 were in Northern America (23.5), Northern Europe (19.1), Eastern Asia (16.2), Western Europe (14.8), Oceania (14.1), and Caribbean (12.2). Apart from Eastern Asia, whose overall rates are dominated by China, in all these populations smoking prevalence in women has been moderate to high. The high mortality in China (18.0 per 100,000) despite a relatively lower prevalence of female smoking compared to more developed countries is likely due to higher exposure to secondhand smoke and indoor air pollution from unventilated combustion of coal used for heating and cooking purposes (8,14). Lung cancer mortality rates in women were the lowest in the regions where female smoking has been historically uncommon, including Western Asia (6.2 per 100,000), Central America (4.3 per 100,000), South-Central Asia (3.1 per 100,000), Northern Africa (2.8 per 100,000), and sub-Saharan Africa (2.2 per 100,000). The lowest estimated mortality rates were for Middle Africa (0.7 per 100,000).

Tobacco epidemic

In most high-income countries, smoking prevalence in men started to increase rapidly from the beginning of the 19th century (25,26). After a few decades, this increase was

Table 1 List of countries by regions (based on GLOBOCAN 2012)

Region	Countries
Northern Africa	Algeria, Egypt, Libya, Morocco, Sudan, Tunisia, Western Sahara
Sub-Saharan Africa	
Eastern Africa	Burundi, Comoros, Djibouti, Eritrea, Ethiopia, French La Réunion, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Somalia, South Sudan, Tanzania, Uganda, Zambia, Zimbabwe
Middle Africa	Angola, Cameroon, Central African Republic, Chad, Congo (Democratic Republic of), Congo (Republic of), Equatorial Guinea, Gabon
Southern Africa	Botswana, Lesotho, Namibia, South African Republic, Swaziland
Western Africa	Benin, Burkina Faso, Cape Verde, Cote d'Ivoire, Gambia, Ghana, Guinea-Bissau, Guinea, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo
Northern America	Canada, United States of America
Caribbean	Bahamas, Barbados, Cuba, Dominican Republic, French Guadeloupe, French Martinique, Haiti, Jamaica, Puerto Rico, Trinidad and Tobago
Central America	Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama
South America	Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, French Guiana, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela
Eastern Asia	China, Japan, Korea (Democratic People's Republic of), Korea (Republic of), Mongolia
South-Eastern Asia	Brunei Darussalam, Cambodia, Indonesia, Lao People Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste, Viet Nam
South-Central Asia	Afghanistan, Bangladesh, Bhutan, India, Iran, Kazakhstan, Kyrgyzstan, Maldives, Nepal, Pakistan, Sri Lanka, Tajikistan, Turkmenistan, Uzbekistan
Western Asia	Armenia, Azerbaijan, Bahrain, Georgia, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, State of Palestine, Syrian Arab Republic, Turkey, United Arab Emirates, Yemen
Central and Eastern Europe	Belarus, Bulgaria, Czech Republic, Hungary, Republic of Moldova, Poland, Romania, Russian Federation, Slovakia, Ukraine
Northern Europe	Denmark, Estonia, Finland, Iceland, Ireland, Latvia, Lithuania, Norway, Sweden, United Kingdom
Southern Europe	Albania, Bosnia Herzegovina, Croatia, Cyprus, Greece, Italy, Former Yugoslav Republic of Macedonia, Malta, Montenegro, Portugal, Serbia, Slovenia, Spain
Western Europe	Austria, Belgium, France (metropolitan), Germany, Luxembourg, Netherlands, Switzerland
Oceania	Australia, Fiji, French Polynesia, Guam, New Caledonia, New Zealand, Papua New Guinea, Samoa, Solomon Islands, Vanuatu

Available online: <http://globocan.iarc.fr/Pages/population.aspx>

followed by a substantial increase in smoking prevalence in women (25,26). In the United States, the prevalence reached its peak in the 1950s in men (~55%) and in the 1960s in women (~35%). Changes in smoking prevalence in high-income countries have been reflected in smoking-related mortality by an approximately 3-4 decade lag (26). This pattern is commonly termed the 'tobacco epidemic' or 'cigarette epidemic'. It should be noted that in a few high-income countries, including Japan, smoking prevalence did not increase in females following the increase in male smoking (27). Similarly, female smoking has not substantially increased in many LMICs, in particular Asian

and African countries; however, a surge in male smoking in Asia has happened much more recently than in high-income countries and an increase in male smoking in many sub-Saharan African countries has started only lately.

