

LUNG CANCER MORTALITY AND TOBACCO CONTROL POLICIES IN CZECHIA, HUNGARY AND POLAND: A RETROSPECTIVE ANALYSIS

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Abstract

Long-term tobacco smoking is the primary cause of lung cancer and a major driver of avoidable mortality, but the impact of tobacco control policies on lung cancer mortality is delayed by 20–30 years. This study analyses period and cohort trends in lung cancer mortality in Czechia, Hungary, and Poland from 1950 to 2023 within the framework of the smoking epidemic model and the timing of tobacco control policy implementation. Using harmonised cause-of-death data and population exposure, we examined age-standardised mortality rates and cohort patterns. The results revealed pronounced cohort effects and substantial gender disparities, with earlier peaks and subsequent declines in male mortality, particularly in Czechia, and later increases or plateauing trends among females across all three countries, consistent with different stages of the smoking epidemic model. Comparisons with policy timing indicate that lung cancer mortality declines cannot be attributed to tobacco control policies alone. In Czechia, declines began before major interventions, while in Hungary and Poland, they occurred later but still reflect earlier smoking histories. Lung cancer mortality trends are thus primarily driven by cohort-specific smoking histories, with policies influencing outcomes indirectly over the long term.

Keywords: tobacco control policies, lung cancer mortality, cohort mortality, Central Europe

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INTRODUCTION

Lung cancer is one of the leading causes of cancer mortality worldwide, accounting for 18.7% of all cancer deaths in 2022, mainly due to long-term tobacco smoking, particularly in males (Bray *et al.*, 2024). Due to typically late diagnosis and low survival rates, lung cancer mortality closely reflects cumulative smoking exposure at the population level (de Groot – Wu –

Carter – Munden, 2018). Although other risk factors such as air pollution, second-hand smoke, and genetic predisposition contribute to disease incidence, lung cancer remains largely preventable through reductions in tobacco consumption and effective public health interventions (OECD/Eurostat, 2022).

The relationship between smoking behaviour and lung cancer mortality has been evident since the 1950s (DeVita – Rosenberg, 2012), when a significant pro-

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portion of the population was exposed to smoking, and is best understood within the framework of the smoking epidemic model (Lopez – Collishaw – Piha, 1994). This model describes the evolution of smoking and its health consequences across successive stages, characterised by rising and subsequently declining smoking prevalence, followed after a substantial delay by corresponding changes in mortality. A key feature of this framework is the long lag, typically 20 to 30 years (Islami – Torre – Jemal, 2015), between smoking exposure and lung cancer mortality, implying that observed mortality trends reflect historical smoking patterns rather than contemporaneous behaviours. Tobacco control policies, including taxation, advertising bans, and smoke-free legislation, have been widely implemented to reduce smoking prevalence (Pierce – White – Emery, 2012). Public health campaigns highlighting the risk of lung cancer from long-term smoking have also contributed to declining social acceptance of smoking (Cummings – Proctor, 2014). Among these measures, increases in tobacco taxation are particularly effective in reducing smoking prevalence, especially among adolescents and young adults who are more sensitive to price changes (Chaloupka, 1999). These policies primarily affect smoking initiation and early cessation, shaping the smoking behaviour of younger cohorts. However, their impact on lung cancer mortality is indirect and substantially delayed due to the long latency period between smoking exposure and lung cancer mortality (Thun – Peto – Boreham – Lopez, 2012). As a result, changes in lung cancer mortality trends can rarely be attributed to specific policy interventions, since observed declines typically reflect behavioural shifts that occurred decades earlier (González-Marrón *et al.*, 2019). Consistent with this lag structure, modelling studies project a continued decline in lung cancer mortality in Europe, with persistent gender differences reflecting the later uptake of smoking among females (Gredner – Mons – Niedermaier – Brenner – Soerjomataram, 2021). Cross-national differences in lung cancer mortality may therefore reflect not only variation in policy timing and intensity, but also differences in the stage of the smoking epidemic and cohort-specific smoking histories.

