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ORIGINAL ARTICLE

Estimating lung cancer mortality attributable to second hand smoke exposure in Germany

Heiko Becher[1] · Matthias Belau[2] · Volker Winkler[3] · Annette Aigner[1]

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Abstract

Objectives Public health measures such as nonsmoker protection laws affect smoking prevalence and consequently the number of lung cancer deaths attributable to second hand smoke (SHS). In Germany, a risk assessment of SHS has been performed in 1994 only, and therefore, a reassessment is of interest.

Methods Based on current knowledge on the relative risk of lung cancer from SHS, SHS prevalence, lung cancer deaths in Germany, and two approaches to estimate the number of never smokers among lung cancer deaths, we estimated the current number of deaths attributable to SHS among never smokers in Germany.

Results Based on a relative risk of 1.21 (95% CI 1.14–1.28), recent prevalence of SHS of 39.5% for men and 23.5% for women, the attributable risks are 7.66 and 4.70%, respectively. Out of about 47,000 lung cancer deaths per year, the estimated number of never smokers is about 6000, out of which we estimated 167 being attributable to SHS.

Conclusions Despite an aging population, the number of deaths from lung cancer attributable to SHS decreased considerably. This positive trend should be strengthened by further public health measures.

Keywords Lung cancer · Second hand smoke · Passive smoking · Estimation · Germany

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✉ Heiko Becher
h.becher@uke.de

1 Institute of Medical Biometry and Epidemiology, University Medical Center Hamburg-Eppendorf, Hamburg, Germany

2 Faculty of Health Science, University of Bielefeld, Bielefeld, Germany

3 Institute of Public Health, University Hospital Heidelberg, Heidelberg, Germany

Introduction

Tobacco smoke constitutes the major health hazard in our society. Although the hazards associated with exposure to second hand smoke (SHS), also referred to as passive smoking, are smaller, there is a general consensus that SHS is an independent risk factor for several chronic diseases, such as lung cancer (International Agency for Research on Cancer 2004). Becher and Wahrendorf (1994) published an estimate of the number of lung cancer deaths due to SHS in the German population. They estimated that SHS accounted for about 400 deaths from lung cancer among never smokers per year. During that time, the discussion whether SHS is a risk factor for lung cancer was still ongoing.

Since then, scientific evidence has accumulated contributing to the knowledge that SHS is causally related to lung cancer, and new studies provided more precise estimates of the relative risk (RR) due to SHS (International Agency for Research on Cancer 2004; US Department of Health and Human Services 2006; Kim et al. 2014). In the first decade of the 21st century, nonsmoker protection laws have been implemented in Germany just as in numerous other countries (European Commission's Directorate for public health and risk assessment 2017), which should have led to a reduction in SHS exposure, and subsequently to a reduction in the number of lung cancer deaths attributable to SHS. However, on the other hand, the demographic change towards an older population continued in Germany and most neighboring countries, suggesting an overall increase in the number of lung cancer deaths.

The assessment of SHS exposure and its operationalization are challenging (International Agency for Research on Cancer 2004; Florescu et al. 2009). Past exposure can only be assessed through questionnaires and is subject to various sources of bias. In the majority of studies, exposure at home, and therefore, mostly by a smoking spouse was used as a primary source of exposure (Hackshaw et al. 1997; International Agency for Research on Cancer 2004). Others included workplace exposure and exposures in other places summarized in an exposure index (Zhong et al. 2000; International Agency for Research on Cancer 2004; US Department of Health and Human Services 2006). This implies some variation which cannot completely be controlled for in meta-analyses. Moreover, like any environmental exposure, low levels of exposure apply to almost the whole population, i.e. a completely non-exposed reference group does not exist.

In this study, we present the relative risk estimates of lung cancer death due to SHS over time from the literature, as well as the prevalence of SHS exposure as obtained from health surveys in Germany, the number of lung cancer deaths, and lung cancer mortality in the German population over the last decades as obtained from the official mortality statistics on Germany. We estimate the proportion of never smokers among lung cancer deaths, to finally answer our main research question on today's absolute number of lung cancer deaths among never smokers attributable to SHS exposure. This is of great public health interest in general, and could be used to evaluate whether policies to protect nonsmokers have had a direct effect on the prevalence of passive smoking.