In the process of tobacco epidemic, usually the average intensity of smoking (or the number of cigarettes smoked per day) increases while the age of smoking initiation decreases. The mean age of smoking initiation after the epidemic is established is generally <20 years, while it is usually higher before or in the earlier stages of the tobacco epidemic (3,28). Over time, an increase in smoking intensity, smoking initiation in earlier ages, or a combination of both

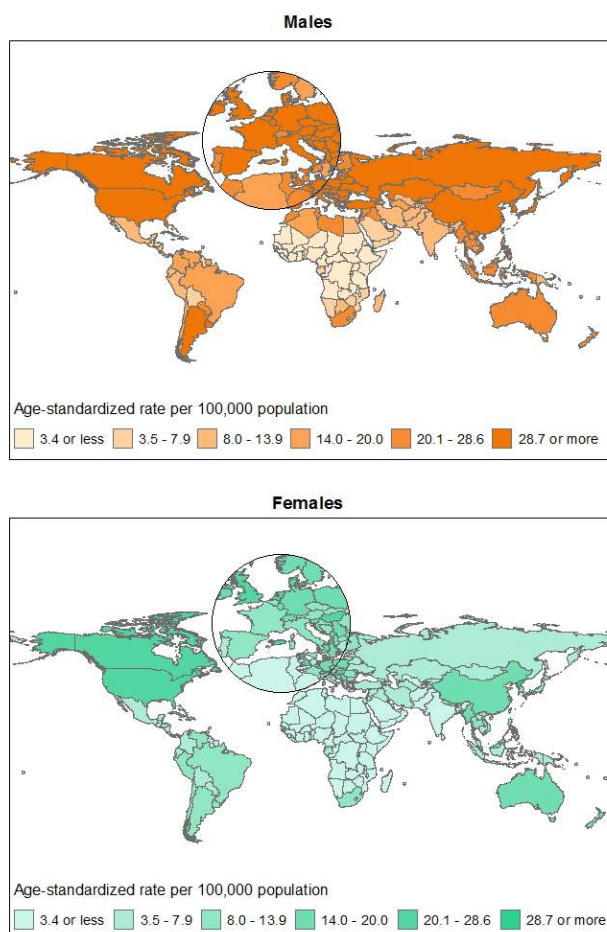


Figure 1 Lung cancer mortality by sex, 2012, age-standardized rate (world). Data source: GLOBOCAN 2012.

can increase the magnitude of the association between smoking and lung cancer in a population. In the United States, the relative risk for the association between current smoking and lung cancer mortality in women increased from 2.7 to 12.7 and to 25.7 in cohorts conducted in the 1960s, 1980s, and 2000s, respectively (29).

There are substantial differences in smoking prevalence in socioeconomic groups in many countries. In high-income countries, smoking prevalence at the beginning of the tobacco epidemic (before the middle of the last century) in both men and women was highest in persons with higher socioeconomic status (30,31). Over time, in particular after the health effects of smoking became known in the 1950s and early 1960s, the high smoking prevalence shifted to lower socioeconomic groups as persons with higher socioeconomic status became more likely to quit and less likely to initiate smoking (32). In 1940 and 2009–2010, respectively, smoking

prevalence in the United States in those with college education and above was 40% and 13%, whereas in those with less than high school education, it was 36% and 35%, respectively (31,32). In LMICs, similar changing patterns of smoking prevalence by socioeconomic status have been reported (33–35). Some ethnic groups have higher smoking prevalence in part because they are disproportionately represented in lower socioeconomic groups (36,37). Similar to patterns of smoking, mortality rates within a country are usually higher among lower socioeconomic groups.

Trends in smoking prevalence and lung cancer mortality rates by region

In 2012, an estimated 928 million men and 207 million women were current smokers (38). Currently, countries with the highest male smoking prevalence are generally in Eastern and South-Eastern Asia and Eastern Europe (*Figure 4*). European countries have the highest female smoking rates, followed by Oceania and Northern and Southern America.

There have been substantial variations in trends of smoking prevalence across countries (22). While many countries, notably high-income countries, have seen a considerable decrease in smoking prevalence in both males and females, in many other countries there has been little decrease or even an increase in smoking prevalence (21). Similarly, the lung cancer patterns vary across countries, from decreasing, stabilizing, and increasing in view of temporal trends in lung cancer rates which lag 3–4 decades following smoking trends (26).