Trends in cigarette smoking prevalence and lung cancer mortality reveal pronounced differentiations between males and females and between countries with

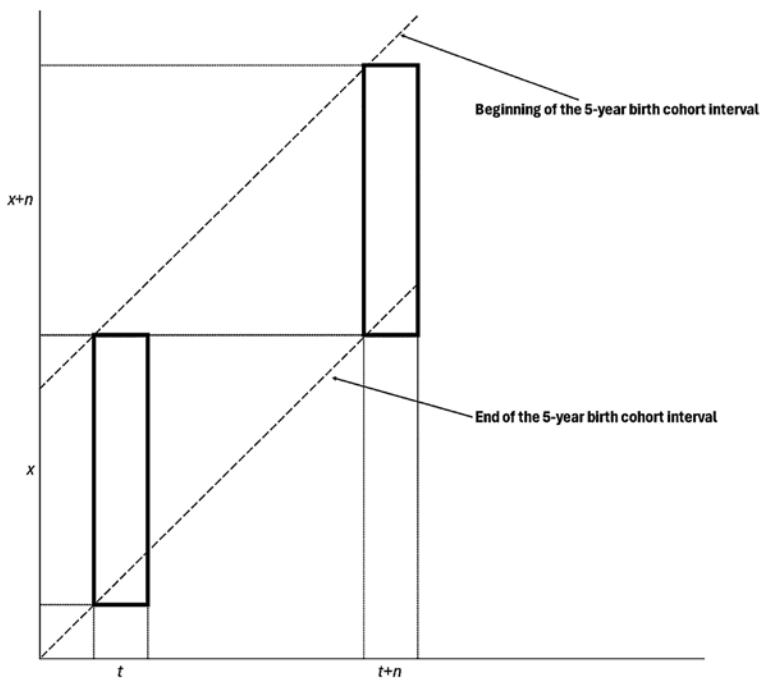
the same level of development (Barta – Powell – Wisnivesky, 2019). Countries in Central and Eastern Europe provide a particularly relevant context for examining these dynamics. During the socialist period, smoking prevalence was high and tobacco consumption was subject to limited regulation, followed by the introduction of comprehensive tobacco control policies during the post-1990 transition (Neuberger, 2019). This study focuses on Czechia, Hungary, and Poland, which share similar historical and socioeconomic backgrounds but exhibit different trajectories in lung cancer mortality, particularly in the timing of peak mortality among males and subsequent declines. These differences allow for a comparative assessment of how cohort-specific smoking patterns and the timing of policy implementation are reflected in long-term mortality trends.

The aim of this study is to analyse period and cohort trends in lung cancer mortality in Czechia, Hungary, and Poland from 1950 to 2023, and to interpret these trends within the smoking epidemic framework and the timing of tobacco control policies. By combining age-standardised mortality rates with cohort-based analysis, the study seeks to clarify the extent to which observed lung cancer mortality changes are driven by long-term smoking behaviours versus policy interventions, while explicitly accounting for the lag between exposure and outcomes.

DATA AND METHODS

The research is designed to assess the changes in trachea, bronchus and lung cancer mortality (further referred to as lung cancer) in Czechia, Hungary, and Poland in alignment with previously implemented tobacco control policies and legislation amendments on tobacco products. For this, the perspectives of changes in mortality patterns within calendar years (a period approach) and changes in death rates between 5-year birth cohorts were considered. Thus, to assess the period changes in the age profile of lung cancer, age-specific mortality and age-standardised death rates were calculated. Mortality standardisation was performed by using the direct method, for which the New European Standard Population of the 2013 revision was used (Eurostat, 2013). To establish cohort changes in age- and cause-specific mortality, period data were transformed into cohort data. Figure 1

Figure 1 The algorithm for transforming the period mortality rates into a cohort mortality vector displayed on a Lexis diagram



Source: Authors' processing.

presents the algorithm for transforming the period age- cause-specific mortality rates into a cause-specific mortality vector according to the following formula:

$$m_c = \{m_{x,t+x}\}_{x=0}^{\omega};$$

where: m_c is the mortality vector for the birth cohort c , x is the age, from 0, to the last open age group ω , $m_{x,t+x}$ is the mortality rate at age x within the period $t+x$.