Methods

Data

Relative risk estimates of SHS and lung cancer

In 1981, the first study on the relative risk for lung cancer due to SHS exposure among never smokers was published by Trichopoulos et al. (1981). It provided a very high odds ratio estimate, but initiated several further studies. Wald et al. (1986) published the first meta-analysis based on ten case–control studies and three cohort studies with the result of a RR estimate for lung cancer among never smokers due to SHS by a smoking spouse of 1.35 (95% CI 1.19–1.54). Saracci and Riboli (1989) published another meta-analysis, deriving the same estimate of 1.35 (95% CI 1.20-1.53). This estimate, combined with two estimates from studies published shortly afterwards, was used in the previous study on never smoker lung cancer deaths attributable to SHS by Becher and Wahrendorf (1994). Since then several other meta-analyses have been published (Hackshaw et al. 1997; Zhong et al. 2000; Boffetta 2002; International Agency for Research on Cancer 2004; US Department of Health and Human Services 2006). The most recent study from 2014 provided a pooled analysis of 18 case–control studies from the database of the International Lung Cancer Consortium (ILCCO) (Kim et al. 2014). This estimate is the same as the estimate from the last published meta-analysis from 2006 (US Department of Health and Human Services) (Fig. 1).

Prevalence of SHS in Germany

In the early 1990s, the prevalence of SHS was estimated to be 60 and 70% in men and women, respectively (Becher et al. 1987; Riboli et al. 1990; Jöckel 1991). In the German National Health Interview and Examination Survey of 1998 (GNHIES98), the prevalence of SHS exposure was 60 and 51% in never and former smokers between age 18 and 79 for men and women, respectively (Schulze and Lampert 2006). A number of studies have provided further evidence on SHS exposure among German never smokers (Augustin et al. 2005; Kreuzer et al. 2006; Baumeister et al. 2008). More recent estimates indicate a strong decline. The German Epidemiological Survey of Substance Abuse (ESA) from 2003 included 8061 individuals between 18 and 59 years (Kraus and Augustin 2005). Participants were asked with a self-administered questionnaire how often they stay in rooms at work, at home, or in other places where people smoke cigarettes. The prevalence in never smoking men and women regularly exposed to SHS (once per week or daily) was 42 and 26%, respectively. In 2006, the ESA was repeated including 7912 people between 18 and 64 years (Kraus and Baumeister 2008), where the prevalence in never smoking men and women regularly exposed to SHS decreased to 37 and 21%, respectively. The German Health Interview and Examination Survey for Adults (DEGS1) provided the most recent representative data on SHS exposure among the adult population in Germany (Gosswald et al. 2013). It was carried out by the Robert Koch-Institute (RKI) between November 2008 and December 2011, and included 7988 individuals between 18 and 79 years (Kamtsiuris et al. 2013). The prevalence of exposure to SHS in never smoking men and women was 40 and 24%, respectively (Robert Koch-Institute and Department of Epidemiology and Health Monitoring 2015) (Fig. 2). All questionnaires and operationalization of the exposure variables are described in more detail in the Supplementary Appendix.

