Impact of Tobacco Control Policies on Smoking-Related Cancer Incidence in Germany 2020 to 2050—A Simulation Study

Thomas Greden1,2, Tobias Niedermaier1, Hermann Brenner1,3,4, and Ute Mons1,5

ABSTRACT

Background: Germany is known for its weak tobacco control. We aimed to provide projections of potentially avoidable cancer cases under different tobacco control policy intervention scenarios.

Methods: To estimate numbers and proportions of potentially avoidable cancer cases under different policy intervention scenarios (cigarette price increases, comprehensive marketing ban, and plain packaging), we calculated cancer site–specific potential impact fractions by age, sex, and year of study period (2020–2050), considering latency periods between reduction in smoking prevalence and manifestation in declining cancer excess risks. To obtain estimates of future incident case numbers, we assumed a continuation of recent smoking trends, and combined German cancer registry data with forecasted population sizes, published effect sizes, and national daily smoking prevalence data.

Introduction

Cancer is a major public health burden in Germany, accounting for about 490,000 new cases and 230,000 deaths each year (1). Projections of the numbers of future cancer cases suggest that this burden will continue to increase mainly due to population aging (2). Despite reductions in smoking prevalence over the past decades, smoking remains the most important preventable cancer risk factor in Germany, which is, according to the current state of knowledge, causally associated with at least 12 different types of cancer (3, 4). Given the still quite high rates of smoking (men: 26.4% and women: 18.6%; ref. 5) and the fact that one of five cancers are estimated to be attributable to smoking in Germany (6), a large proportion of cancer cases could be prevented through determined tobacco control efforts. However, despite the considerable smoking attributable disease burden, Germany continues to be ranked among the most inactive countries in Europe when it comes to implementing evidence-based tobacco control policies. According to the most recent edition of the tobacco control scale, Germany brings up the rear in tobacco control activity in Europe (7).

To assess the potential of tobacco control policies in reducing the smoking-associated cancer burden, we set out to provide projections of potentially avoidable cancer cases under different tobacco control policy intervention scenarios in Germany over a 30-year horizon.

In previous studies, such predictions have often been based on the Prevent macro-simulation model (8), which calculates the effect of changes in risk factor prevalence on cancer burden. However, the Prevent software entails some disadvantages that naturally come along with a menu-driven interface, such as limited flexibility and transparency with regards to model calculations. For the purpose of our study, we thus developed a similar, yet more flexible and transparent modeling strategy to simulate the impact of tobacco control policy interventions on future cancer incidence based on the “potential impact fraction” (PIF) and incorporating time effects [lag (LAG) and latency times (LAT)] as well as demographic changes in the population.

Material and Methods

For the reference scenario under status quo policies, we estimated the future numbers of site-specific cancer cases for 5-year age and sex groups for the German population aged 15 years and above by combining the following sources of data.

Trend in daily smoking prevalence

National data on the age- and sex-specific prevalence of daily smoking were obtained from the Microcensus 2017 of the Federal Statistical Office of Germany. The Microcensus is a representative
annual survey of one percent of German households (5). Figure 1 shows the sex-specific prevalence of daily smoking in 5-year age groups. To project future smoking prevalence until 2050, we assumed a continuation of recent smoking trends (2005–2015) and applied published sex-specific annualized rates of change in smoking prevalence (9) to the baseline smoking prevalence of the year 2017 and stepwise to each following year until the end of the study period. Accordingly, we expected the smoking prevalence to be reduced by 0.6% in men and 0.5% in women, respectively, for each year of the study period.

Forecasted population

Population forecasts by 5-year age groups and sex for the years 2020–2050 for Germany were obtained from the Federal Statistical Office of Germany, assuming a constant trend regarding birth rates and life expectancy, and a low net migration (10). Starting with a German population of 81.4 million in 2020, the projected population is steadily aging, and at the same time decreasing to 71.9 million by 2050, reflecting the expected demographic changes in Germany.