Data on death counts for lung cancer were retrieved from the World Health Organisation Mortality Database (*WHO Mortality Database*) and the Czech Statistical Office (*Český statistický úřad*), and harmonised according to the International Classification of Diseases (ICD) of the 7th–9th (code 162), and 10th (codes C33–C34) editions. Data on population by age and sex were obtained from the Human Mortality Database (*Human Mortality Database*).

Information on tobacco control policies and laws for tobacco products by country was collected from the national legislative framework. The tobacco control

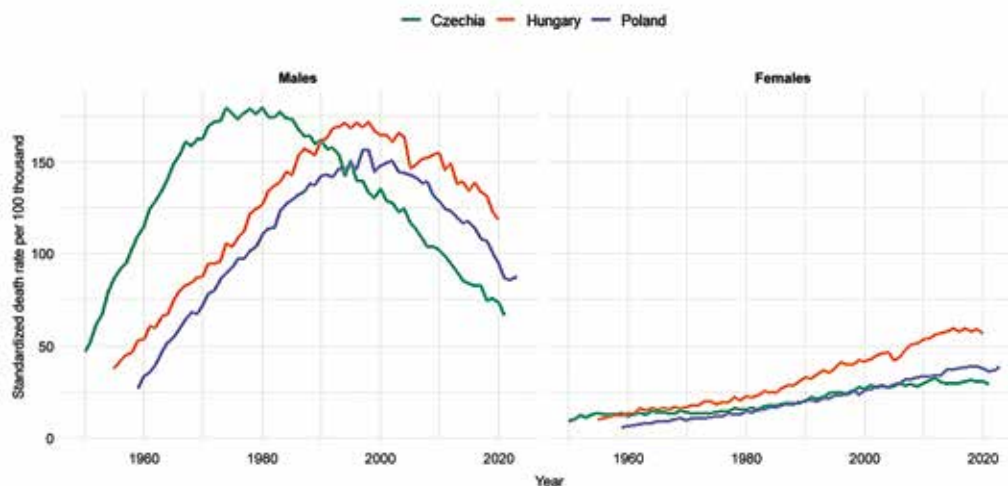
policies implemented in Czechia, Hungary and Poland are presented in Appendix.

RESULTS

Figure 2 presents age-standardised death rates (SDR) for trachea, bronchus, and lung cancer from the 1950s to the most recent available years. Lung cancer mortality increased markedly across all analysed countries from the 1950s onwards, reaching peak levels among males in Czechia in 1980 and in Hungary and Poland in 1998.

In Czechia, male lung cancer mortality rose rapidly from 47 deaths per 100 thousand in 1950 to a peak of 179 deaths per 100 thousand in 1980, followed by a sustained decline to approximately 65 deaths per 100 thousand in recent years. Hungary and Poland exhibited a similar pattern, with male lung cancer mortality peaking at 171 and 156 deaths per 100 thousand, respectively, in 1998, after which rates gradually decreased.

Figure 2 Age-standardised mortality rate for trachea, bronchus and lung cancer for Czechia, Hungary, and Poland for 1950–2023, by sex



Source: The WHO Mortality Database, the Human Cause-of-Death Data series.

Among females, lung cancer mortality remained substantially lower throughout the period. Increases were more gradual and continued into recent decades, reaching peak values of 32 deaths per 100 thousand in Czechia in 2012, and 40 and 60 deaths per 100 thousand in Poland and Hungary, respectively, in 2019.

Overall, female lung cancer mortality rose during a period when male mortality was already declining, reflecting a pronounced temporal lag between sexes. The steepest increase in female lung cancer mortality occurred from the 1980s onwards, with peak or near-peak levels observed approximately 15–20 years later than in males across all analysed countries.