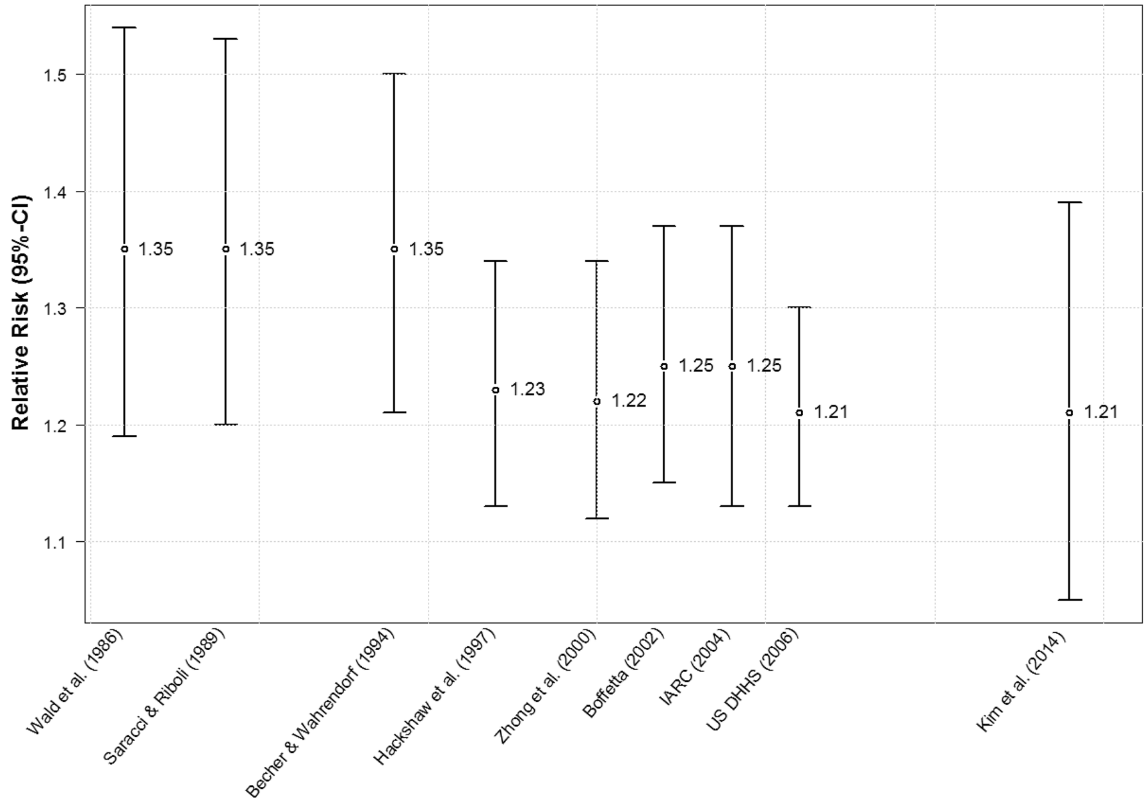

Fig. 1 Relative risk estimates for lung cancer due to second hand smoke exposure at home (e.g. smoking spouse) from meta-analyses and other studies, 1986–2014

Lung cancer deaths and mortality rate in Germany

Over the last decades, the lung cancer mortality rate strongly decreased in men, but increased in women (German Cancer Research Center (DKFZ) 2016). Due to the demographic change of the German population, the numbers of lung cancer deaths for both sexes have increased during the same period. Lung cancer deaths between 1991 and 2013 (Statistisches Bundesamt 1993–2014; Statistisches Bundesamt 2015) and mortality rates between 1991 and 2012 (German Cancer Research Center (DKFZ) 2016) are presented in Fig. 3. In 1991, 27,785 men and 7252 women died from lung cancer, whereas in 2013, these figures increased to 31,303 men and 15,566 women. This corresponds to an approximate change in the sex ratio females:males from 1:4 to 1:2.

Statistical methods

We combined the two most recent estimates for the relative risk of lung cancer due to SHS ($\mathrm{RR}^{\mathrm{SHS}}$) (US Department of Health and Human Services 2006; Kim et al. 2014) using inverse variance weights. Based on this estimate and the estimates for the prevalence of SHS exposure in never smokers by sex i and age group j (p_{ij}^{SHS}) (Robert Koch-Institute and Department of Epidemiology and Health Monitoring 2015), we derived the attributable risk of SHS $\left(\mathrm{AR}_{ij}^{\mathrm{SHS}}\right)$ for each group as

$$\mathrm{AR}_{ij}^{\mathrm{SHS}} = \frac{p_{ij}^{\mathrm{SHS}}(\mathrm{RR}^{\mathrm{SHS}} - 1)}{1 + p_{ij}^{\mathrm{SHS}}(\mathrm{RR}^{\mathrm{SHS}} - 1)}.$$

As recent direct estimates of the proportion or the absolute number of never smokers among lung cancer deaths are not available, we used the following two indirect approaches to estimate the proportion of never smokers among those who died of lung cancer.

Approach I

As a first approach (I) we used the relative risk estimates for lung cancer due to current $\left(\mathrm{RR}^{\mathrm{S}}\right)$ and former smoking $\left(\mathrm{RR}^{\mathrm{FS}}\right)$ relative to never smoking (Gandini et al. 2008), just as population estimates of the proportion of smokers ($P_{ij}(\mathrm{S})$), former smokers ($P_{ij}(\mathrm{FS})$), and never smokers ($P_{ij}(\mathrm{NS})$) (Robert Koch-Institute and Department of Epidemiology and Health Monitoring 2015), respectively. Using the Bayes formula, we derived the probability of being a never smoker among the lung cancer cases $P_{ij}(\mathrm{NS}|\mathrm{LC})$ as