Cancer data and RR estimates

Most recent national cancer incidence data, which were those for the year 2016, were drawn from the German Centre for Cancer Registry Data (ZKD; ref. 11). We estimated the number of site-specific cancer cases for each year of the study period (2020–2050), stratified according to age- and sex-group, by multiplying these rates with the corresponding age- and sex-specific population forecasts for Germany. We used incidence data for all cancers determined as causally related with smoking, based on the evaluations of carcinogenicity of the International Agency for Research on Cancer (IARC; ref. 12) and health authorities in the United States (3). The cancer site-specific RR estimates for current smokers compared with never smokers were taken from the U.S. Surgeon General reports (3, 13–15). If reported, the age-specific RRs were used. All cancer sites considered in this study with corresponding ICD-10 codes and age- and sex-specific risk estimates are presented in Table 1.

Impact of tobacco control policies

For the policy intervention scenarios, we considered evidence-based tobacco control policies that have been shown to be effective in terms of reducing the prevalence of smoking. As such, we focused on those tobacco control policies that are embedded in the World Health Organization (WHO) Framework Convention on Tobacco Control (16), but which are currently not fully implemented in Germany (see also the most recent WHO report on the global tobacco epidemic; ref. 17, for more details on the current state of tobacco control in Germany). By screening the literature, we identified the effect sizes of the corresponding interventions on the prevalence of smoking from pertinent reviews or meta-analyses.

Cigarette price regulation

The effect of changes in cigarette price on consumption can be measured by price elasticities. A recent study estimated cigarette price elasticity as $-0.503$ [95% confidence interval (CI), $-0.291$ to $-0.715$] for high-income countries in Europe (18). Accordingly, an increase by 10% in cigarette prices would be expected to reduce cigarette consumption by 5.03%. On the basis of findings of studies examining the effect of price increases on both smoking prevalence and intensity, it is assumed that smoking prevalence is reduced by about half those rates (19, 20). For our model, we therefore assumed that for each 10% increase in price, a relative reduction of 2.5% in the prevalence of daily smoking occurs.

Comprehensive marketing ban

The empirical evidence shows that a comprehensive advertising ban applied to all media can substantially decrease tobacco consumption. In this context, a study (21) of 22 high-income countries concluded that while partial advertisement bans have little or no
effect, a comprehensive marketing ban could reduce tobacco consumption by up to 7.4%. The Germany SimSmoke model (22) assumed that with a comprehensive marketing ban in Germany, smoking prevalence is expected to be reduced by 5%. For our model, we likewise assumed that a comprehensive marketing ban would lead to a reduction in the smoking prevalence by 5% in the first year of implementation.

**Plain packaging**

Plain packaging is a demand-reduction measure that has been shown to be effective in reducing smoking prevalence independently from health warning labels, which are usually printed prominently on plain tobacco packs. In Australia, the introduction of plain packaging was followed by a significant decline in smoking prevalence: a study (23) evaluating the effectiveness of the tobacco plain packaging measure found a reduction in smoking prevalence of 3.7% (95% CI, 1.1–6.2) in the first year after implementation followed by additional annual declines of 1.7% (95% CI, 1.3–2.2). For our model, we applied these effect sizes to the German population and assumed the implementation of plain packaging would result in a 3.7% decline in smoking prevalence within the first year and an annual 1.7% decrease over the following 4 years, as the effects of plain packaging are expected to wear out after a few years.

Overall, we modeled five different intervention scenarios that were set to start in 2020. An overview of the different investigated scenarios and corresponding effect on smoking prevalence is shown in Table 2. When calculating the combined effect of intervention scenarios, we expected the different tobacco control policies to influence smoking prevalence independently.

### Change in cancer risk

The time that elapses between the removal of a cancer risk factor and the full manifestation of the resulting decline in cancer excess risk is modeled using the concept of LAT and LAG (8, 24). LAT is the time the cancer risk remains constant until changes in exposure to the cancer risk factor start being reflected in cancer risk. LAG is the time taken for the risk among previously exposed persons to reduce to the level of unexposed persons.

The likelihood of developing cancer as well as the decline of the excess risk after smoking cessation depends on a variety of smoking-related factors, such as the intensity and duration of smoking over the life course, as well as the age at smoking cessation. Although it is difficult to determine a universally valid LAT irrespective of these factors for all cancer sites, we defined, in analogy with previous modeling studies (8, 25) and based on existing evidence (26), the LAT to be 5 years and the LAG to be 15 years assuming a log linear decline in cancer risk.