Americas

In many countries in the Americas, smoking prevalence is approximately 20–30% in men and 10–20% in women, although prevalence is lower in most countries in Central America, especially among women. Following the start of a considerable decrease in male smoking prevalence from the 1950s and 1960s in the United States and Canada, lung cancer mortality rates in men have substantially dropped in both countries, from a peak of over 50 deaths per 100,000 in 1990 to about 30 deaths per 100,000 around 2010 (*Figure 5*). The decrease in smoking and lung cancer mortality among women in these two countries followed a similar pattern but with an approximately 20 years lag (*Figure 6*) (26).

The tobacco epidemic in many South American and Caribbean countries began a few decades later than in Northern America, with the smoking prevalence first increasing

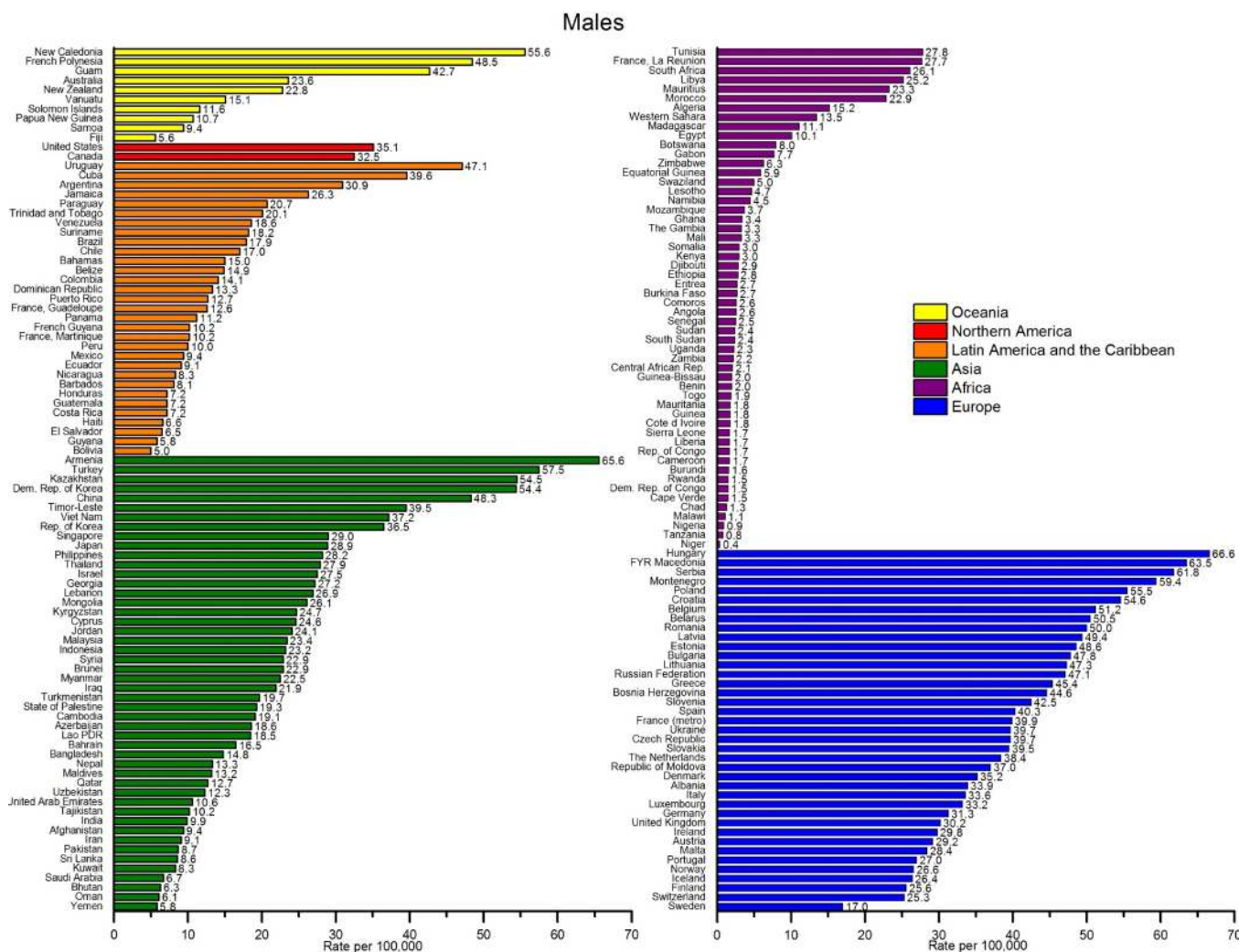


Figure 2 Lung cancer mortality rates in males, all ages, 2012. Age-standardized rate (world). Data source: GLOBOCAN 2012.