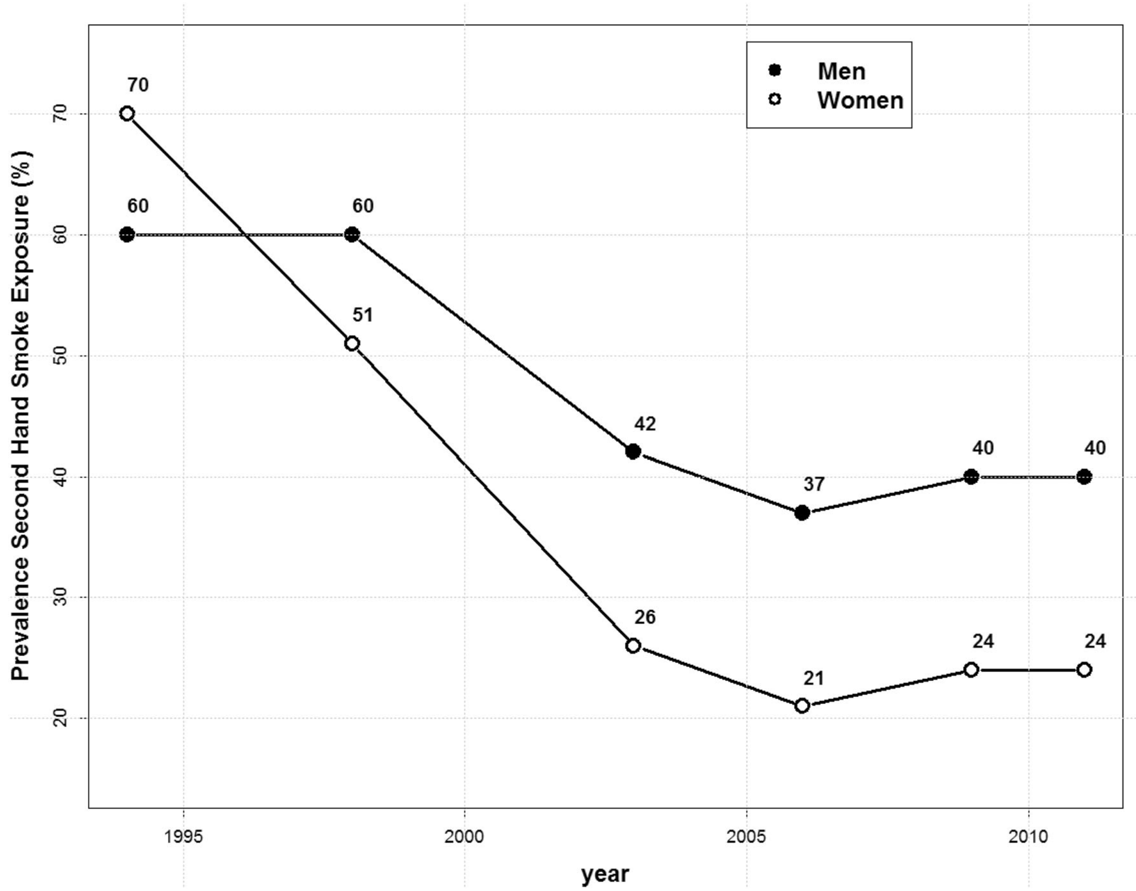

Fig. 2 Prevalence estimates of second hand smoke exposure in Germany, 1994–2011

$$P_{ij}(\mathrm{NS}|\mathrm{LC}) = \frac{P_{ij}(\mathrm{LC}|\mathrm{NS}) \times P_{ij}(\mathrm{NS})}{P_{ij}(\mathrm{LC}|\mathrm{NS}) \times P_{ij}(\mathrm{NS}) + P_{ij}(\mathrm{LC}|\mathrm{S}) \times P_{ij}(\mathrm{S}) + P_{ij}(\mathrm{LC}|\mathrm{FS}) \times P_{ij}(\mathrm{FS})}$$
$$= \frac{P_{ij}(\mathrm{NS})}{P_{ij}(\mathrm{NS}) + \mathrm{RR}^{\mathrm{S}} \times P_{ij}(\mathrm{S}) + \mathrm{RR}^{\mathrm{FS}} P_{ij}(\mathrm{FS})}.$$

Finally, given the number of lung cancer deaths in Germany by sex i and age group j (D_{ij}) (Statistisches Bundesamt 2015), we obtained estimates for the lung cancer deaths among never smokers by sex i and age group j ($D^{\mathrm{NS}}_{ij(I)}$) as $D^{\mathrm{NS}}_{ij(I)} = P_{ij}(\mathrm{NS}|\mathrm{L}) \times D_{ij}$.

Approach II

As a second approach (II) we combined two published estimates of the mortality rate of lung cancer in never smokers (λ_i^{NS}). The first estimate was based on Table 1 in Winkler et al. (2011), being $\log_{10}(\lambda(\mathrm{age})) = -16.07 + 0.041\,\mathrm{age} + 4.82 \ln(\mathrm{age})$. Using this equation we calculated the predicted, age-specific rates for all 5-year groups from 20 to 95. The second estimate was from a more recent study by Lee and Forey (2013), providing age- and sex-specific lung cancer mortality rates in their Table 2. These estimates were combined using a linear regression model separately for men and women of the form $\ln(\lambda_i^{NS}(\mathrm{age})) = \alpha + \beta_1\,\mathrm{age} + \beta_2 \ln(\mathrm{age})$.