**Statistical analysis**

Similar to the mathematical calculations in Prevent, we used a simulation modeling based on the epidemiologic measures “trend impact fraction” (TIF) and PIF (8). The TIF and PIF derive a proportional change in cancer risk from a change in risk factor exposure due to an autonomous trend or an intervention, respectively, and the RR of the association of that risk factor with cancer.

To obtain the number of cancer cases in the reference scenario taking into account the autonomous development of smoking prevalence, the TIF was calculated for each age, sex, year of study period, and smoking-related cancer site using the following equation (27):

\[
TIF_i = \frac{\sum_{n=1}^{n} p_i \cdot RR_c - \sum_{n=1}^{n} p_i^* \cdot RR_c}{\sum_{n=1}^{n} p_i \cdot RR_c}
\]

where \( p_i \) is the proportion of the age-, sex-, and period-specific population in risk factor category \( c \); \( RR_c \) is the corresponding time-dependent and cancer site-specific RR for that category; and \( p_i^* \) is the altered proportion in category \( c \) taking into account the autonomous trend. The TIF is applied to the corresponding number of predicted cancer cases, derived by multiplying the most recent cancer incidence rates with the forecasted population sizes, to estimate the future number of cancer cases in the reference scenario.

Subsequently, the number of cancer cases prevented by a specific intervention was calculated using the analogous equation for the PIF:

\[
PIF_i = \frac{\sum_{n=1}^{n} p_i \cdot RR_c - \sum_{n=1}^{n} p_i^* \cdot RR_c}{\sum_{n=1}^{n} p_i \cdot RR_c}
\]

where \( p_i^* \) is now the altered smoking prevalence in risk factor category \( c \) due to the intervention. In analogy to the TIF estimates,
Table 2. Investigated tobacco control policies, description, and effect on smoking prevalence.

<table>
<thead>
<tr>
<th>Tobacco control policy</th>
<th>Description</th>
<th>Assumed effect on smoking prevalence (base case)</th>
<th>Sensitivity analysis</th>
<th>Reference(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single cigarette price increase</td>
<td>10% price increase in cigarettes in 2020 (e.g., through tax increase)</td>
<td>2.5% reduction in 2020</td>
<td>Effect worst case: 1.5% reduction in 2020; Effect best case: 3.6% reduction in 2020</td>
<td>Yeh and colleagues, 2017 (18); IARC, 2012 (19)</td>
</tr>
<tr>
<td>Repeated cigarette price increases</td>
<td>Annual 10% price increase in cigarettes for 10 years (2020–2029; e.g., through tax increases)</td>
<td>Annual 2.5% reduction from 2020 to 2029</td>
<td>Effect worst case: Annual 1.5% reduction from 2020 to 2029; Effect best case: Annual 3.6% reduction from 2020 to 2029</td>
<td>Yeh and colleagues, 2017 (18); IARC, 2012 (19)</td>
</tr>
<tr>
<td>Comprehensive marketing ban</td>
<td>Introduction of a complete advertising ban in 2020 applied to all kind of media</td>
<td>5% reduction in 2020 (by assumption)</td>
<td>Effect worst case: 2.5% reduction in 2020 (by assumption); Effect best case: 7.5% reduction in 2020 (by assumption)</td>
<td>Levy and colleagues, 2012 (22); Saffer and colleagues, 2000 (21)</td>
</tr>
<tr>
<td>Plain packaging</td>
<td>Implementation of plain packaging in 2020</td>
<td>3.7% reduction in 2020; 1.7% reduction from 2021 to 2024</td>
<td>Effect worst case: 1.1% reduction in 2020; Effect best case: 6.2% reduction from 2020 to 2024</td>
<td>Diethelm and colleagues, 2015 (23)</td>
</tr>
<tr>
<td>All combined</td>
<td>A combination of tobacco control policies: repeated cigarette price increase, comprehensive marketing ban, and plain packaging</td>
<td>12% reduction in 2020; 4.2% reduction from 2021 to 2024; 2.5% reduction from 2025 to 2029</td>
<td>Effect worst case: 5.1% reduction in 2020; Effect best case: 17.3% reduction in 2020</td>
<td></td>
</tr>
</tbody>
</table>

The PIF is age-, sex-, and cancer site-specific and is calculated for each year of study period. By applying the cancer site–specific PIFs for each hypothetical intervention scenario to the future number of cancers under the reference scenario, we then estimated the number of future cancer cases that would be expected under the corresponding scenario for each age group, sex, cancer site, and period.