in men and then in women. In most of these countries, smoking prevalence has decreased in both men and women, although the decreases were smaller and started later than in Northern America. There has been no significant decrease in smoking prevalence in a few countries in this region, including Chile, Costa Rica, Jamaica, Peru, and Suriname (22). Depending on whether or when smoking prevalence has started to decline in these countries, the lung cancer mortality trend is a mixture of decreasing (Argentina, Mexico) or stable (Brazil, Cuba) mortality rates in men (Figure 5), while in many countries it has been increasing in women (Argentina, Brazil) (Figure 6) (39).

Europe

Some Northern European countries have been able to

substantially reduce smoking prevalence in both men and women (21). In these countries, lung cancer mortality rates in men have been decreasing for several decades, such as in the United Kingdom and Denmark (Figure 5), but among women, the mortality rate has just recently started to decrease in the United Kingdom and become stable in other countries (Figure 6), reflecting a later decline in smoking prevalence in women. Many other high-income countries in Europe, such as Germany and the Netherlands, have also seen a major decrease in prevalence of smoking in men, but with only a recent and modest decrease in female smoking (22). Consequently, lung cancer mortality rates in men in these countries have seen a substantial decrease in recent decades but they are still increasing in women. On the other hand, several countries in Eastern and Southern Europe and former