Given the resulting mortality rate estimates by sex i and a specific age among never smokers ($\lambda_i^{\mathrm{NS}}(\mathrm{age})$), we estimated the number of never smoking lung cancer cases by sex i and age group j ($D^{\mathrm{NS}}_{ij(\mathrm{II})}$) as

$$D^{\mathrm{NS}}_{ij(\mathrm{II})} = (\lambda_i^{\mathrm{NS}}(\mathrm{age}) \times M_{ij},$$

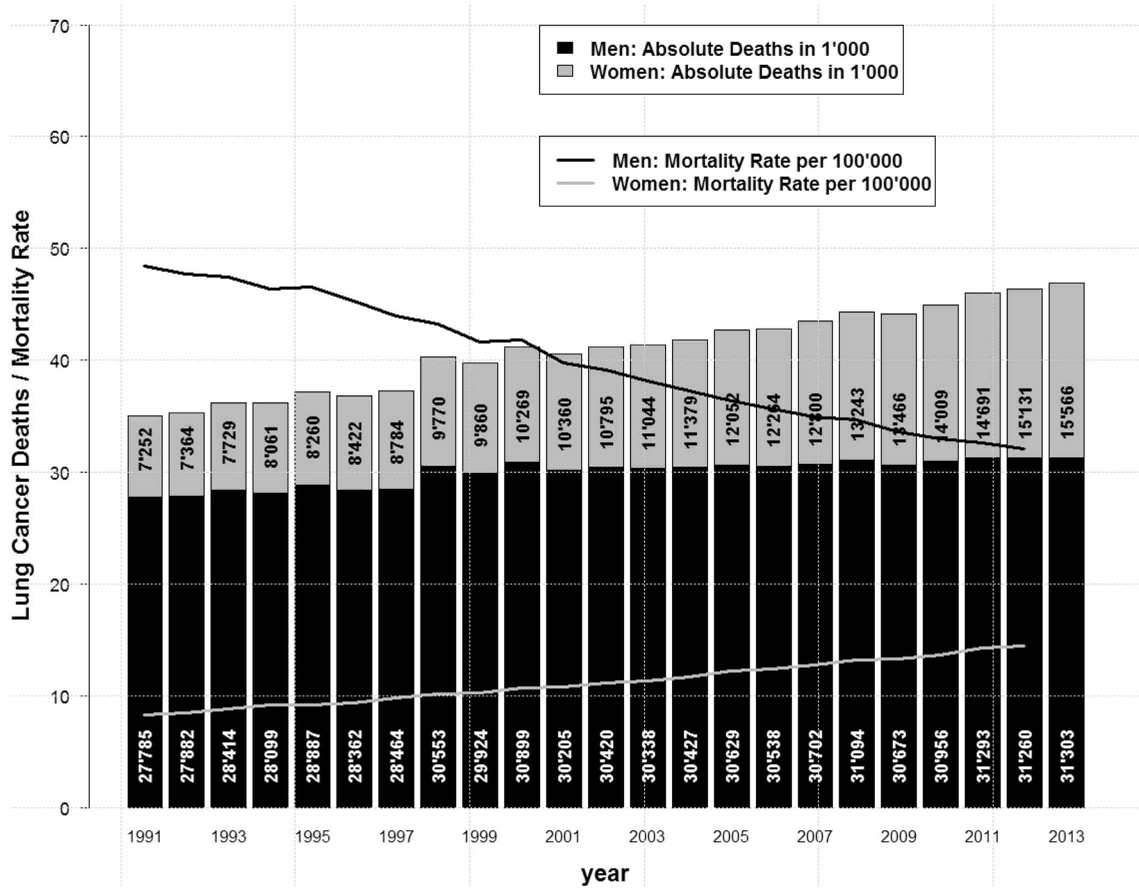

Fig. 3 Absolute number of lung cancer deaths and age-standardized (Segi world standard population) lung cancer mortality rates in Germany, 1991–2013

where M_{ij} is the number of never smokers for sex i and age group j in the German population, derived as the product of the German population figures and $P_{ij}(\mathrm{NS})$.