To calculate the combined incidence for all smoking-related cancer sites that would be expected under a hypothetical intervention scenario, the cancer site–specific TIFs and PIFs were cumulated using the following formula:

\[ \text{Inc}_\text{all} = \sum_{i=1}^{n} \text{Inc}_{i} \left( 1 - \text{TIF}_{i} \right) \left( 1 - \text{PIF}_{i} \right) \]

where \( \text{Inc}_{i} \) is the predicted cancer site–specific baseline incidence and \( \text{TIF}_{i} \) and \( \text{PIF}_{i} \) is the corresponding cancer site–specific TIF or PIF, respectively.

With the reference scenario reflecting autonomous trends and the intervention scenario reflecting the potential impact of the intervention, the difference in cancer incidence between both scenarios can be attributed to the intervention.

**Sensitivity analyses**

To deal with uncertainty in the modeling assumptions, sensitivity analyses were conducted modeling a linear decrease in cancer risk and using different periods of LAG and LAT (see Supplementary Data S2 for more details). In addition, sensitivity analyses were run based on the lower limit of the corresponding 95% CIs, and the upper limit, respectively, of the effect estimate of each tobacco policy intervention.

For the scenario of a comprehensive marketing ban, we used alternative effect estimates of 2.5% and 7.5%, respectively, as no CI limits were reported.

All analyses were performed using the statistical software R version 3.5.2 (28).

**Data availability**

All data used in this research are publicly available (3, 5, 10, 11, 13) and these, as well as the analysis script, can be obtained upon reasonable request from the corresponding author.

**Results**

Prevalence of daily smoking in Germany for the years 2020–2050 for the reference scenario assuming a continuation of recent smoking trends, and under different policy intervention scenarios are shown in Fig. 2. Compared with the baseline smoking prevalence in 2017 (men 22.3% and women 15.3%), we projected the proportion of daily smokers in the German population in the reference scenario to decline to 14.8% in men and 10.2% in women by 2050 assuming a continuation of the previous decreasing trend in smoking prevalence. In the scenario of all tobacco control policies combined, in contrast, the smoking prevalence was projected to decline to 9.7% in men and 6.7% in women.

The estimated number of preventable cancer cases in Germany for all smoking-related cancers under the reference scenario and each policy intervention scenario is shown in Fig. 3. Over a 30-year period, an estimated 14.0% of smoking-related cancer cases in men and 12.2% in women could be prevented, if a combination of the observed tobacco control policies is implemented.
control policy interventions were to be implemented in Germany. Compared with a scenario assuming constant cancer incidence rates and continuously decreasing smoking prevalence, these proportions would correspond to a reduction of approximately 685,000 cancer cases in men and 372,000 cases in women (Table 3). The most effective single intervention was estimated to be annual 10% price increases in cigarettes over 10 years, which may prevent about 8.5% of smoking-related cancer cases in men and 7.3% in women. Implementation of plain packaging was estimated to reduce the burden of incident cancer cases by 4.4% in men and 3.8% in women and a comprehensive marketing ban applied to all forms of tobacco advertisement was estimated to prevent about 2.4% and 2.1% cancer cases in men and women, respectively. If a single 10% price increase were to be enforced, the resulting reduction in the burden of smoking-related cancers was predicted to be 1.2% in men and 1.0% in women, which still translated to approximately 90,000 cases (~58,000 cases among men and ~32,000 cases among women).

The cancers with the greatest proportion of potentially preventable cancers were estimated to be lung cancer (20.5%) for both sexes accounting for about 38.3% of all potentially preventable cases, followed by cancer of the larynx (19.4%), the oral cavity (17.7%), and the esophagus (17.4%). In addition, lung cancer has the highest number of potentially avoidable cancers with approximately 405,000 cases for all policy interventions combined over the 30-year period. Graphical representations of the estimated number of preventable cancer cases for each cancer site are shown in Supplementary Data S1.1–S1.12.

The absolute number of potentially preventable cancer cases was greater among men than women, with higher PIFs for all cancer sites. When looking at the effect of different tobacco control policy interventions combined, PIFs ranged from 10.0% to 20.7% in men and from 7.0% to 20.2% in women.