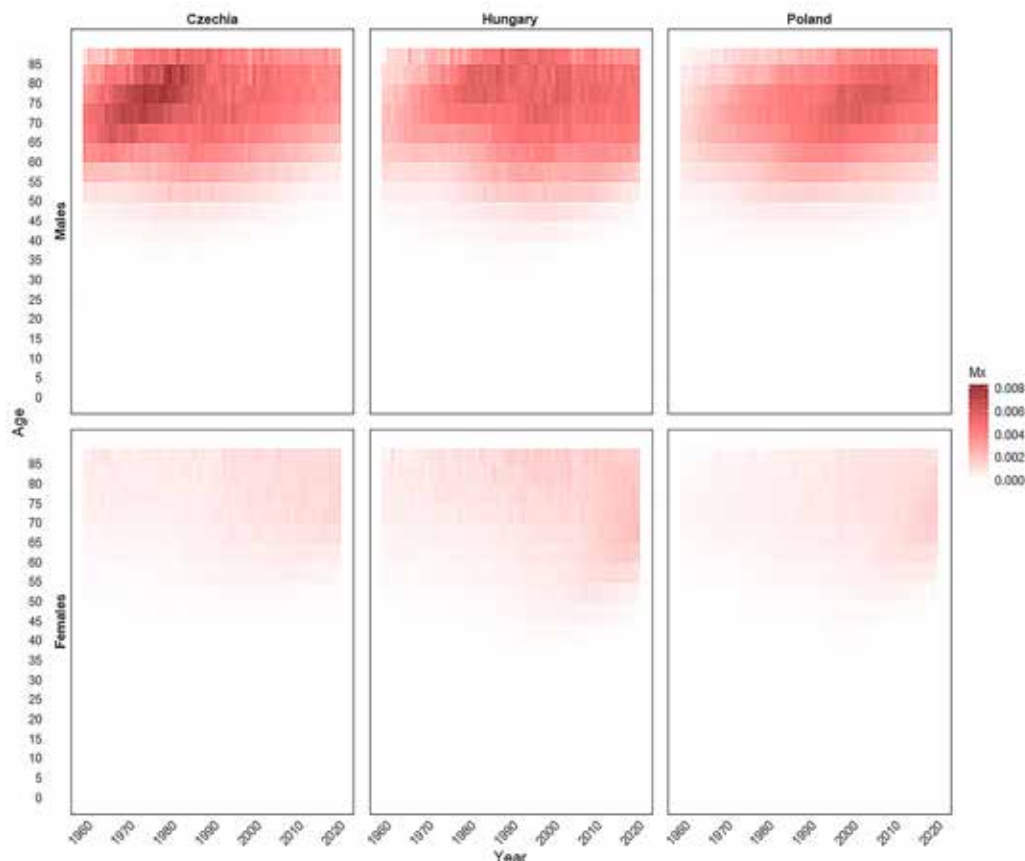
Figure 3 displays annual age-specific lung cancer mortality rates by 5-year age groups from the 1950s to the most recent years, highlighting that lung cancer mortality was concentrated in older age groups. This reflects the long latency period associated with cumulative smoking exposure. Variation in age-specific rates over time also reflects cohort effects, distinguishing generations with different levels of smoking intensity and contributing to the overall trends observed in Figure 2.

In males, the initial increase in lung cancer mortality from the 1950s was driven primarily by rising death rates among those aged 55–74, while younger and older age groups initially showed lower levels. In subsequent decades, the increase shifted towards older ages, alongside declining rates in the 50–69 age group. From the 1980s onwards, high lung cancer mortality rates were observed across all age groups above 50. This pattern persisted until the early 2000s in Czechia and Poland, and until the 2010s in Hungary, after which declines became evident, particularly among those aged 40–59.

In females, age-specific lung cancer mortality rates were consistently lower than in males across all countries and throughout the study period. From the 1950s to the late 1980s, relatively higher female lung cancer mortality was concentrated in older age groups, while rates among females under 70 remained low. From the 1990s onwards, however, all three countries experienced increasing female lung cancer mortality in age groups above 50, reflecting a broader upward shift across older age categories.

Figure 4 presents age-specific lung cancer mortality rates reorganised from period-based data into cohort mortality profiles. Across all three countries,

Figure 3 Annual changes in age-specific mortality rates for 5-year age groups for trachea, bronchus, and lung cancer, displayed on Lexis diagram in Czechia, Hungary, and Poland, for males and females, 1960–2020



Source: The WHO Mortality Database, the Human Cause-of-Death Data series.