Finally, we multiply the estimate for lung cancer deaths among never smokers $(\mathrm{LCD}_{ij}^{\mathrm{NS}})$ with the attributable risk of SHS $\left(\mathrm{AR}_{ij}^{\mathrm{SHS}}\right)$ to get the age- and sex-specific number of lung cancer deaths caused by SHS exposure, and the equivalent total number of deaths as

$$D^{\mathrm{NS,SHS}} = \sum_{ij} AR_{ij}^{\mathrm{SHS}} \times D_{ij}^{\mathrm{NS}}.$$

For this last calculation step, we first used the estimated D_{ij}^{NS} derived from both approaches separately. As both approaches have a theoretical justification, we do not favor one over the other. Numerical differences may result from model assumptions or inaccurateness in the data. Therefore, we give equal weight to both estimates in a joint analysis when combining the results of the two approaches by calculating the mean.

Results

We first combined the estimate from the most recent meta-analysis (US Department of Health and Human Services 2006) and the estimate of the latest study (Kim et al. 2014) to derive a relative risk of lung cancer due to SHS of 1.21 (95% CI 1.14–1.28). Based on this RR estimate and the SHS prevalence data, the overall AR estimates are 7.66% in men and 4.70% in women. The estimates by sex and age group show large variation (Table 1), which can be explained by a high negative association between the prevalence of SHS and age. Compared to the reference study from 1994 (Becher and Wahrendorf 1994), where the estimates were 17% in men and 20% in women, the current AR estimates are a lot lower.

Approach I

The proportion of smokers, former smokers, and never smokers in the population is provided in the DEGS1 survey for 2013 (Robert Koch-Institute and Department of

Table 1 Relative risk of lung cancer due to second hand smoking (SHS) (RR^{SHS}), prevalence of SHS (p_{ij}^{SHS}), and resulting attributable risk due to SHS (AR_{ij}^{SHS}) in Germany 2008–2011, by sex i and age group j

	p_{ij}^{SHS} (%)	AR_{ij}^{SHS} (%)
Men	39.5	7.66
<45	52.6	9.95
45–65	32.2	6.33
>65	16.7	3.39
Women	23.5	4.70
<45	36.2	7.06
45–65	20.6	4.15
>65	7.8	1.61
Source	Own calculation based on Robert Koch-Institute and Department of Epidemiology and Health Monitoring (2015)	Based on: $RR^{SHS} = 1.21$; own calculation based on US Department of Health and Human Services (2006), Kim et al. (2014)

Epidemiology and Health Monitoring 2015) (Table 2). Based on a meta-analysis from 2008, we used an estimate for RR of lung cancer due to smoking of 9.87 (95% CI 6.85–14.24) and 7.58 (95% CI 5.36–10.73) for men and women, respectively (Gandini et al. 2008). In former smokers the RR estimate was 3.85 (95% CI 2.77–5.34) for both sexes (Gandini et al. 2008). Since this estimate was not given separately by sex, we assume an equal ratio of the relative risk for men and women in former smokers as for current smokers. Here, we have 9.87/7.58 = 1.3 which is due to the higher average dose in male compared to female smokers. As a result, the RR estimates we used for former smokers were 4.43 for men and 3.35 for women (Table 2). Given the Bayes formula, in total 8.6% in men and 27.0% in women among lung cancer deaths were never smokers. This resulted in an estimate for the total number of 6909 lung cancer deaths among never smokers per year, out of which 190 were attributable to SHS only (Table 2).

Approach II

The linear regression models combining the two estimates from published studies resulted in the following lung cancer mortality rate estimates among never smokers $\lambda_i^{NS}(\text{age})$ per 100,000

$$\lambda_{\text{men}}(\text{age}) = e^{-39.8902+12.1409\times\log(\text{age})-0.1155\times\text{age}}/100{,}000$$

and

$$\lambda_{\text{women}}(\text{age}) = e^{-38.2996+11.6194\times\log(\text{age})-0.1091\times\text{age}}/100{,}000.$$

Multiplying these lung cancer rates (using the mid-age of each given age group) with the estimated number of never smokers for the corresponding age group in the German population M_{ij} resulted in an estimate of the number of never smoking lung cancer cases of 5235, out of which 143 were attributable to SHS only. We estimated higher numbers for the youngest age group and lower values for the higher age groups (Table 3).

Combining the two estimates for the number of never smokers among the lung cancer deaths, results in a mean of 6072 deaths, out of which 167 were attributable to SHS. This represents 0.36% of all lung cancer deaths in 2013.

