EUROPEAN JOURNAL OF CANCER 46 (2010) 2625–2632

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.ejconline.com

Scenarios of future lung cancer incidence by educational level: Modelling study in Denmark

Gwenn Menvielle[a,b,c,*], *Isabelle Soerjomataram*[c,d], *Esther de Vries*[c], *Gerda Engholm*[e], *Jan J. Barendregt*[f], *Jan Willem Coebergh*[c], *Anton E. Kunst*[g]

[a] *Inserm U1018, Center for Epidemiology and Population Health, Occupational and Social Determinants of Health, Villejuif, France*
[b] *University of Versailles Saint Quentin, UMRS1018, France*
[c] *Department of Public Health, Erasmus MC, Rotterdam, Netherlands*
[d] *Harvard School of Public Health, Boston, USA*
[e] *Dept. of Cancer Prevention and Documentation, Danish Cancer Society, Copenhagen, Denmark*
[f] *University of Queensland, School of Population Health, Herston, Australia*
[g] *Department of Public Health, Academic Medical Center, University of Amsterdam, Amsterdam, Netherlands*

ARTICLE INFO

Article history:
Received 11 May 2010
Received in revised form 14 June 2010
Accepted 15 July 2010

Keywords:
Lung neoplasms
Incidence
Educational status
Socioeconomic factors
Smoking
Forecasting

ABSTRACT

Objective: To model future trends in lung cancer incidence in Denmark by education under different scenarios for cigarette smoking.
Methods: Lung cancer incidence until 2050 was modelled using Prevent software. We estimated lung cancer incidence under a baseline scenario and under four alternative scenarios for smoking reduction: decreasing initiation rates among the young, increasing cessation rates among smokers, a scenario combining both changes and a levelling-up scenario in which people with low and medium levels of education acquired the smoking prevalence of the highly educated. Danish National Health Interview Surveys (1987–2005) and cancer registry data combined with individual education status from Statistics Denmark were used for empirical input.
Results: Under the baseline scenario, lung cancer rates are expected to decrease for most educational groups during the next few decades, but educational inequalities will increase further. Under the alternative scenarios, an additional decrease in lung cancer rates will be observed from 2030 onwards, but only from 2050 onwards it will be observed under the initiation scenario. The cessation and the combined scenarios show the largest decrease in lung cancer rates for all educational groups. However, in none of these scenarios would the relative differences between educational groups be reduced. A modest decrease in these inequalities will be observed under the levelling-up scenario.
Discussion: Our analyses show that relative inequalities in lung cancer incidence rates will tend to increase. They may be reduced to a small extent if the smoking prevalence of people with a low level of education was to converge towards those more highly educated people. An important decrease in lung cancer rates will be observed in all educational groups, however, especially when focusing on both initiation and cessation strategies.

* *Corresponding author:* Address: Inserm U1018, Occupational and social determinants of health, Bat 15/16, 16 ave Paul Vaillant Couturier, 94807 Villejuif Cedex, France. Tel.: +33 1 77 74 74 20, fax: +33 1 77 74 74 03.
E-mail address: Gwenn.Menvielle@inserm.fr (G. Menvielle).
0959-8049/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ejca.2010.07.027

1. Introduction

Lung cancer is one of the main cancers in developed countries.[1,2] Between the mid-1990s and early 2000s in Europe, incidence and mortality rates started to decrease in men whereas an increase is still observed among women in most countries.[3] Tobacco smoking is the major risk factor for lung cancer, with a population-attributable fraction of around 85%.[4] Most European countries have reported higher lung cancer incidence and mortality rates among people with a lower socioeconomic position.[5–7] To explain these inequalities, a common hypothesis is that higher exposure to risk factors explains the higher incidence of lung cancer in low socioeconomic groups. Studies have reported that a substantial part of this inequality could be attributed to differences in smoking prevalence by socioeconomic position.[8,9]

The existence of socioeconomic inequalities in lung cancer incidence and mortality is a major public health concern. Because of the long latency period between exposure to smoking and lung cancer incidence, any public health policy aimed at reducing smoking would only affect lung cancer incidence several years after its implementation. Projections of the incidence of the disease are thus the only means for public health professionals and policy-makers to decide which one should be implemented.[10] Therefore, it is crucial to develop tools to estimate the timing and the magnitude of the impact of such public health policies. Such projection models will also document short-term trends in lung cancer rates that may be expected in view of recent trends in smoking.