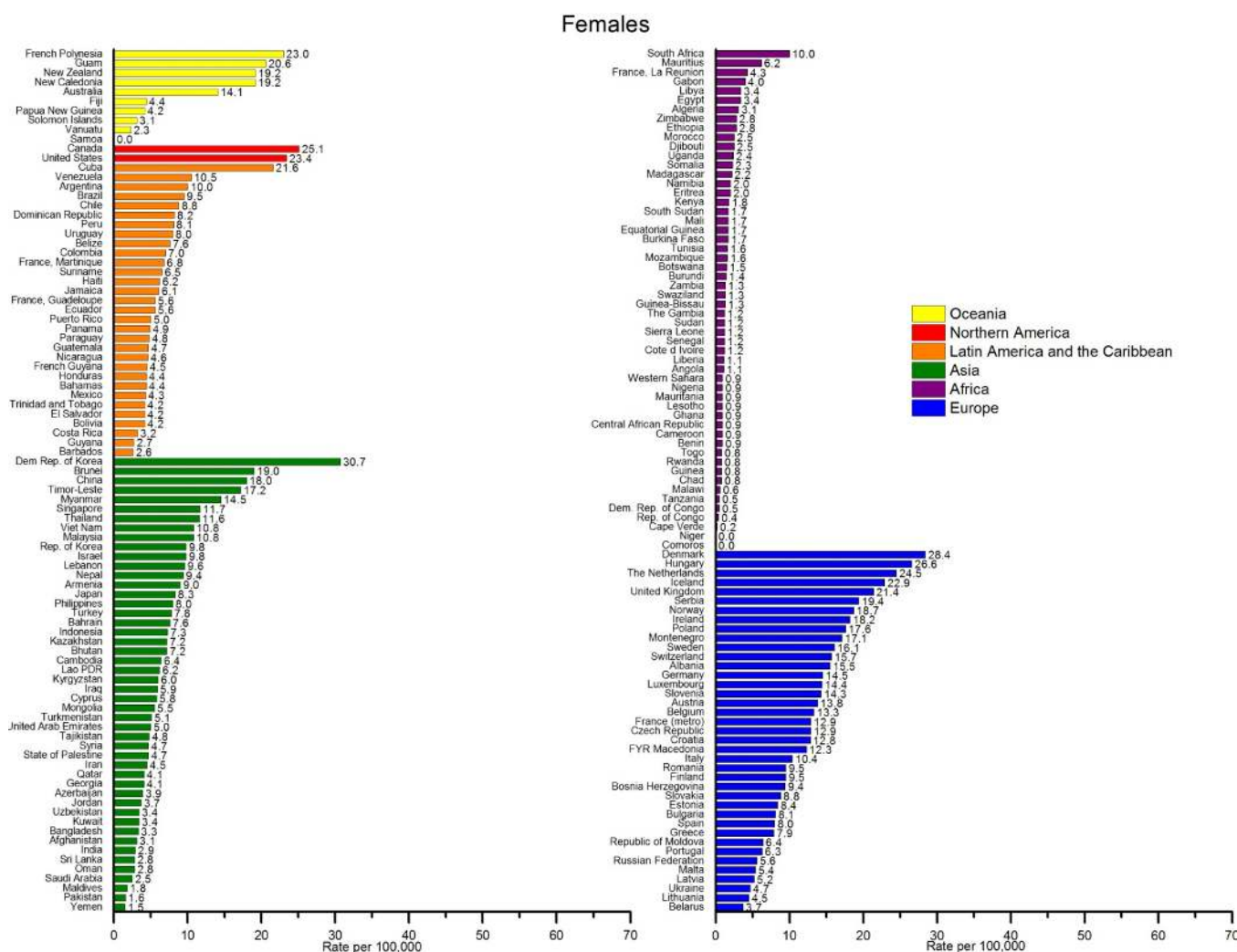


Figure 3 Lung cancer mortality rates in females, all ages, 2012. Age-standardized rate (world). Data source: GLOBOCAN 2012.

republics of the Soviet Union have seen little/modest or very recent decreases in male smoking prevalence, and the prevalence is still high (generally, a daily smoking prevalence of $\geq 33\%$). In these countries, lung cancer mortality rates have been flat or increasing in men and increasing in women. Nevertheless, in many European countries in which the overall lung cancer mortality rates in women is increasing or stable, younger women (age 30–49 years) have seen a decrease in the mortality rates in more recent years, as this age group reflects the early effect of decreases in initiation of smoking (40).

Asia

Following an increase in smoking prevalence in most

LMICs in Asia in the 1980s in men, the prevalence started to decrease in the mid-1990s in many of these countries, although the decrease has been mostly modest. However, smoking prevalence in men did not decrease in several countries in South-Eastern Asia (including Indonesia with male adult daily smoking prevalence of 57.1%, the highest in the world), Western Asia, and republics of the former Soviet Union in Central Asia (such as Kazakhstan, Turkmenistan, and Uzbekistan).

In higher-income populations of Asia, including Japan and Hong Kong (China), where male smoking prevalence surged and declined earlier than in other Asian countries, lung cancer mortality rates in men started a substantial decrease in the 1980s–1990s (*Figure 5*). Japan, Hong Kong (China), and Singapore have had some of the highest

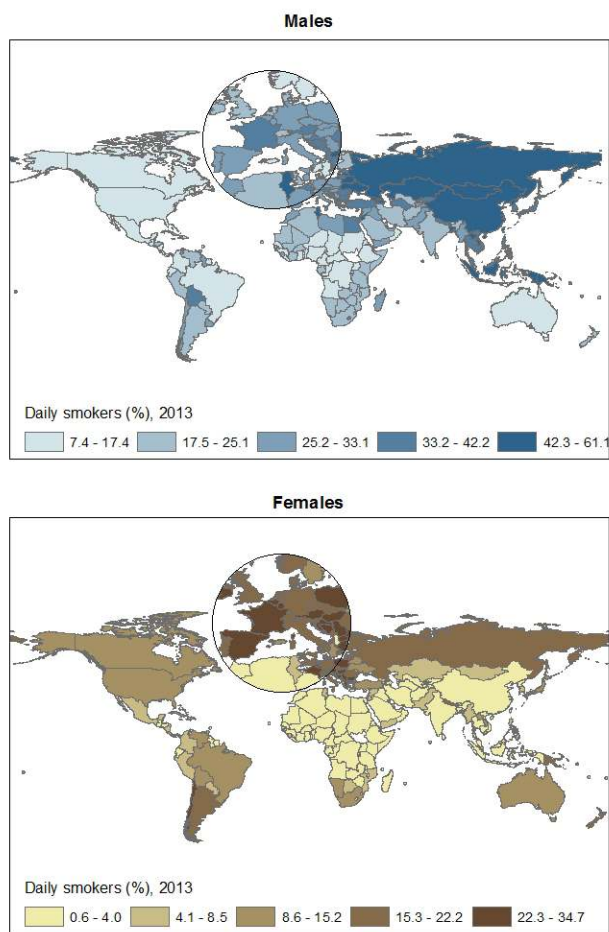


Figure 4 Estimated daily smoking prevalence (%) by sex, 2013. Data source: *The Tobacco Atlas*, 5th edition.

decreases in male smoking prevalence in Asia during 1980–2012 (41). In other high-income Asian countries, however, only a modest decrease in lung cancer mortality in South Korea from the 2000s (42,43) and an increase in Taiwan (44) have been reported.