Table 2 Lung cancer deaths among never smokers ($D_{ij(I)}^{NS}$) and lung cancer deaths among never smokers attributable to second hand smoke (SHS) ($D_{ij(I)}^{NS,SHS}$) in Germany 2013, by sex i and age group j, data and results for Approach I

	AR_{ij}^{SHS} (%)	$P_{ij}(S)$ (%)	$P_{ij}(FS)$ (%)	P_{ij} (NS) (%)	RR^S	RR^{FS}	D_{ij} (n)	P_{ij}(NS|LC)(%)	$D_{ij(I)}^{NS}$ (n)	$D_{ij(I)}^{NS,SHS}$ (n)
Men	7.66	32.6	33.7	33.7	9.87	4.43	31,303		2701	107
<45	9.95	43.0	19.1	37.9			247	6.93	17	2
45-65	6.33	30.3	43.0	26.7			8710	5.17	450	29
>65	3.39	11.5	50.8	37.6			22,346	10.00	2234	76
Women	4.70	26.9	22.8	50.3	7.58	3.35	15,566		4208	83
<45	7.06	34.9	17.9	47.2			153	12.70	19	1
45-65	4.15	27.8	30.3	41.9			4960	11.83	587	24
>65	1.61	9.0	20.0	71.1			10,453	34.46	3602	58
Total									6909	190
Source	Table 1	Own calculation based on Robert Koch-Institute and Department of Epidemiology and Health Monitoring (2015)			Gandini et al. (2008)		Statistisches Bundesamt (2015)			

AR_{ij}^{SHS} attributable risk for lung cancer due to second hand smoke, $P_{ij}(S)$ proportion of smokers, $P_{ij}(FS)$ proportion of former smokers, $P_{ij}(NS)$ proportion of never smokers, RR^S relative risk of lung cancer due to smoking, RR^{FS} relative risk of lung cancer due to former smoking, D_{ij} number of lung cancer deaths in Germany, $P_{ij}NSLC$ probability of being a never smoker among lung cancer cases

Table 3 Lung cancer deaths among never smokers ($D^{NS}_{ij(II)}$) and lung cancer deaths among never smokers attributable to second hand smoke (SHS) ($D^{NS,SHS}_{ij(II)}$) in Germany 2013, by sex i and age group j, data and results for approach II

	Mid-age (years)	AR^{SHS}_{ij} (%)	M_{ij} (n)	λ^{NS}_i(age)* per 100,000	$D^{NS}_{ij(II)}$ (n)	$D^{NS,SHS}_{ij(II)}$ (n)
Men					1756	71
<25	22.5	9.95	867,910	0.01	0	0
25–29	27.5	9.95	1,030,880	0.06	1	0
30–34	32.5	9.95	986,916	0.25	2	0
35–39	37.5	9.95	940,299	0.8	8	1
40–44	42.5	9.95	949,016	2.06	20	2
45–49	47.5	6.33	878,697	4.47	39	2
50–54	52.5	6.33	936,636	8.45	79	5
55–59	57.5	6.33	804,204	14.31	115	7
60–64	62.5	6.33	675,510	22.1	149	9
65–69	67.5	3.39	782,832	31.58	247	8
70–74	72.5	3.39	694,848	42.21	293	10
75–79	77.5	3.39	707,632	53.24	377	13
80–84	82.5	3.39	381,640	63.84	244	8
85–89	87.5	3.39	189,880	73.21	139	5
>89	92.5	3.39	53,392	80.68	43	1
Women					3479	72
<25	22.5	7.06	1,024,712	0.01	0	0
25–29	27.5	7.06	1,211,624	0.06	1	0
30–34	32.5	7.06	1,178,584	0.25	3	0
35–39	37.5	7.06	1,144,600	0.76	9	1
40–44	42.5	7.06	1,159,704	1.88	22	2
45–49	47.5	4.15	1,345,409	3.97	53	2
50–54	52.5	4.15	1,441,360	7.35	106	4
55–59	57.5	4.15	1,267,056	12.26	155	6
60–64	62.5	4.15	1,119,987	18.72	210	9
65–69	67.5	1.61	1,601,883	26.54	425	7
70–74	72.5	1.61	1,510,875	35.28	533	9
75–79	77.5	1.61	1,689,336	44.38	750	12
80–84	82.5	1.61	1,067,922	53.18	568	9
85–89	87.5	1.61	697,491	61.06	426	7
>89	92.5	1.61	322,794	67.5	218	4
Total					5235	143
Source		Table 1	Statistisches Bundesamt (2015)			

AR^{SHS}_{ij} attributable risk for lung cancer due to second hand smoke, M_{ij} never smokers, $\lambda^{NS}_i(age)$ lung cancer mortality rate estimates among never smokers

Sensitivity analyses

There are different prevalence estimates in the estimation process, and the procedures used are based on several assumptions. Since these uncertainties can only partly be captured by random variation, a formal sensitivity analysis is difficult. If we consider the two limits of the 95% CI of the RR estimate, i.e. 1.14 and 1.28, the range of lung cancer deaths among never smokers due to SHS for the first approach is 128–250, for the second approach 97–189, and for the combination of both approaches 113–220.