Sensitivity analyses
Sensitivity analyses using the 95% confidence limits of effect estimates on the impact of tobacco control policies indicated a potential range of 8.0%–18.0% of preventable cancer cases for the combined effect of all policy interventions (Supplementary Data S2.1) indicating that the results are fairly robust within the applied effect range.

As would be expected, the sensitivity analysis modeling a linear decrease in cancer risk (Supplementary Data S2.2) yielded slightly lower estimates of proportion and number of potentially preventable cancer cases as the linear risk function implicates that the reduction of the excess risk would occur at a slower rate.

On the contrary, the sensitivity analyses varying LATs and LAGs indicated a potential range of 8.4%–16.3% of preventable cancer cases (Supplementary Data S2.3). Despite the fact that the proportion of potentially preventable cancers is essentially the same in all scenarios after the full decline in excess cancer risk occurred, the projections are particularly dependent on the latency assumptions of the model. In the conservative scenario, when using a LAT of 10 years and a LAG of 20 years, it would take until the final year of the study period until the full impact.
Figure 3.
Total number of cancer cases (A and B) and number of potentially preventable cancer cases (C and D) for cancers causally linked to smoking under different tobacco control policy scenarios over a 30-year period (2020–2050), stratified by sex.
Table 3. Estimated proportion and number of smoking-related cancer cases preventable by different tobacco control policies over a 30-year period (2020–2050) in the German population, stratified by sex.

<table>
<thead>
<tr>
<th>Cancer site (ICD-10)</th>
<th>Expected cancer cases</th>
<th>Total (N) and relative (%) number of preventable cancer site-specific cases per scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lip, pharynx, and oral cavity (C00–C14)</td>
<td>307,978</td>
<td></td>
</tr>
<tr>
<td>Esophagus (C15)</td>
<td>187,335</td>
<td></td>
</tr>
<tr>
<td>Stomach (C16)</td>
<td>344,788</td>
<td></td>
</tr>
<tr>
<td>Colon and rectum (C18–C20)</td>
<td>1,194,097</td>
<td></td>
</tr>
<tr>
<td>Liver (C22)</td>
<td>226,333</td>
<td></td>
</tr>
<tr>
<td>Pancreas (C25)</td>
<td>338,935</td>
<td></td>
</tr>
<tr>
<td>Larynx (C32)</td>
<td>103,482</td>
<td></td>
</tr>
<tr>
<td>Trachea, bronchus, and lung (C33–C34)</td>
<td>1,264,094</td>
<td></td>
</tr>
<tr>
<td>Kidney and renal pelvis (C64–C65)</td>
<td>345,041</td>
<td></td>
</tr>
<tr>
<td>Bladder (C67)</td>
<td>477,229</td>
<td></td>
</tr>
<tr>
<td>Acute myeloid leukemia (C92)</td>
<td>111,621</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4,300,933</td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lip, pharynx, and oral cavity (C00–C14)</td>
<td>133,706</td>
<td></td>
</tr>
<tr>
<td>Esophagus (C15)</td>
<td>59,669</td>
<td></td>
</tr>
<tr>
<td>Stomach (C16)</td>
<td>208,253</td>
<td></td>
</tr>
<tr>
<td>Colon and rectum (C18–C20)</td>
<td>929,496</td>
<td></td>
</tr>
<tr>
<td>Liver (C22)</td>
<td>97,069</td>
<td></td>
</tr>
<tr>
<td>Pancreas (C25)</td>
<td>330,407</td>
<td></td>
</tr>
<tr>
<td>Larynx (C32)</td>
<td>15,842</td>
<td></td>
</tr>
<tr>
<td>Trachea, bronchus, and lung (C33–C34)</td>
<td>704,444</td>
<td></td>
</tr>
<tr>
<td>Cervix uteri (C53)</td>
<td>129,655</td>
<td></td>
</tr>
<tr>
<td>Kidney and renal pelvis (C64–C65)</td>
<td>200,501</td>
<td></td>
</tr>
<tr>
<td>Bladder (C67)</td>
<td>133,706</td>
<td></td>
</tr>
<tr>
<td>Acute myeloid leukemia (C92)</td>
<td>203,978</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3,054,615</td>
<td></td>
</tr>
</tbody>
</table>

*The “All combined” scenario comprises a combination of a repeated cigarette price increase, a comprehensive marketing ban, and plain packaging.