Much less data on trends in lung cancer mortality are available from LMICs in Asia. However, patterns of male smoking prevalence suggest that lung cancer mortality among men in South-Eastern Asia and republics of the former Soviet Union in Central Asia are increasing and will stay high for several decades. In 2013, China had over 276 million daily smokers, of which 264 million were men (21). Following a substantial increase, China has seen a modest decrease in male smoking prevalence, with both the increase and decrease starting earlier in the urban population. Similarly, after an increase in lung cancer mortality rates in both the urban and rural populations of China, rates have

started to slightly decline in the urban population, but they are still increasing in the rural population (45,46). In the remaining Asian LMICs, lung cancer mortality trends vary from increasing or stable to a modest decrease, depending on patterns of male smoking (47–51). Smoking in women in the majority of Asian LMICs has been traditionally low (mostly below 5%) and has changed little during 1980–2012 (22). Consequently, lung cancer mortality rates among women have been low and relatively stable in these countries (40), with an exception of some Asian countries, especially North Korea and China, where indoor air pollution appears to be an important risk factor for lung cancer in women. Notably, the lung cancer rate in Chinese women is higher than in many European countries with higher smoking prevalence, such as Germany, France, and Italy.

Africa

The overall smoking prevalence in African men is lower than in men from other parts of the world (*Figure 4*). With greater affordability of tobacco products, however, smoking prevalence in many sub-Saharan African countries has started to rise, and this increase has been predicted to continue if appropriate tobacco control interventions are not implemented (52). Information on trends of lung cancer mortality in Africa is sparse, but a few available epidemiological studies have suggested a decrease in lung cancer mortality among men in relatively higher income countries in Southern Africa (53), following a comprehensive tobacco control program including high tax on cigarettes (54). However, lung cancer mortality rates in men are expected to increase in many other African countries. Similar to Asia, smoking prevalence and lung cancer mortality among women in Africa has been low.

Oceania

Australia and New Zealand are among the few countries, along with the US and the UK, where the tobacco epidemic was first established (at the early part of the last century). Smoking prevalence substantially decreased in both sexes in recent decades (to <20% in 2013); consequently, lung cancer mortality rates in these countries have been decreasing in men and stabilizing in women (*Figures 5,6*). Smoking prevalence among men in some other countries in this region is generally high, and these countries are among some of the countries with highest lung cancer mortality rates worldwide (*Figure 2*). Although in several of these countries

