RESEARCH PAPER

Mortality, morbidity and costs attributable to smoking in Germany: update and a 10-year comparison

Simone Neubauer, Robert Welte, Alexandra Beiche, Hans-Helmut Koenig, Katharina Buesch, Reiner Leidl

Tobacco Control 2006;**15**:464–471. doi: 10.1136/tc.2006.016030

See end of article for authors' affiliations

Correspondence to: S Neubauer, GSF-National Research Center for Environment and Health, Institute of Health Economics and Health Care Management, Ingolstaedter Landstrasse 1, 85764 Neuherberg, Germany; simone.neubauer@gsf.de

Received 2 February 2006
Accepted 2 August 2006

Objective: To assess the negative health consequences and associated costs of cigarette smoking in Germany in 2003 and to compare them with the respective results from 1993.
Methods: The number of deaths, years of potential life lost (YPLL), direct medical and indirect costs caused by active cigarette smoking in Germany in 2003 is estimated from a societal perspective. The method is similar to that applied by Welte *et al,* who estimated the cost of smoking in Germany in 1993. Therefore, a direct comparison of the results was possible. Methodological and data differences between these two publications and their effect on the results are analysed.
Results: In 2003, 114 647 deaths and 1.6 million YPLL were attributable to smoking. Total costs were €21.0 billion, with €7.5 billion for acute hospital care, inpatient rehabilitation care, ambulatory care and prescribed drugs; €4.7 billion for the indirect costs of mortality; and €8.8 billion for costs due to work loss days and early retirement. From 1993 to 2003, the proportionate mortality attributable to smoking remained relatively stable, rising from 13.0% to 13.4%. The smoking-attributable deaths in men is lowered by 13.7% whereas that in women increased by 45.3%. Total real direct costs rose by 35.8%, and total real indirect costs declined by 7.1%, rendering an increase of 4.7% to real total costs. Accountable factors are changes in cigarette smoking prevalence and in disease-specific mortality and morbidity, as well as a rise in general healthcare expenditure.
Conclusions: Despite the growing knowledge about the hazards of smoking, the smoking-attributable costs increased in Germany. Further, female mortality attributable to smoking is much higher than it was in 1993.

As a result of the devastating health consequences of smoking, many countries have implemented anti-smoking measures. For example, Ireland and Italy banned smoking in all public buildings and at all workplaces, including pubs and restaurants. Several publications have shown that Germany is still rather friendly to the tobacco industry.[1] This is also supported by recent decisions not to implement a smoking ban or to prohibit smoking in all public places. However, Germany increased the tax on tobacco products three times since 2004, which decreased cigarette sales and smoking prevalence in the age group 12–17 years.[2 3]

The first cost-of-smoking study for Germany used 1993 as the reference year,[4] and was published by some of us. Since then, three other studies have been published: one is by Ruff *et al*,[5] which cannot be used for comparison because of a lack of methodological transparency, and two by Wegner *et al*,[6 7] which considered only indirect costs. Thus, costs of smoking can be compared with only the first study.

This study presents the most recent estimate for both direct and indirect costs of cigarette smoking in Germany, based on the latest available data and referring to the year 2003. As a similar method was applied, costs of smoking can be directly compared between 1993 and 2003.

METHODS

The direct medical and indirect costs of diseases attributable to cigarette smoking were estimated for Germany in 2003 from a societal perspective. The method used, although similar to the previous publication by Welte *et al*,[4] was improved. Although the calculation of direct and indirect costs remained mostly unchanged, the database was partially modified as more detailed data were now available. The prevalence-based approach and the concept of smoking-attributable fractions (SAFs) were applied for the diseases (table 1).[8 9] SAFs for smoking-attributable deaths were calculated using an epidemiological model that accommodates three levels of cigarette smoking status: current, former and never.[10]

A top–down approach was used and data were derived from databases and publications. In the baseline analysis, future costs were discounted at 3%, as recommended by Gold *et al*.[11] Indirect costs were estimated using the human capital approach. A univariate sensitivity analysis was used to determine the robustness of the results.

The prevalence of cigarette smoking was considered in two different ways using (a) nine age groups (baseline analysis) and (b) two age groups (<65, ⩾65 years). There are two regularly conducted surveys in which the smoking prevalence in Germany is measured: (1) the Microcensus, a representative household sample survey, in which typically one household member answers the questionnaire for all other household members[12]; and (2) the Telephone Health Survey, another regularly performed representative statistical survey, for which people are randomly selected from the resident population.[13] We chose the results from the Telephone Health Survey 2003 as the prevalence data source because of the greater chance of under-reporting in the Microcensus. For current smokers, the Telephone Health Survey assesses cigarette smoking, whereas for former smokers, it does not distinguish between different types of tobacco smoking. To estimate the prevalence of former

Abbreviations: CPS, Cancer Prevention Survey; ICD, International Classification of Diseases; SAF, smoking-attributable fraction; YPLL, years of potential life lost