Discussion

In this study, we simulated the change in future smoking-related cancer cases associated with a reduction in daily smoking prevalence due to different tobacco control policies. Our results suggest that the burden of smoking-related cancer cases could be considerably reduced in Germany over a 30-year horizon even with small reductions in the prevalence of daily smoking as a result of a single increase in cigarette prices, for example, through a tax hike. If a combination of the investigated evidence-based tobacco control policy interventions were to be implemented in Germany in 2020, that is, plain packaging, a comprehensive marketing ban, and repeated strong tax increases over 10 years, we estimated that about 14.0% of smoking-related cancer cases in men and 12.2% in women could be prevented by 2050. Compared with a scenario assuming constant cancer incidence rates and continuously decreasing smoking prevalence, this would translate to a reduction of the future burden of incident cancers in Germany by approximately 1,057,000 cancer cases.

Similar to other simulation studies (8, 25, 29), the modeling approach used in our study is based on the PIF estimating counterfactual-based effects of changing risk factor prevalence. In this methodologic framework, the calculations are predicated on the assumption that there is a causal relationship between exposure to a cancer risk factor and the occurrence of cancer, and that the only difference between the reference scenario and each intervention scenario is because of the altered prevalence level.

In our modeling, the projected number of future incident cancer cases in the reference scenario was on the basis of the predicted population projections and most recent available cancer incidence rates for Germany. The coverage of cancer incidence data is very heterogeneous across the different German federal states; however, since 2009, Germany has achieved nationwide coverage of population-based cancer registration. Assuming constant incidence rates over the study period, changes in numbers of cancers reflect the demographic changes in the German population and the autonomous trend in smoking prevalence. However, this simple prediction approach disregards cancer site-specific trends in incidence rates beyond these factors. For example, reflecting the differential progression of the tobacco epidemic, an increase in lung cancer incidence rates is expected for women, while a considerable decline is predicted for men (2). Although large variation can also be seen by cancer type, there is evidence that overall standardized cancer incidence rates in Germany will increase by 5% over the next decade (2), which makes our estimates of the number of preventable cancer cases likely to be underestimated.

Generally, while the epidemiologic simulation framework developed and used for this study allows the comparison of the impact of different health interventions on cancer burden by using only few different data sources, it should not be considered a reliable prediction.
tool for future cancer incidence, as only a simple forward prediction was applied. The purpose of our simulation model was not to provide valid predictions of the future cancer incidence in Germany, but rather to model the difference in proportions and numbers of preventable cancer cases under different scenarios of changing smoking prevalence when other factors remain unchanged. Given our long study period and the limited availability of historic incidence data, the inclusion of more detailed cancer incidence predictions would have required further modeling assumptions and correspondingly would have introduced further uncertainties (30, 31). However, because the PIF is not sensitive to changes in cancer incidence rates, only the predictions of absolute case numbers but not of the proportions of potentially avoidable cancer cases would be affected by other assumptions regarding future incidence rates.

To incorporate an autonomous trend in smoking prevalence, we assumed recent trends in smoking prevalence (2005–2015) to continue until the end of the study period without considering an attenuation effect in prevalence decline, again potentially contributing to an underestimation of the number of preventable cancer cases. On the other hand, different external factors, such as a potential widespread uptake of alternative nicotine products, could accelerate declining trends in smoking prevalence and thus lead to an overestimation of the number of preventable cancer cases.

To simulate the potential impact of tobacco control policies on health outcomes, a lot of different statistical and computational modeling methods have been used in previous international studies (32). For Germany, for example, the SimSmoke model has been used to quantify the effect of tobacco control policies on future smoking prevalence and smoking attributable deaths (22). However, only few studies investigated the impact of changing smoking prevalence on future cancer incidence (8, 25, 33–36). A study (25) of Nordic countries using the Prevent macro-simulation model to estimate the future number of cancer cases under different counterfactual scenarios found that proportion of smoking-related cancers preventable by a combination of different country-specific interventions ranged between 6.7% and 10.6%. Overall, our estimates of preventable cancer cases are higher than those reported for the Nordic countries, but because not exactly the same tobacco control policies were considered, a direct comparison is difficult. Country-specific differences in the prevalence of smoking as well as the use of more recent risk estimates in our study could be further explanatory factors for differences in results. However, the estimates for lung cancer are very similar indicating that about 20% of lung cancer cases could be prevented by a combination of country-specific tobacco control policies.