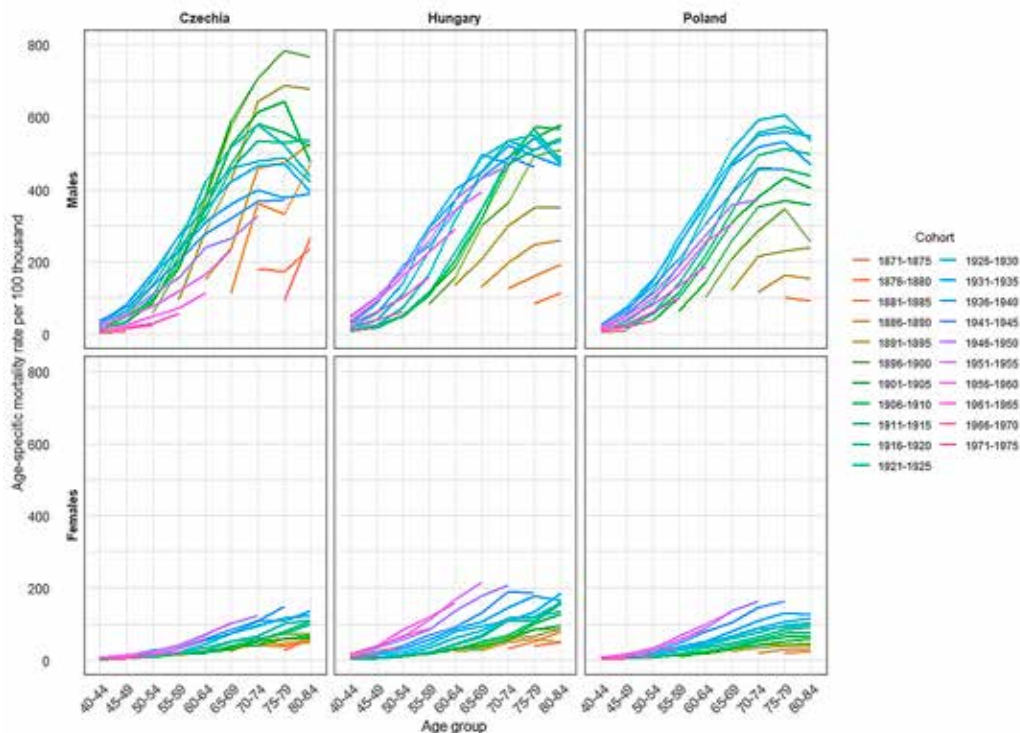
male cohorts born before the early 1900s showed low lung cancer mortality even at older ages, while successive cohorts exhibited substantially higher mortality levels. Among Czech males, the highest lung cancer mortality was observed in cohorts born between 1896 and 1925, followed by a marked decline in subsequent generations, particularly among those born after 1950. In contrast, Hungarian and Polish males showed a more continuous cohort increase, with each successive cohort experiencing higher lung cancer mortality than the previous one. A reversal of this trend was only evident in the youngest cohorts born after the 1950s.

Age patterns were broadly similar across countries. In all cases, lung cancer mortality was negligible be-

fore age 35, rose sharply thereafter, and peaked in the 70–74 age group, followed by a slight decline at older ages. In Czechia, cohorts born between 1886 and 1940 displayed relatively similar mortality levels between ages 35 and 64, while the largest cohort differences emerged at ages 65 and above. In Hungary and Poland, cohorts born between 1926 and 1950 showed substantially higher lung cancer mortality between ages 35 and 69 compared with earlier cohorts born between 1896 and 1915.

Compared with males, female lung cancer mortality remained considerably lower across all countries, cohorts and age groups. Nevertheless, successive female cohorts showed increasing lung cancer mortality, with a gradual shift towards younger ages, although this

Figure 4 Age-specific mortality rates for trachea, bronchus, and lung cancer displayed for 5-year cohorts in Czechia, Hungary, and Poland, for males and females



Source: The WHO Mortality Database, the Human Cause-of-Death Data series.

pattern appeared to improve in more recent generations. Intercohort differences were less pronounced in Czech females than in Hungary and Poland.

The highest female lung cancer mortality was observed among cohorts born in the 1930s and 1940s. Cohorts born after the 1950s continued to exhibit increasing lung cancer mortality, especially at ages above 60, although this upward trend appeared to stabilise in the youngest generations.