Table 1 Relative mortality risks of smoking-associated diseases for the US

ICD-10	Disease category	Smoking status: Men, Current	Men, Former	Women, Current	Women, Former
Neoplasms					
C00–14	Lip, oral cavity, pharynx	10.89	3.40	5.08	2.29
C15	Oesophagus	6.76	4.46	7.75	2.79
C25	Pancreas	2.31	1.15	2.25	1.55
C32	Larynx	14.60	6.34	13.02	5.16
C33–34	Trachea, bronchus, lung	23.26	8.70	12.69	4.53
C53	Cervix, uteri	–	–	1.59	1.14
C67	Urinary bladder	3.27	2.09	2.22	1.89
C64–66, 68	Kidney, other urinary	2.72	1.73	1.29	1.05
Cardiovascular diseases					
I00–9	Rheumatic heart disease	1.78	1.22	1.49	1.14
I10–15	Hypertension	2.11	1.09	1.92	1.02
I20–25	Ischaemic heart disease				
	Age 35–64 years	2.80	1.64	3.08	1.32
	Age ⩾65 years	1.51	1.21	1.60	1.20
I26–28	Pulmonary heart disease	1.78	1.22	1.49	1.14
I30–52	Other forms of heart disease	1.78	1.22	1.49	1.14
I60–69	Cerebrovascular disease				
	Age 35–64 years	3.27	1.04	4.00	1.30
	Age ⩾65 years	1.63	1.04	1.49	1.03
I70	Atherosclerosis	2.44	1.33	1.83	1.00
I71	Aortic aneurysm	6.21	3.07	7.07	2.07
I72, 74–78	Other arterial disease	2.07	1.01	2.17	1.12
Respiratory diseases					
A15–16	Respiratory tuberculosis	1.75	1.36	2.17	1.10
J10–18	Pneumonia, influenza	1.75	1.36	2.17	1.10
J40–43	Bronchitis, emphysema	17.10	15.64	12.04	11.77
J45–46	Asthma	1.75	1.36	2.17	1.10
J44	Chronic airways obstruction	10.58	6.80	13.08	6.78
Perinatal diseases					
P07	Short gestation/low birth weight	1.83	1.83	1.83	1.83
P22	Respiratory distress syndrome	1.30	1.30	1.30	1.30
P23–28	Other respiratory conditions in newborns	1.41	1.41	1.41	1.41
R95	Sudden infant death syndrome	2.29	2.29	2.29	2.29

ICD, International Classification of Diseases.
Source: Centers for Disease Control and Prevention,[8] Gavin *et al.*[9]

cigarette smoking, we assumed the age-specific and sex-specific proportion of former cigarette smokers to all former smokers to be the same as reported in the Microcensus 2003. However, smoking behaviour during pregnancy was based on the most recent data for this subgroup—that is, the German Perinatal Survey from 1995 to 1997.[14] Relative risks were determined from the 6-year follow-up of the Cancer Prevention Study II.[9] Smoking-attributable deaths were derived by applying the SAFs to the number of deaths by age, sex and disease.[15] The relative mortality risks of cigarette smoking were used as proxy for the relative morbidity risks of cigarette smoking as a result of a lack of other data. This approach has also been used in other cost studies.[4 6 7 16–18] Smoking-attributable years of potential life lost (YPLL) were calculated by multiplying the smoking-attributable deaths by age and sex with the respective group-specific life expectancy.[19] The relative risk ratios were available for people aged ⩾35 years. Therefore, we estimated the cost of smoking for these age groups.

The calculation of smoking-attributable costs of outpatient and acute hospital care was based on data from the ''Health—cost of illness 2002'' report published by the Federal Statistical Office, Germany.[20] The report presents cost data for several healthcare institutions according to International Classification of Diseases (ICD) groups, which were generated by applying a top-down approach. Where possible, costs were allocated according to the main diagnosis. Otherwise, equal shares of the costs were divided between all stated diagnoses. The outpatient data of this report were based on two regional samples of subjects for whom healthcare expenses according to age, sex and disease were obtained. These detailed analyses were available only for 2002. Hence, it was assumed that the ratio between the cost per ICD group and total costs did not change between 2002 and 2003. As the cost data were available only for a higher aggregated ICD level than needed, it was assumed that the distribution of the costs of acute hospital and outpatient care within the ICD groups is linearly related to the hospital days per disease. The smoking-attributable costs of acute hospital care and ambulatory visits were estimated by calculating the proportion of smoking-attributable hospital days to the total sum of hospital days. Smoking-attributable hospital days were derived by applying the SAFs to the hospital days for Germany in 2003 according to age, sex and disease (see appendix for an example).[21] As hospital care expenses do not include publicly funded hospital investments, the costs were increased by 4.4%, corresponding to the ratio between total hospital investments and the expenses for total hospital care.[22] Costs for research and education were excluded.

Smoking-attributable costs of inpatient rehabilitation were estimated similarly as the hospital costs. However, instead of

Table 2 Mortality and years of potential life lost attributable to smoking, in Germany 2003

	Neoplasms	Cardiovascular diseases	Respiratory diseases	Perinatal diseases	Burn deaths	Total
Deaths						
Men	36 055	29 293	14 404	110	162	80 024
Women	10 260	16 528	7 650	80	105	34 623
Both sexes	46 315	45 821	22 053	190	267	114 647
Both sexes (%)	40.4	40.0	19.2	0.2	0.2	100.0
YPLL						
Men	537 083	388 744	146 171	8 331	4 738	1 085 067
Women	182 975	196 473	84 705	6 498	2 395	473 046
Both sexes	720 058	585 217	230 876	14 829	7 133	1 558 113

YPLL, years of potential life lost.

hospital days, rehabilitation cases in 2003, according to age, sex and disease, were multiplied by the sex-specific and disease-specific number of rehabilitation days per patient.[23] The proportion of smoking-attributable rehabilitation days to all rehabilitation days was used to determine the smoking-attributable costs from the total costs of inpatient rehabilitation.[24] The calculations of the inpatient rehabilitation sector were based on data from the statutory pension insurance. Most Germans are enrolled in the statutory pension insurance. Similar to the previous paper,[4] costs of other payers (eg, employers, private health insurance, private households) were also considered by assuming that the sector-specific proportions of smoking-attributable costs were the same as for the statutory pension insurance.

The estimation of the smoking-attributable costs of prescribed drugs in the ambulatory sector was based on a report of prescribed drugs,[25] which categorises prescribed drugs by diagnostic categories. These diagnostic categories were assigned to ICD10 main groups, and the specific proportions of the ICD10 main groups determined from hospital care (smoking-attributable hospital days divided by all hospital days) were applied to the drug costs of the respective ICD10 main groups. Drugs prescribed in hospitals and inpatient rehabilitation are included in the total cost in each of these categories.