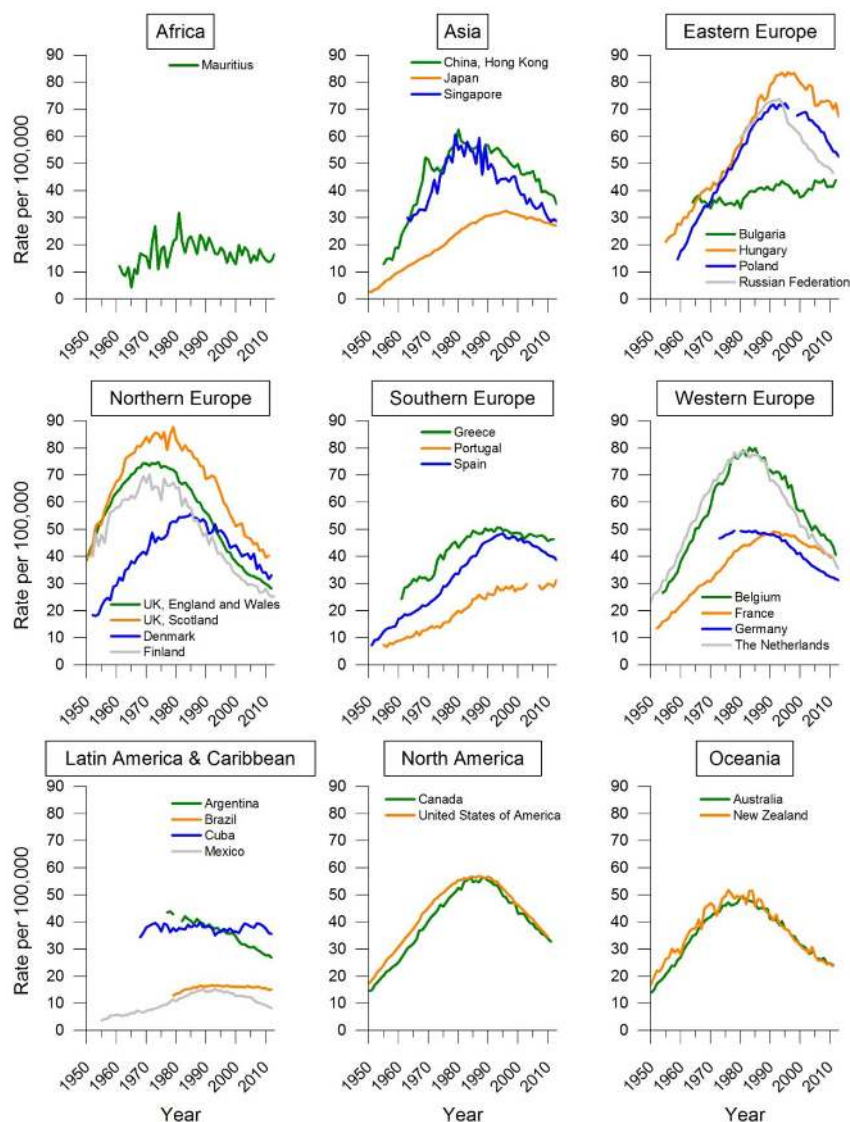


Figure 5 Trends in lung cancer mortality rates among males for select countries, 1950–2013. Age-standardized rate (world). Data source: WHO IARC Cancer Mortality Database.

female smoking prevalence is <5%, in several others it is >10%, resulting in a wide variation in lung cancer mortality rates in females across the countries (Figure 3). Most of these countries have seen little change or modest decreases in smoking prevalence in recent decades (22).

Future perspectives

Lung cancer could be cured if it is diagnosed in early stages and if appropriate treatment is accessible. Low-dose computed tomographic screening of high-risk individuals for early detection of lung cancers could improve prognosis

of lung cancer in this group (55,56), although this screening method has not been studied outside of high-income countries. Nevertheless, the best practice to reduce the burden of lung cancer is to prevent it, because even the most successful screening programs would avert only a subset of all lung cancer deaths (this has been estimated to be ~8% in the US) (57), and the treatment of lung cancer is complicated and may not be accessible to everybody, particularly in low-resource countries. As the majority of lung cancer cases can be attributed to smoking, the main priority is to reduce smoking prevalence through effective tobacco control policies and regulations. Tobacco