DISCUSSIONS

This study analyses long-term trends in lung cancer mortality in Czechia, Hungary, and Poland using period and cohort perspectives, in relation to the timing of implemented tobacco control policies. The results revealed a pronounced cohort effect, with substantial gender differences, highlighting the historical evolution of smoking behaviour across generations.

Although smoking prevalence was high during the socialist era in all these countries, lung cancer trajectories diverged, particularly in the timing of increases and declines among males and in the continuing increase and recent plateauing among females.

Observed trends in lung cancer mortality can be interpreted within the framework of the smoking epidemic, which conceptualises tobacco-attributable mortality as progressing through four stages (*Lopez – Collishaw – Pihl, 1994*). In Czechia, males experienced an earlier transition to the later stages of the epidemic than in Hungary and Poland, with a peak in lung cancer mortality in the late 1970s to early 1980s, followed by a subsequent decline. In contrast, Hungarian and Polish men experienced an increase in lung cancer mortality until the mid-1990s, emphasising a delayed progression through the stages of the smoking epidemic. Females in all three countries exhibited

patterns consistent with earlier stages of the smoking epidemic, characterised by later smoking uptake and a continuous increase in lung cancer mortality. These gender differences were also evident in the cohort mortality analysis, where the male cohorts with the highest lung cancer mortality rate were born in the early 20th century, while the most affected female cohorts were born several decades later.

The findings emphasised the substantial lag between smoking exposure, tobacco control policies implementation, and lung cancer mortality outcomes. Given the long latency of smoking-attributable lung cancer, current mortality trends largely reflect the smoking behaviour from previous decades (*Thun – Peto – Boreham – Lopez*, 2012). This time lag challenges the direct attribution of lung cancer mortality declines to specific tobacco control policies. For instance, lung cancer mortality among Czech males began to decline prior to the widespread introduction of tobacco control measures, possibly reflecting earlier shifts in social norms and lifestyle (*Hoek – Edwards – Waa*, 2022) that reduced smoking prevalence among young and middle-aged males in the mid 1980s (*Škodová et al.*, 2000; *Spilková – Džúrová – Pikhart*, 2011). In Hungary and Poland, the later decline in lung cancer mortality among males aligns more closely with implemented tobacco control policies, even though a decline in smoking prevalence was observed decades before (*Zatoński et al.*, 2017).

In addition to tobacco control policies, other factors have likely contributed to shaping lung cancer mortality trends (*Mackenbach – Karanikolos – McKee*, 2013). Changes in cigarette composition, particularly reductions in tar and nicotine levels, and the introduction of cigarette filters, may have reduced the disease risk, although their overall impact remains debated (*Lee*, 2001; *Lee – Sanders*, 2004). Broader socioeconomic transformations that affected smoking behaviour and access to healthcare, as well as the improvements in lung cancer diagnosis and treatment, have also likely contributed to reduced risk exposure and improved survival.

An important consideration in interpreting these results is the role of competing risks among smok-

ers. High cardiovascular mortality in earlier decades may have reduced the number of individuals surviving to older ages, where lung cancer is more prevalent. Accounting for this dynamic is therefore important when assessing long-term trends in lung cancer mortality.

This study has several limitations. First, the analysis relied on aggregated cause-specific mortality data, which limited the ability to establish a causal relationship between tobacco control policies and lung cancer mortality outcomes. Second, despite efforts to harmonise causes of death across the ICD revisions, some inconsistencies may persist. Third, cohort mortality vectors were estimated by aligning annual age-specific mortality rates with corresponding 5-year birth cohorts, which does not fully account for within-period variation. Finally, the study does not explicitly quantify the impact of competing risks on lung cancer mortality.