The indirect costs of smoking were estimated using the yearly labour costs, according to age and sex, as an approximation for the net production of a person. The smoking-attributable costs of premature mortality were determined by multiplying the smoking-attributable deaths, according to age and sex, with the age-specific and sex-specific present value of the future net product per capita. This value was estimated by multiplying the age-specific and sex-specific survival probabilities[19] with the respective (yearly) net product,[26] and summing the yearly net products to the age of 90 years (baseline analysis) or 65 years (sensitivity analysis). The smoking-attributable costs of early retirement were determined by multiplying the smoking-attributable cases of early retirement, according to age and sex, with the respective present value of the future net products per employed person, by age and sex.[27] The remaining productivity associated with early retirement was estimated at 25% and 50%, depending on whether retirement was due to complete or partial inability to work, respectively. Only these categories can be distinguished from the available data. The smoking-attributable costs of work days lost were calculated by multiplying the smoking-attributable work days lost as a result of acute illness or rehabilitation[28] with the net product of employed persons per effective work day by age and sex. The smoking-attributable work days lost as a result of acute illness were estimated analogously to the acute hospital days.

In the sensitivity analysis, the effect of using the friction cost method and including the loss of unpaid work (eg, household services, taking care of relatives) was investigated, the unpaid work potentially gaining relevance in an ageing society. Friction cost was calculated using a friction time of 71 days,[29] and an elasticity for annual labour time versus a labour productivity of 0.8.[30] The average time spent on unpaid work by age and sex was derived from the most recent German time budget study (2001–2).[31] For valuation of unpaid work, the substitution cost approach and the minimum opportunity cost approach were used—that is, the effective labour costs of employed housekeepers and the effective net income per employed housekeeper, respectively. Additional sensitivity analyses were performed to investigate the robustness of our results with respect to using different databases.

For the comparison of the present results with those of 1993,[4] the 1993 prices were inflated to 2003 levels according

Table 3 Cost of cigarette smoking in Germany 2003 (million Euros)

	Neoplasms	Cardiovascular diseases	Respiratory diseases	Perinatal diseases	Burn deaths	Total
Direct costs	1 693	3 735	1 867	185	Not considered	7 480
Hospital care	1 126	1 747	663	69		3 605
Ambulatory care	312	853	489	115		1 769
Rehabilitation	112	120	68	0		300
Prescribed drugs	144	1 015	647	0		1 806
Indirect costs	6 574	2 888	3 920	88	75	13 545
Mortality	3 436	658	444	88	75	4 701
Morbidity	3 138	2 230	3 476	0	0	8 844
Work days lost	217	1 289	2 387	0	0	3 893
Early retirement	2 921	941	1 089	0	0	4 951
Total costs	8 267	6 623	5 787	273	75	21 025

to the consumer price index.[32] Otherwise, no appropriate data are available regarding the sector-specific price increase for German healthcare. Indirect costs were adjusted by the average wage increase over the decade.

RESULTS

Tables 2 and 3 show the main results of our calculations. In 2003, 114 647 (13.4%) deaths were attributable to cigarette smoking in Germany. In all, 20.2% of all male deaths and 7.6% of all female deaths were caused by cigarette smoking.

More than two thirds (69.8%) of all smoking-attributable deaths were male deaths. Most smoking-attributable deaths (71.7%) occurred in people aged ⩾65 years. The number of YPLL totalled almost 1.6 million, of which 294 000 could be assigned to the age group <65 years (current statutory age of retirement for men in Germany).

The total smoking-attributable costs added up to €21 billion, of which 35.6% were direct and the remaining 64.4% were indirect. Cardiovascular diseases were the main cost driver, accounting for half of the direct costs (49.9%), followed by respiratory diseases (25.0%) and neoplasms (22.6%). Perinatal diseases accounted for 2.5% of the direct costs. However, most expenses were due to hospitalisation and acute outpatient care, which made up 71.9% of the direct costs. Prescribed drugs accounted for 24.1% of direct costs, whereas rehabilitation accounted for only a small amount of these costs. The direct cost of smoking accounted for 3.3% of the total healthcare expenditure in Germany in 2003.

In contrast with direct costs, the main driver of indirect costs was neoplasms. Mortality and morbidity accounted for one third and two thirds of the indirect costs, respectively, with 56% of the morbidity costs due to early retirement and 44% due to work days lost.

Sensitivity analysis

Figure 1 shows that the indirect costs of smoking were highly sensitive to the valuation method chosen, particularly with respect to the valuation of unpaid work. The inclusion of unpaid work led to a substantial increase of indirect costs. Valuing unpaid work by opportunity costs increased the indirect costs by 76%, whereas applying the substitution cost method even increased these costs by 166%. Use of the friction cost method instead of the human capital approach and, to a lesser extent, the choice of the discount rate also had an effect on the indirect costs. Assuming that productivity ended at age 65 years further decreased the indirect costs by 10%.

Factors that influenced indirect and also direct costs and mortality were smoking prevalence, the number of smoking prevalence strata and the relative risk estimates. When using the prevalence rates of the Microcensus 2003,[12] smoking-attributable costs and mortality declined, as the prevalence rates were lower than those in the Telephone Health Survey 2003.[33] Stratification of smoking prevalence into only two age groups instead of nine slightly increased the direct and indirect costs and the mortality. Using a smaller number of prevalence groups led to higher smoking prevalence estimates in older age groups. The groups aged ⩾65 years accounted for 73% of all male deaths and 88% of all female deaths in 2003. Hence, small changes in smoking prevalence in these age groups had a substantial influence on smoking-attributable mortality (fig 1). Applying the overall instead of the cigarette smoking prevalence would inappropriately increase mortality and costs, as only about 89% of male smokers and about 99% of females aged ⩾35 years smoke cigarettes. Further, using the 4-year follow-up[34] of the Cancer Prevention Study II instead of the baseline 6-year follow-up led to higher smoking-attributable mortality and costs because of different estimates of relative risk. This calculation shows that changes in smoking prevalence of people aged ⩾65 years as well as in relative mortality risks had a considerable effect on the smoking-attributable mortality.