Overall, we think that the range from 113 to 220 per year is a reasonable interval to describe the uncertainty in our estimate, although we acknowledge that this interval has no clear statistical properties and cannot be interpreted as a confidence interval.

Discussion

Our results suggests that 167 lung cancer deaths among never smokers are attributable to SHS per year, which is a strong decline by about 58% compared to the estimate of about 400 from 1994. Relating these figures to the total number of lung cancer deaths per year, the proportion has reduced from 1.1% in 1994 to 0.36% in 2011. These results show that the relevance of SHS for lung cancer mortality has decreased considerably in the last two decades, in particular due to a reduction in exposure to SHS. However, we note that this decrease is partly due to the current RR estimate being lower than the one in the reference publication (Becher and Wahrendorf 1994). If we had used the current RR estimate, the earlier estimate would have decreased by about 100 to about 300 lung cancer deaths among never smokers.

Under additional assumptions, the presented results can be transferred to the incidence of lung cancer, rather than mortality. A current estimate of the ratio of lung cancer incidence to lung cancer mortality in Germany is about 1.2 in men and 1.3 in women [Robert Koch-Institute and Association of Population-based Cancer Registries in Germany (GEKID) 2013]. This allows a rough estimate of the number of incident lung cancer cases attributable to SHS.

The prevalence data used in the current study are in accordance with the new findings on SHS and tobacco use among young people in Germany from Kuntz and Lampert (2016). However, the decline in smoking has recently been accompanied with an increasing popularity of electronic cigarettes. To date there is no reliable epidemiological data on the prevalence and their impact due to the short observation time, but Rowell and Tarran (2015) revealed that inhaling smoke of an e-cigarette filled with a nicotine-liquid contains a comparable degree of nicotine as a conventional cigarette.

A decrease of smoking prevalence and enforced laws for protection of nonsmokers have been observed for other countries as well. All EU countries have adopted measures to protect citizens against exposure to tobacco smoke. However, national measures differ considerably in extent and scope. The strictest measures were introduced by Ireland, the UK, Greece, Hungary, Bulgaria, Malta and Spain (European Commission's Directorate for public health and risk assessment 2017). These laws have an effect on SHS exposure as well. For example, overall 28% of Europeans were exposed to second hand smoke in bars in 2012—down from 46% in 2009 (European Commission 2017). Therefore, we assume a similar decline of lung cancer deaths in the EU overall caused by SHS. Since there is still a large variation between countries, the decline may differ considerably by country.

Our calculations are based on a number of simplifying assumptions. In particular, the information on the number of never smokers among lung cancer deaths and the prevalence of SHS exposure to a relevant extent potentially has a strong impact on the estimates. Unfortunately, data on the smoking status of lung cancer cases is not available, which is why we had to resort to indirect approaches.

As the two approaches differ conceptionally, it was to be expected that the results differ to some extent. Looking at the estimates by sex and age group, the largest difference is observed in the group of older males (>65 years), where approach I yields 76 cases, approach II only 45. A possible explanation for this difference is an underestimation of the lung cancer rate in nonsmokers in the modelling procedure in Winkler et al. (2011). However, overall the extent of the differences was limited, which is why we believe that the estimates presented here are realistic.

Other limitations are related to the latency period from exposure to disease and the choice of prevalences for the current number of lung cancer cases. In this case, we have used the latest prevalence data. Since these prevalence rates have remained relatively constant over the last ten years, we consider this to be appropriate.

Our study shows that the number of lung cancer cases attributable to SHS exposure has considerably decreased, as a consequence of a decrease in smoking and SHS prevalence in the German population. By now, smoke-free conditions in restaurants, public buildings, and public transportation are taken for granted. However, the proportion of smokers and individuals who are exposed to SHS is still quite high in Germany, and further public health measures are warranted. In this study, lung cancer was considered the target disease; however, many other diseases are caused by or associated with SHS as well. As a consequence, the positive effects of a reduction in SHS exposure in the general population are not limited to the prevention of lung cancer only. The health effects of active and passive smoking remains considerable and further prevalence reduction remains a challenge for health policy.

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