The aim of this analysis is to estimate changes in future lung cancer incidence for different educational groups given different types of interventions on smoking, using the software Prevent. In particular, the model will document how long it would take before the changes in educational differences in lung cancer incidence could be expected. The analyses are based on long-term and good quality Danish data on smoking[11] and cancer incidence,[7] both including information about education.

2. Materials and methods

We stratified all analyses by sex and education. Education was coded into three categories: less than ten years of education (primary, secondary and grammar school) referred to as having a low level of education, 10–12 years of education (vocational education) referred to as having a medium level of education and 13 years of education or more (tertiary education) referred to as having a high level of education.[7]

A detailed description of the methodology including formulas used in Prevent can be found elsewhere.[12] In our analyses, Prevent estimates the changes in lung cancer incidence in a population due to changes in smoking prevalence. The method is based on the effect measure 'potential impact fraction' (PIF). PIF represents the proportional change in the number of incident cases at a certain time due to changes in risk factor prevalence in the past. The PIF is computed from the proportion of the population exposed to smoking and the relative risk quantifying the association between smoking and lung cancer. We used a relative risk of 9.9 among male smokers compared with never-smokers, and a relative risk of 7.6 among female smokers.[13] PIF is specific to each disease–risk factor association (here, lung cancer and smoking), for a specific age, sex and education combination and for a specific point in time.

A time component accounts for the delay between exposure to tobacco and the onset of lung cancer and is represented by latency (LAT) and lag time (LAG). LAT is the time between a change in smoking rate and a change in lung cancer incidence. LAG is the time needed for a formerly exposed (or unexposed) person to return to the risk of an unexposed (or exposed) person, decreasing (or increasing) in an exponential manner. We set LAT at seven years, and LAG at 25 years. These values are consistent with the available evidence on decrease in lung cancer incidence rates after stopping smoking.[14,15] As a result, a change in smoking prevalence does not change the PIF for the first seven years. After that it changes exponentially over the following 25 years until it reflects the full effect of change in smoking prevalence. Because of the exponential relationship, most of the decrease occurred during the first ten years of this 25-year decrease.

The PIF associated with a specific point in time is multiplied by the lung cancer incidence rate of the base year to calculate the incidence at that point in time. Baseline incidence by education was obtained from the Danish Cancer Society for 2004.[7] In addition, Prevent also allows an autonomous trend in lung cancer incidence, which is the trend that would be observed in the absence of changes in smoking.

The main results of this paper were based on the assumption that lung cancer trends were fully driven by the changes in smoking. In additional analyses, we assumed an autonomous trend that accounted for past exposure to asbestos, which is the second major risk factor for lung cancer.[16] The excess lung cancer cases due to exposure to asbestos can be estimated from the number of mesothelioma observed, the latter being almost entirely caused by exposure to asbestos.[16] Reviews have estimated the ratio of excess lung cancer cases due to exposure to asbestos relative to mesothelioma cases. We used a ratio of two lung cancers to one mesothelioma, which is suggested to be conservative in a recent report.[17] Based on this ratio, we derived the autonomous trend for lung cancer incidence from the estimated annual percentage change observed in Denmark for male mesothelioma incidence.[18] The trend was assigned to men with low and medium levels of education aged 40 years or older. We did not assign this trend to women and to highly educated men as the level of asbestos exposure was very low in these groups.

Demographic data were needed to estimate future lung cancer incidence rates. First, annual all-cause mortality rates for the base year were estimated per education level by taking into account estimates of mortality by education level during the 1990s for a national sample of the Danish population.[19] Further, information on population size projected for the years 2005–2050 is needed to make projections on other outcomes. This information is derived from the general population and was not available by education level. Therefore, we did not present the number of lung cancer cases by education but presented incidence rates only.

Table 1 – Age-specific smoking prevalence by education, gender and calendar year between 1987 and 2005 in Denmark.

Year	Age group	Men			Women		
		Low	Middle	High	Low	Middle	High
1987	20–24	59	49	44	69	57	42
	25–44	67	52	45	57	52	43
	45–66	60	59	52	50	46	46
	67+	44	44	38	28	29	41
1994	20–24	45	39	35	64	46	29
	25–44	37	51	36	68	54	40
	45–66	59	56	43	49	42	28
	67+	34	47	42	26	31	36
2000	20–24	69	46	28	76	38	27
	25–44	60	47	33	62	51	32
	45–66	53	46	37	44	40	32
	67+	36	34	32	24	27	26
2005	20–24	70	43	39	67	52	38
	25–44	61	48	36	63	48	32
	45–66	50	42	33	47	41	29
	67+	30	31	32	32	28	21

Smoking prevalence was estimated as a function of smoking initiation and cessation rates, all estimated per age, sex and educational level. Smoking prevalence was computed cohort-wise. We assumed smoking to be 0 below age 20 and smoking initiation to be effectuated and completed at age 20. We then applied age-, sex-, period- and education-specific cessation rates to compute smoking prevalence by age among people over 20.