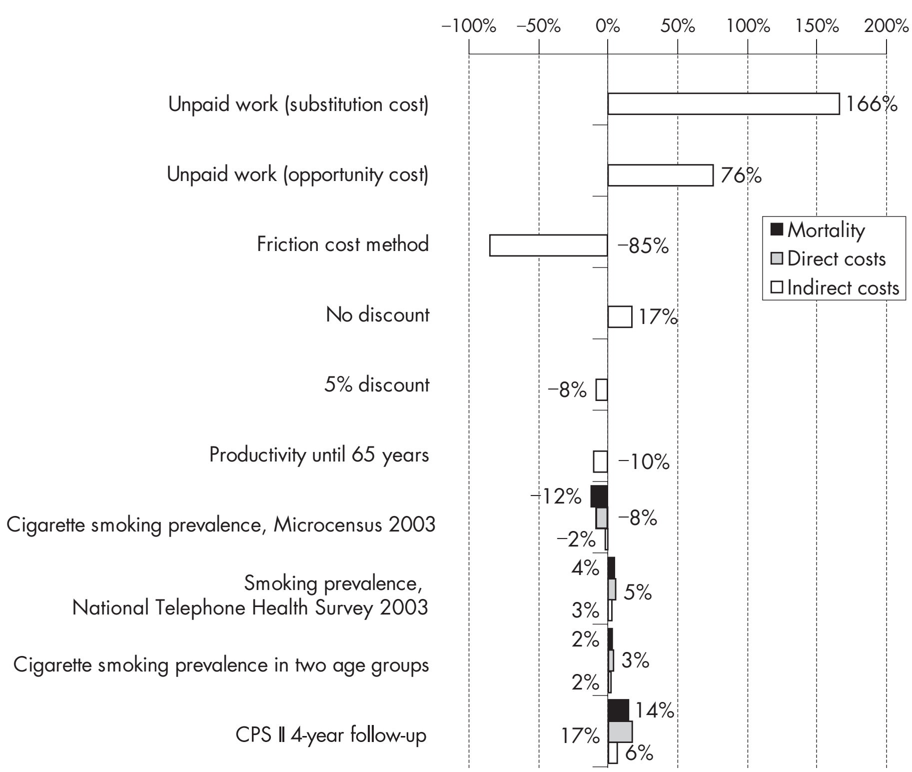

Figure 1 Sensitivity analysis, percentage change in deaths, direct costs and total costs. CPS, Cancer Prevention Survey.

Table 4 Cigarette smoking prevalence in Germany in 2003 and 1992

Age groups (years)	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	⩾75
Smoking status in the Telephone Health Survey, 2003									
Men									
Current	0.42	0.40	0.39	0.28	0.24	0.21	0.14	0.12	0.12
Former	0.25	0.27	0.33	0.35	0.35	0.42	0.42	0.52	0.51
Women									
Current	0.38	0.35	0.37	0.31	0.23	0.17	0.11	0.06	0.06
Former	0.23	0.25	0.26	0.27	0.28	0.21	0.17	0.22	0.22
Change to Microcensus 1992 (applied by Welte *et al*[4])									
Men									
Current	−0.03	0.01	0.02	−0.04	−0.04	−0.04	−0.05	−0.06	0.00
Former	0.07	0.07	0.10	0.11	0.08	0.08	0.04	0.16	0.19
Current	0.05	0.06	0.13	0.15	0.09	0.05	0.02	−0.02	0.03
Former	0.09	0.12	0.13	0.18	0.20	0.13	0.07	0.13	0.17

Source: Robert Koch Institute,[13] Federal Statistical Office.[35]

Comparison 2003 versus 1993

A method similar to that used by Welte *et al*[4] updated and improved, was used, which also influenced the results. SAFs were calculated on the basis of method used in the 1993 model. However, instead of using the 4-year follow-up data, the 6-year follow-up data of the Cancer Prevention Survey (CPS) II were used, which were newly available. Most relative risks decreased in the 6-year follow-up but some increased, such as those for bronchitis and emphysema (ICD10 J40–43).

Further, the most recent cigarette smoking prevalence rates from the Telephone Health Survey 2003 were used instead of the data from the Microcensus 2003. Whereas the prevalence of male smokers predominantly decreased, the corresponding percentage of female smokers increased in almost all age groups between 1992 and 2003 (table 4[13 35]).

In the calculation, smoking prevalence, relative risk estimates and the absolute number of deaths in the population contribute to smoking-attributable mortality. In total, the proportionate mortality attributable to smoking (the proportion of smoking-attributable deaths to overall deaths) remained relatively stable—it increased slightly from 13.0% to 13.4%. However, the absolute number of smoking-attributable deaths decreased during the past 10 years by 1.6% (table 5), which corresponds to the decline in overall mortality by 4.8% between 1993 and 2003.

Smoking-attributable female deaths rose by about 45.3% between 1993 and 2003, which can be mainly explained by using a different data source for smoking prevalence. Using the same but updated data source as in the 1993 study, smoking-attributable female mortality would have been 5.4% higher than in 1993. The lower relative risk estimates compared with those in 1993 somewhat lowered the strong increase in smoking-attributable female mortality. Further, more deaths were caused by diseases with a relative high smoking-attributable fraction. In contrast, smoking-attributable male deaths decreased by 13.7%. This development is linked to a decrease in relative risks of cardiovascular diseases and fewer overall deaths compared with those in 1993. Changes in the smoking prevalence in men slightly diminished the decrease in the corresponding smoking-attributable mortality.