Limitations and strengths

Our results are based on several assumptions that inherently bring along some limitations and result in a simplification of the complex reality of cancer occurrence. For the selection of the hypothetical intervention scenarios, we focused on tobacco control policies embedded in the Framework Convention for Tobacco Control to investigate the impact of scenarios that best match recommendations of already existing cancer prevention programs.

Our simulations were restricted to interventions for which estimates of the impact on the prevalence of smoking were available. Other effective tobacco control policies such as the implementation of comprehensive smoke-free legislation including all public places could not be taken into account, because a partial implementation is already in place in Germany.

To quantify the change in smoking prevalence resulting from price changes, for example, through tax increases, we used price elasticities. However, we were not able to consider potential substitution effects accompanying cigarette price increases by using cross-elasticities of demand for other tobacco products. For the scenario of repeated cigarette price increases, we assumed the price elasticity to be constant over time, although there might be an attenuation effect in the corresponding decrease in smoking prevalence.

When calculating the potential impact for a combination of tobacco control policies, we assumed these policies to independently affect smoking prevalence, because no information was available on the magnitude of effect sizes for combinations of policies. Because both a synergistic or attenuating effect could be possible, the estimated impact for this scenario may be under- or overestimated, respectively.

Furthermore, we did not take into account the impact of tobacco control policies on occasional smokers as well as indirect effects on second-hand smoke exposure due to a decline in smoking, even though second-hand smoke also contributes to the cancer burden in Germany (37).

In our simulations, we focused on effects of tobacco control policies on smoking prevalence in the adult populations, although there might be even stronger effects on smoking prevalence among youths. In New Zealand (38), a large decline in the proportion of youth ever and daily smokers was observed after the introduction of an annual increase in tobacco excise by at least 10% since 2010. Generally, we assumed the selected effect estimates to influence the prevalence of daily smoking homogeneously across sex and age groups in the whole German population. As smoking is highly addictive, tobacco control policies such as marketing bans or plain packaging might affect long-term smokers to a lesser extent. In contrast, younger smokers are more responsive to price increases for tobacco products as well as more susceptible to tobacco advertising (39, 40).

Finally, to take into account the delay in effects of tobacco control policies on cancer incidence, we included in our model lag and latency periods from the intervention to the complete decline in cancer excess risk. In agreement with previous studies, we set these time shifts at 20 years in total (8, 25). It is, however, important to note that there is evidence for an elevated cancer risk even beyond this period, in particular with regard to lung cancer (14, 26). In extensive sensitivity analyses, we compared different simulation scenarios by varying the magnitude of LAG and LAT, the effect estimates, and using a linear decline in cancer risk to deal with uncertainty in assumptions. They illustrate that, depending on the true length of latency, the full effect of tobacco control policies could take several years to emerge. However, our findings show the considerable potential of tobacco control policies in reducing the smoking-related cancer burden in any case and underline the need for urgent efforts.

This is the first modeling study to provide estimates of the impact of different tobacco control policies on future smoking-related cancer incidence in Germany using nationally representative prevalence data on daily smoking, latest RR estimates from cohort studies, as well as most recent population projections and cancer registry data. Our straightforward modeling framework enables a comparison of the impact of different health policy measures and thereby contributes to a better understanding of the importance of tobacco control for primary cancer prevention. Such data could well be used to underpin advocacy efforts to strengthen tobacco control in Germany and beyond.

Conclusions

Our results suggest that the expected cancer incidence in Germany could be considerably reduced by implementing tobacco control
Impact of Tobacco Control on Cancer Incidence in Germany

Analysis and interpretation of data (e.g., statistical analysis, biostatistics, computational analysis); T. Gredner, H. Brenner, U. Mons

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Study supervision: H. Brenner, U. Mons

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Impact of Tobacco Control on Cancer Incidence in Germany

policies as part of a primary cancer prevention strategy. To further accelerate the currently observed tentative trend of declining smoking prevalence in Germany, there is a great need to urgently intensify efforts in tobacco control. This study illustrates that introducing proven-to-be-effective measures such as plain packaging, a comprehensive marketing ban, and repeated annual tax increases in Germany have the potential to avoid a tremendous amount of cancer cases over a 30-year horizon.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

Authors’ Contributions

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References


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