CONCLUSIONS

The results of this study suggest that lung cancer mortality trends in Czechia, Hungary, and Poland are primarily driven by a cohort-specific history of tobacco smoking, where tobacco control policies have important but indirect and delayed influence. The observed decline in lung cancer mortality reflects the previous reductions in smoking prevalence, particularly among males. The recent plateau in female lung cancer mortality is consistent with the later diffusion of smoking and the ongoing progression of the smoking epidemic among females. These findings underscore the importance of accounting for cohort effects and lag structures when assessing the impact of tobacco control policies, which is crucial for the development of effective public health strategies. Future lung cancer mortality trends will largely depend on smoking prevalence in the population, smoking initiation among younger generations, as well as the countries' ability to enforce effective tobacco control policies and the capacity of their healthcare systems to provide preventive measures and timely, efficient treatment.

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SUMMARY

Long-term tobacco smoking is the primary cause of lung cancer development, and prevention efforts are therefore focused mainly on tobacco control policies. In this regard, most developed countries banned smoking advertising and increased excise taxes on tobacco products, ultimately prohibiting public smoking.

This study analyses period and cohort changes in lung cancer mortality in Czechia, Hungary, and Poland, with a focus on tobacco control policies and amendments.

Data from the WHO Mortality Database on trachea, bronchus, and lung cancer were harmonised according to the International Classification of Diseases to ensure a consistent data series since the 1950s.

For decades, Czechia, Hungary, and Poland have shared a similar legislative framework for tobacco control, while recording some of the highest smoking rates and lung cancer mortality among European nations. However, since the 1990s, all three countries have enacted a series of legislative amendments to discourage cigarette smoking. The further lung cancer mortality decline, predominantly observed in males, is rather a result of the shift in the population structure, as the generations that experienced a smaller tobacco smoking exposure were ageing, while the cohorts of heavy smokers still registered high death rates. In females, a decline in smoking prevalence began later than in males, with lung cancer mortality rates plateauing only in recent years.

APPENDIX

Table 1. Chronology of implemented tobacco control legislation in Czechia, Hungary, and Poland

Czechia

Act No. 40/1995 on the Regulation of Advertising and on Amendments to Act No. 468/1991, on radio and television broadcasting.

Act No. 379/2005 on measures to protect against damage caused by tobacco products, alcohol and other addictive substances, and amending related laws.

Decree No. 344/2003 on Stipulating the requirements for tobacco products.

Act No. 132/2010 on on-demand Audiovisual Media Services.

1 Jun 2012 Rectification of the WHO Framework Convention on Tobacco Control.

Decree No. 261/2016 on tobacco products.

Decree No. 37/2017 on Electronic Cigarettes, Refill Containers, and Herbal Products for Smoking.

Act No. 65/2017 on Protection of Health Against the Harmful Effects of Addictive Substances.

Hungary

Act 1 of 1996 on Radio and Television Broadcasting.

Act XLII of 1999 on the Protection of Non-Smokers and Certain Regulations on the Consumption and Distribution of Tobacco Products.

Act CXXVII of 2003 on the Excise Tax and Excise Tax Rules in the Marketing of Products.

7 Apr 2004 Rectification of the WHO Framework Convention on Tobacco Control.

Act XLVIII of 2008 on the Basic Requirements of and Certain Restrictions on Commercial Advertising Activities.

Decree No. 291/2011 on the Regulation of Tobacco Products Labelling.

Act CXXXIV of 2012 on Reducing Smoking Prevalence Among Minors and on the Retail of Tobacco Products.

Government Decree No. 39/2013 on the Production, Placing on the Market and Control of Tobacco Products, on Combined Warnings, and the Detailed Provisions on the Application of Healthcare Penalties.

Government regulation No. 239/2016 on the amendment of government regulation 39/2013 on the detailed rules of production, distribution and control of tobacco products, the combined warnings and the application of health protection fines.

Government Decree No. 120/2024 of 10 June 2024 amending Government Decree No. 39/2013 of 14 February 2013 on the production, placing on the market and control of tobacco products, on combined warnings, and the detailed provisions on the application of healthcare penalties.

Poland

Act of November 9, 1995, on the protection of health against the effects of using tobacco and tobacco products.

Decree of the Minister of Health of February 24, 2004, on testing the amount of certain substances in cigarette smoke and the notifications and warnings placed on tobacco product packaging.

15 Sep 2006 Rectification of the WHO Framework Convention on Tobacco Control.

Act of May 21, 2025, on the amendment of the Act on protection of health against the consequences of the use of tobacco and tobacco products.