If we had used the CPS II 4-year follow-up data and the Microcensus 2003 data as in Welte *et al*,[4] smoking-attributable deaths would have been 113 740, which is almost the same as in our baseline analysis (table 5). The similarity of the result stems from two counterbalancing effects. On the one hand, the CPS II 4-year follow-up with predominantly higher relative risks would have led to an increase in smoking-attributable deaths. On the other hand, using the Microcensus 2003 with lower smoking prevalence instead of the Telephone Health Survey 2003 would have resulted in fewer smoking-attributable deaths.

The number of YPLL in 2003 was 5.1% higher compared with that in 1993. Whereas there was a slight decrease (−6.8%) in male YPLL, the number of female YPLL rose by 48.6%. This decrease in female YPLL was because of the relatively strong increase in female smoking-attributable mortality. The distribution of the YPLL between the three main diseases (neoplasms, cardiovascular diseases and respiratory diseases) did not change substantially.

The real direct costs of smoking increased by 35.8% between 1993 and 2003 (table 5). Whereas the costs for rehabilitation decreased, all other cost categories increased by at least 33%. The higher direct costs of smoking-attributable diseases can be partially explained by the growth in total healthcare expenditures amounting to 42.7% between 1993 and 2003.[24]

Smoking-attributable costs for hospitalisation rose by 43.4% within this decade. Although the total number of inpatient days was lower in 1993,[36] the number of smoking-attributable inpatient days increased by 10% between 1993 and 2003. This effect was mainly caused by the higher number of hospitalisation days in 2003 as a result of neoplasms with a relative high SAF. Compared with 1993, using a more specific method for the calculation of costs due to the availability of more detailed data for the present

Table 5 Comparison of smoking-attributable deaths, years of potential life lost and cost, cost in 1993 with respect to prices in 2003

	1993	2003	Difference (%)
Mortality	116 507	114 647	−1.6
YPLL	1 483 070	1 558 113	5.1
Direct costs	5 507	7 480	35.8
Hospital care	2 514	3 606	43.4
Ambulatory care	1 328	1 769	33.2
Rehabilitation	377	300	−20.3
Prescribed drugs	1 288	1 805	40.1
Indirect costs	14 573	13 545	−7.1
Mortality	4 851	4 701	−3.1
Morbidity	9 721	8 844	−9.0
Days of work lost	4 019	3 892	−3.2
Early retirement	5 702	4 952	−13.2
Total costs	20 080	21 025	4.7

YPLL, years of potential life lost.

study[20] led to a slight increase in costs of smoking-attributable hospitalisation. In the previous study, total hospital costs were not available for ICD groups.

Total ambulatory expenditures grew by 54.4% during this decade,[24] whereas the percentage increase in smoking-attributable ambulatory costs was lower (33.2%). Applying the method used in the previous publication, the cost of ambulatory care would have been 48% higher or an additional €851 million. Welte *et al*[4] derived the smoking-attributable ambulatory costs from the proportion of smoking-attributable contacts to all contacts. The contacts were available by ICD chapter. As these data are from the early 1980s, we used the more detailed ambulatory costs by ICD group,[20] recently published by the Federal Statistical Office, to calculate the smoking-attributable ambulatory costs.

Using the same calculation method as used in Welte *et al*,[4] expenses for prescribed drugs rose by 40.1% between 1993 and 2003. As in other cost categories, the general increase in expenses for prescribed drugs and the increase in smoking-associated diseases in hospital days was the main reason for this development.

Indirect costs decreased by 7.1% between 1993 and 2003 because smoking-attributable deaths in employable ages decreased during this decade. The strong decrease in smoking-attributable deaths in men aged 35–64 years more than compensated for the increase in the same variable for women.

DISCUSSION

We estimated the smoking-attributable mortality, YPLL and economic cost attributable to smoking in Germany in 2003. More than 114 000 premature deaths, 1.6 million YPLL and €21 billion are the social and economic burdens of smoking. Although only 19% of the YPLL occur before the age of 65 years, the economic burden due to the associated productivity loss is remarkably high. Direct medical costs per smoker added up to €346 and total costs per smoker amounted to €974 in 2003.

Our study permits a direct comparison between the costs of smoking in 2003 and 1993, as the method used was similar to that used in the study in 1993.[4] During this 10-year period, the direct costs increased enormously, whereas the indirect costs slightly decreased. This decrease in indirect costs is a consequence of the reduced mortality in employable ages. The changes in direct costs can be explained mainly by the substantial increase in overall expenditures for healthcare between 1993 and 2003.

Compared with other studies on cost of smoking in developed countries,[37 38] the proportion of smoking-attributable medical costs to the total medical costs at 3.3% lies at the lower end. A comparison of international findings requires a cross-sectional analysis of the applied methods, whereas comparison in this study focused on developments over time.

Other studies used econometric models for calculating medical care costs.[39 40] As against the attributable risk approach, these models consider all smoking-attributable direct costs and control for other risk behaviours, such as alcohol use, and also confounding factors.[38 41] As this study focused on the comparison of the results with those obtained 10 years ago, we used the attributable risk approach. Further, no individualised data but only aggregate data were available for our study, which enabled the applied approach.

We used the relative risk estimates from the CPS II, which was not a nationally representative sample.[42] Malarcher *et al*[41] used a combination of two representative US samples and found that the overall smoking-attributable mortality based on the CPS II was 19% higher than that based on the other combined sample. Age-adjusted relative risks were smaller in the representative US samples, whereas further adjustment of smoking-attributable mortality for education, alcohol use, hypertension and diabetes mellitus did not change the results substantially. As it is not clear to what extent the US relative risks match German relative risks for mortality,[4] further research should be undertaken to derive those estimates for Germany. As our study also focused on the comparison of results with those obtained 10 years ago, we used the data from the CPS II.