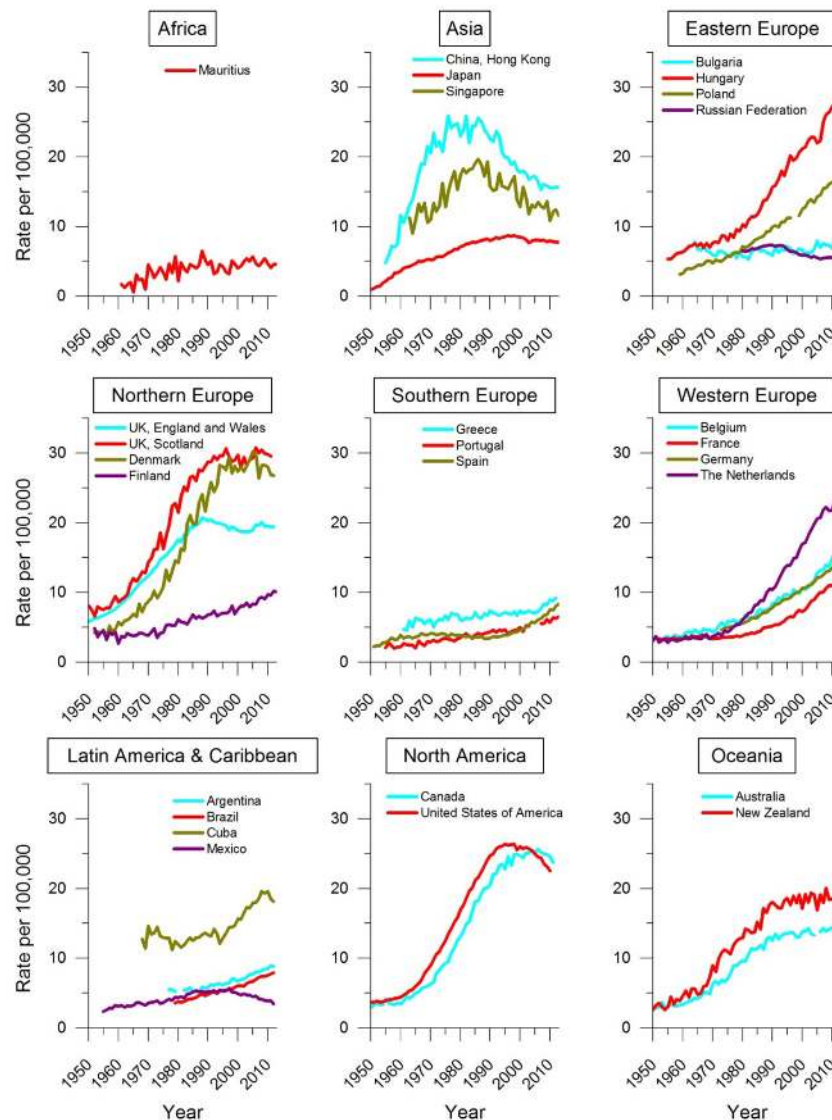


Figure 6 Trends in lung cancer mortality rates among females for select countries, 1950–2013. Age-standardized rate (world). Data source: WHO IARC Cancer Mortality Database.

control policies averted an estimated number of over 800,000 premature deaths from lung cancer only in the US from 1975 to 2000 (58), despite wide variations in implementation of these policies across states. In the US, tobacco control policies are implemented at the state level, and southern states generally have less intense tobacco control and consequently higher smoking prevalence than other states (37). Tobacco control could not only reduce lung cancer mortality, but also lower the burden of multiple other smoking-related diseases. It has been shown that few public health investments provide greater dividends than tobacco control (21).

The WHO’s Framework Convention on Tobacco Control is a basis for countries to implement tobacco control policies and is an effective tool to reduce smoking prevalence and related harms (59). In order to facilitate implementation of these policies in countries, WHO has introduced MPOWER measures, which include (I) monitoring tobacco use and prevention policies; (II) smoke-free air policies; (III) cessation programs; (IV) warnings (health warnings and mass media); (V) bans on advertising, promotion, and sponsorship; and (VI) raising tobacco taxes (60). These policies can be implemented at increasing levels. Despite great achievements in tobacco control in a

number of countries, the global coverage of the policies is still far behind the recommended levels by WHO. For example, out of 194 countries in the WHO's list, only 29 countries have complete tobacco advertising ban policies, 71 countries have moderate to complete smoke-free policies, and 49 countries (with approximately 20% of the world's population) are covered by at least two policies at the highest level (60). In 2012, Turkey became the first (and so far the only) country that has achieved the highest level of all six MPOWER measures (61,62). Iran, Panama, and Uruguay are the countries that have achieved the highest level of recommended for five measures (all measures except for taxation) (63).

A major priority for most LMICs is to prevent the tobacco epidemic in women, and for most sub-Saharan African countries is to prevent a surge in smoking in both sexes. In addition to local funding, international aid could help tobacco control programs being implemented in very low-resource countries. In addition to tobacco control, efforts should be made to reduce the exposure to other risk factors of lung cancer, notably indoor and outdoor air pollution, when applicable.

Conclusions

Despite major achievements in tobacco control, with current smoking patterns lung cancer will remain a major cause of death worldwide for several decades. Effective tobacco control policies must be implemented or enforced in order to further reduce smoking prevalence. Lung cancer mortality is likely to greatly increase in sub-Saharan Africa if appropriate tobacco control programs are not implemented. Although smoking is a highly preventable risk factor for lung cancer, exposure to other risk factors (e.g., indoor and outdoor air pollution) also needs to be reduced, when applicable.

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Footnote

Conflicts of Interest: The authors have declared no conflicts of interest.

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