The SAF for mortality was used as a proxy for the smoking-attributable healthcare utilisation and expenditures, as no relative risk estimates for morbidity were available. Clearly, this assumption might lead to an overestimation or underestimation for morbidity SAFs, depending on the respective disease. Examples for overestimation are diseases with relatively short duration until death (eg, lung cancer) and those for underestimation are chronic diseases that often occur with other diseases (eg, chronic airways obstruction). The relative risk estimates used in this study neither vary over calendar time nor vary by the time span during which a person smokes. Study results thus do not reflect any effects of smoking that might derive from respective differences between the CPS II population and the populations investigated here.

Also, owing to lack of data, it was assumed that the distribution of ambulatory visits for each ICD code is equal to that of hospital days. The ACUT database, from 1991, provides the most recent data regarding the number of patient contacts with office-based general practitioners and internists in Germany according to ICD9 main groups. The proportion of contacts due to cardiovascular diseases almost equals the proportion of hospital days. In contrast, the ratio of hospital days due to neoplasms overestimates outpatient contacts, whereas the ratio of hospital days due to respiratory diseases underestimates them. The ratio differences were almost the same if hospital cases were used instead of the hospital days. As the ACUT database does not reflect possible shifts between diseases, as was observable for smoking-attributable mortality, the hospital days in 2003 were used as a proxy.

John and Hanke[17] calculated the smoking-attributable mortality in 1995 in Germany. They concluded that smoking-attributable mortality was underestimated in previous studies by at least 24.4%. In contrast with these results, we did not use the overall smoking prevalence in Germany but only the prevalence of cigarette smokers, as the applied relative risk estimates from the CPS II are also only for cigarette smokers. Further, whereas they used a unique and sex-specific prevalence rate for people aged ⩾35 years, we used prevalence rates according to 5-year age groups. Populating our model with the overall and age-group non-specific smoking prevalence of 1995 leads to similar smoking-attributable deaths as calculated by John and Hanke. However, using the same prevalence rate for all age groups renders an overestimation of smoking-attributable deaths, as smoking prevalence decreases with age whereas mortality rises.

The cost of passive smoking was not included as available data are scarce. The Centers for Disease Control and Prevention estimated that 8.6% of all smoking-attributable deaths between 1995 and 1999, which were caused by lung cancer or ischaemic heart diseases, were due to secondhand smoke.[43] Keil *et al*[44] estimated that >3300 people die every year because of passive smoking in Germany.

To compare the study results of 1993 and 2003, the 1993 results were inflated to 2003 using the consumer price index.[45] This adjustment of results may lead to underestimation. Owing to technological advances and high labour intensity in healthcare, sector-specific inflation would be

What this paper adds

- Cigarette smoking is the largest preventable risk factor for morbidity and mortality in developed countries.
- The number of deaths, years of potential life lost, and direct medical and indirect costs caused by active cigarette smoking in 1993 and 2003 in Germany were compared using a similar calculation method.
- Although the proportionate mortality attributable to smoking remained relatively stable (from 13.0% to 13.4%), real direct costs increased by 35.8% and real indirect costs decreased by 7.1%.
- The main reasons for these observations are changes in smoking prevalence, disease-specific mortality and morbidity, and a rise in general healthcare expenditure.

expected to exceed that of general consumption. However, even after special requests, the Federal Statistical Office could not provide a medical care price index. Although the Organisation for Economic Cooperation and Development health data include the price index of health expenditures, only a price index primarily focused on pharmaceutical products is available for Germany,[46] which does not adequately reflect the total price development in the German healthcare sector.

Our estimation of indirect costs using the human capital approach rendered results similar to those of the German study in 1999 by Wegner *et al*.[6] However, applying the friction cost method leads to different results. In the present study, indirect costs add up to €2.1 billion, which is less than half of what Wegner *et al*[7] calculated. This difference is due to the smaller friction period used in the present study.

Differences between the wages of smokers and non-smokers were not considered, although non-smokers are known to have higher average incomes than the smokers.[47] Using more detailed data would lead to lower indirect costs of paid work.

Despite the growing knowledge about the hazards of smoking, the smoking-attributable costs increased and the proportionate mortality attributable to smoking remained relatively stable during the past 10 years in Germany. The effect of female smoking, however, is much higher than that found in the 1993 study, mainly because of a more precise way of surveying smoking prevalence. During the past 5 years, various intervention programmes such as several tobacco tax increases or warning notices on cigarette packs were started or intensified. The findings of this study regarding the burden of smoking and its development over the past decade provide the opportunity to use cost results in the economic evaluation of smoking interventions and also the necessary information for rational policy making.

ACKNOWLEDGEMENTS

We thank Thomas Lampert, Robert Koch Institute, Berlin, for providing the cigarette smoking prevalence data 2003.

Authors' affiliations

S Neubauer, R Welte, K Buesch, R Leidl, GSF-National Research Center for Environment and Health, Institute of Health Economics and Health Care Management, Neuherberg, Germany

A Beiche, Department of Surgery, General Hospital Laupheim, Laupheim, Germany

H-H Koenig, Health Economics Research Unit, Department of Psychiatry, University of Leipzig, Leipzig, Germany

Competing interests: None declared.

REFERENCES

1 **Poetschke-Langer M**, Schunk S. Germany: tobacco industry paradise. *Tob Control* 2001;**10**:300–3.
2 **Bundeszentrale für gesundheitliche Aufklärung**. *Die Drogenaffinität Jugendlicher in der Bundesrepublik Deutschland 2004—Teilband Rauchen* [Drug affinity among young people in the Federal Republic of Germany 2004]. Köln, 2004.
3 **Statistisches Bundesamt**. *Finanzen und Steuern, Fachserie 14, Reihe 9.1.1. Absatz von Tabakwaren* [Finance and taxes, series 14 (9.1.1), tobacco sales]. Wiesbaden: Metzler-Poeschel, 2005.
4 **Welte R**, König H-H, Leidl R. Tobacco—the costs of health damage and productivity losses attributable to cigarette smoking in Germany. *Eur J Public Health* 2000;**10**:31–8.
5 **Ruff LK**, Volmer T, Nowak D, *et al.* The economic impact of smoking in Germany. *Eur Respir J* 2000;**16**:385–90.
6 **Wegner C**, Gutsch A, Hessel F, *et al.* Loss in productivity cost due to smoking in Germany. A partial sickness cost analysis study based on the human capital potential method. *Gesundheitswesen* 2004;**66**:423–32.
7 **Wegner C**, Gutsch A, Hessel F, *et al.* Economic productivity losses as a result of smoking—an analysis under consideration of the friction cost method. *Gesundh Ökon Qual Manag* 2005;**10**:356–64.
8 **Centers for Disease Control and Prevention**. *Smoking-attributable mortality, morbidity, and economic costs (SAMMEC): adult and maternal and child health software.* Atlanta, GA: US Department of Health and Human Services, 2003.
9 **Gavin N**, Wiesen C, Layton C. *Review and meta-analysis of the evidence on the impact of smoking on perinatal conditions built into SAMMEC II*, Final report to the National Centers for Chronic Disease Prevention and Health Promotion. Research Triangle Institute, RTI Project No. 7171-010. Atlanta: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion. North Carolina, 2001.
10 **Shultz JM**, Novotny TE, Rice DP. Quantifying the disease impact of cigarette smoking with SAMMEC II software. *Public Health Rep* 1991;**106**:326–33.
11 **Gold MR**, Siegel JE, Russel LB, *et al. Cost-effectiveness in health and medicine.* Oxford University Press, Oxford, 1996.
12 **Statistisches Bundesamt**. *Rauchgewohnheiten der Bevölkerung - Ergebnisse des Mikrozensus 2003* [Smoking habits of the population—results of the microcensus 2003]. Wiesbaden: Statistisches Bundesamt, 2004.
13 **Robert Koch Institut**. *Cigarette smoking prevalence 2003—statistical evaluation on special request.* Berlin: Robert Koch Institut, 2006.
14 **Voigt M**, Hesse V, Honke B, *et al.* Kosten des Rauchens der Mütter in der Schwangerschaft für die Perinatalmedizin [Cost of smoking during pregnancy for the perinatal medicine]. In: Haunstein K-O. *Rauchen und kindliche Entwicklung—Raucherschäden und Primärprävention* Nürnberg, Perfusion, 2001.
15 **Statistisches Bundesamt**. *Gesundheit—Todesursachen in Deutschland 2003 nach einzelnen Diagnosen (3-stellige ICD)* [Health—causes of deaths in Germany 2003]. Bonn: Statistisches Bundesamt, 2005.
16 **Rasmussen SR**, Prescott E, Sorensen TI, *et al.* The total lifetime costs of smoking. *Eur J Public Health* 2004;**14**:95–100.
17 **John U**, Hanke M. Tabakrauch-attribuable Mortalität in den deutschen Bundesländern [Mortality attributable to smoking in German Federal States]. *Gesundheitswesen* 2001;**63**:363–9.
18 **Yang MC**, Fann CY, Wen CP, *et al.* Smoking attributable medical expenditures, years of potential life lost, and the cost of premature death in Taiwan. *Tob Control* 2005;**14**(Suppl I):i62–70.
19 **Statistisches Bundesamt**. *Perioden-Sterbetafeln für Deutschland. Allgemeine und abgekürzte Sterbetafeln von 1871/1881 bis 2001/2993* [Life tables for Germany. General and abbreviated life tables from 1871/1881 to 2001/2003]. Wiesbaden: Statistisches Bundesamt, 2004.
20 **Statistisches Bundesamt**. *Gesundheit—Krankheitskosten 2002* [Health—cost of illness 2002]. Wiesbaden: Statistisches Bundesamt, 2004.
21 **Statistisches Bundesamt**. *Aus dem Krankenhaus Entlassene und Verweildauer 2003 nach Geschlecht* [Check out of hospital and length of stay by sex]. Wiesbaden: Statistisches Bundesamt, 2005.
22 **Deutsche Krankenhausgesellschaft**. *Krankenhausfinanzierung und -planung—Bestandsaufnahme zur Krankenhausplanung und Investitionsfinanzierung in den Bundesländern* [Hospital funding and planning—inventory of hospital planning and fund raising for investment in the New Federal States]. Deutsche Krankenhausgesellschaft, Berlin, 2004.
23 **Verband deutscher Rentenversicherer**. *Stationäre Leistungen zur medizinischen Rehabilitation und sonstige Leistungen zur Teilhabe für Erwachsene im Berichtsjahr 2003* [Inpatient services for medical rehabilitation and other services for participating of adults in 2003]. Würzburg: Verband deutscher Rentenversicherer, 2005.
24 **Statistisches Bundesamt**. *Gesundheit—Ausgaben 1992–2003* [Health—expenditures 1992–2003]. Wiesbaden: Statistisches Bundesamt, 2005.
25 **Schwabe U**, Paffrath D. *Arzneiverordnungsreport 2004* [Report of prescribed drugs 2004]. Heidelberg: Springer, 2004.
26 **Statistisches Bundesamt**. Durchschnittlicher Bruttomonats- und Bruttojahresverdienst 2002 und 2003 [Average monthly and yearly gross income 2003 and 2003]. Personal communication 2005, C Powilat.
27 **Verband deutscher Rentenversicherer**. *Rentenzugang 2003* [New pensions 2003]. Würzburg: Verband deutscher Rentenversicherer, 2004.
28 **Bach H-U**, Koch S, Magvas E, *et al. Der Arbeitsmarkt 2002 und 2003* [The labour market 2004 and 2005]. Nürnberg: Bundesanstalt für Arbeit, 2002.
29 **Magvas E**. *Wie lange dauert es, eine Stelle zu besetzen? Wer wird eingestellt?* [How long does it take to fill a vacancy? Who will be engaged?]. Nürnberg: Bundesanstalt für Arbeit, 1999.

30 **Koopmanschap MA**, Rutten FF, van Ineveld BM, *et al.* The friction cost method for measuring indirect costs of disease. *J Health Econ* 1995;**14**:171–89.
31 **Statistisches Bundesamt**. *Wo bleibt die Zeit? Die Zeitverwendung der Bevölkerung in Deutschland 2001/02* [The time use survey of the population in Germany 2001/02]. Bonn: Statistisches Bundesamt, 2003.
32 **Bundesministerium für Gesundheit und Soziale Sicherung**. *Statistisches Taschenbuch 2005, Arbeits- und Sozialstatistik.* Bonn: Bundesministerium für Gesundheit und Soziale Sicherung, 2005.
33 **Lampert T**, Burger M. *Rauchgewohnheiten in Deutschland—Ergebnisse des telefonischen Bundes-Gesundheitssurveys 2003* [Smoking habits in Germany—results of the German Nation Telephone Health Survey 2003]. *Das Gesundheitswesen* 2004;**66**:511–17.
34 **US Department of Health and Human Services**. *Reducing the health consequences of smoking: 25 years of progress*, A report of the surgeon general. Rockville: Office on Smoking and Health, Center for Chronic Disease Prevention and Health Promotion, 1989.
35 **Statistisches Bundesamt**. Kranke und Unfallverletzte, Jodsalzverwendung, Rauchgewohnheiten 1992. *Fragen zur Gesundheit.* Fachserie 12, Reihe S3 [Sick persons and injured persons, usage of iodine salt, smoking behaviour 1992. Questions about health, series 12 (S3)]. Stuttgart: Methler-Poeschel, 1994.
36 **Bundesministerium für Gesundheit**. *Arbeitsunfähigkeit und Krankenhausbehandlung nach Krankheitsarten 1993* [Work disability and acute hospital treatment by diseases 1993]. Stuttgart: Metzler-Poeschel, 1997.
37 **Warner KE**, Hodgson TA, Carroll CE. Medical costs of smoking in the United States: estimates, their validity, and their implications. *Tob Control* 1999;**8**:290–300.
38 **Max W**. The financial impact of smoking on health-related costs: a review of the literature. *Am J Health Promot* 2001;**15**:321–31.
39 **Miller LS**, Zhang X, Novotny T, *et al.* State estimates of Medicaid expenditures attributable to cigarette smoking, fiscal year 1993. *Public Health Rep* 1998;**113**:140–51.
40 **Miller VP**, Ernst C, Collin F. Smoking-attributable medical care costs in the USA. *Soc Sci Med* 1999;**48**:375–91.
41 **Malarcher AM**, Schulman J, Epstein LA, *et al.* Methodological issues in estimating smoking-attributable mortality in the United States. *Am J Epidemiol* 2000;**152**:573–84.
42 **Sterling TD**, Rosenbaum WL, Weinkam JJ. Risk attribution and tobacco-related deaths. *Am J Epidemiol* 1993;**138**:128–39.
43 **Centers for Disease Control and Prevention**. Annual smoking-attributable mortality, years of potential life lost, and economic costs—United States, 1995–1999. *MMWR Morb Mortal Wkly Rep* 2002;**51**:300–3.
44 **Keil U**, Becher H, Heidrich J, *et al.* Passivrauchbedingte Morbidität und Mortalität in Deutschland [Second-hand smoke morbidity and mortality in Germany]. In: Passivrauchen—ein unterschätztes Gesundheitsrisiko, Deutsches Krebsforschungszenfrum, Heidelberg, 2005.
45 **Statistisches Bundesamt**. *Statistisches Taschenbuch 2005* [Statistical paperback 2005]. Bonn: Statistisches Bundesamt, 2005.
46 **OECD**. OECD health data 2005—statistics and indicators for 30 countries 2005.
47 **Mielck A**. *Soziale Ungleichheit und Gesundheit—Empirische Ergebnisse, Erklärungsansätze, Interventionsmöglichkeiten* [Social inequality and health—empirical results, explanatory approaches and possible interventions]. Bern: Hans Huber, 2000.

APPENDIX

EXAMPLE FOR A SIMPLIFIED CALCULATION OF THE COSTS FOR HOSPITAL CARE DUE TO SMOKING-ATTRIBUTABLE HYPERTENSION (ICD10: I10–15)

Gender-specific and age-specific smoking-attributable fractions (SAFs) of hypertension were obtained by multiplying the gender-specific and age specific smoking prevalence by the relative risk of hypertension. The SAF in men ranges from 0.15 to 0.33, whereas the female SAF lies between 0.06 and 0.26.

As mentioned in the Methods, it is assumed that the expenditures for hospital care are linearly related to the hospital days. To calculate the smoking-attributable costs for hospital care caused by hypertension, the corresponding smoking-attributable and total hospital days were used. By multiplying the age-specific and gender-specific SAFs by the age-specific and gender-specific hospital days, the smoking-attributable hospital days due to hypertension were obtained. The total hospital days due to hypertension sum up to 1 670 846, whereas the derived smoking-attributable hospital days sum up to 203 469. Hence, 12.2% of all hospital days caused by hypertension can be attributed to smoking.

According to the Federal Statistical Office, the expenditures of hospital care caused by hypertension add up to €706 million in Germany in 2003. Hence, 12.2% of this amount—that is, €86 million—can be attributed to smoking.

The Lighter Side