Historical smoking prevalence data were obtained from the Danish National Health Interview Survey in 1987, 1994, 2000 and 2005 (Table 1).[11] For the period between 1987 and 2005, cessation rates were computed with the model proposed by Mendez and colleagues,[20] taking into account population dynamics (number of people who started smoking, stopped smoking and died in each age group) and using the historical data on smoking and on population size.

To estimate future cessation rates by age, sex and education, we used unpublished rates available from an Italian study on smoking cessation rates of Italian men with high and low levels of education (Table 2).[21] This choice was based on the available evidence but presents limitations that will be discussed later. We computed cessation rates among people with a medium level of education as the average between people with low and high levels of education. The cessation rates were assumed to be similar for men and women. Among people with a low level of education, cessation rates were higher among people aged 50+ years (4.25% smokers successfully quit per year) than among their younger counterparts (2.53% and 2.58% cessation rates for the age group 20–30 and 30–50, respectively). Among highly educated people, cessation rates were generally higher and more similar by age group: 4.03% among people aged 20–30, 3.44% among those aged 30–50, and 3.965% among people aged 50+.

Table 2 – Cessation rates by education, gender and age group applied to the baseline scenario.[a]

Education	Age		
	20–30	30–50	50+
Low	0.0253	0.0258	0.0425
Middle	0.0328	0.0301	0.0411
High	0.0403	0.0344	0.0397

[a] These cessation rates were used to project smoking prevalence between 2006 and 2050. Reprinted with permission from Federico et al.[21]

We defined a baseline scenario and four smoking reduction scenarios derived from this baseline scenario:

1. *Baseline scenario* – in this scenario, future smoking cessation and initiation rates remained at the 2005 level. Cessation rates are presented in Table 2 and initiation rates are those observed for the age group 20–24 in 2005 (Table 1).
2. *Initiation scenario* – this scenario assumed a 50% decrease in initiation rates during the next 15 years, so that initiation rates are halved in 2020 compared with the baseline year (2005). This corresponded to a 4.5% yearly decrease in smoking initiation rates in each educational group.
3. *Cessation scenario* – this scenario assumed a 50% increase in cessation rates for all age groups during the next 15 years. This corresponds to a 2.9% yearly increase in smoking cessation rates in each educational group.
4. *Combined scenario* – this scenario combined the two previous scenarios. During the next 15 years, initiation rates were halved and there would be a 50% increase in cessation rates.
5. *Levelling-up scenario* – we assumed that the cessation rates and the initiation rates of those with lower and middle educational levels would converge during the next 15 years towards the levels of highly educated people as observed at baseline.

To measure socioeconomic inequalities, we computed age-standardised lung cancer incidence rates with the 2005 Danish population as the standard. We computed the rate ratio between those with a low level or those with a middle level of education relative to highly educated persons as a measure of relative inequalities.

3. Results

Smoking prevalence generally decreased between 1987 and 2005 for all education groups among men and women (Table 1). Educational differences were observed in smoking prevalence with higher rates associated with a lower level of education in both men and women. In 2005 smoking prevalence was broadly similar for men and women in each educational group. Smoking prevalence decreased at every age for all education groups.

Relative differences in smoking prevalence between the scenarios began to change in 2030 (Table 3). The cessation scenario differed least from the baseline scenario. The lowest smoking prevalence was found with the combined scenario, followed by the initiation scenario. For the levelling-up

Table 3 – Age-standardised smoking prevalence by education, gender and calendar year according to different smoking scenarios between 2010 and 2050 in Denmark.

Scenario	Education	Men					Women				
		2010	2020	2030	2040	2050	2010	2020	2030	2040	2050
Baseline	High	25	18	14	12	11	20	15	12	11	10
	Middle	30	21	16	14	13	31	23	19	17	16
	Low	35	29	25	24	23	37	30	26	24	23
Initiation	High	25	17	12	8	6	20	15	11	8	6
	Middle	30	21	14	10	8	31	23	17	12	10
	Low	35	28	22	16	13	37	30	23	17	14
Cessation	High	25	15	10	8	7	20	14	9	7	6
	Middle	30	20	13	11	10	30	21	15	13	12
	Low	35	26	20	18	17	37	27	21	18	16
Combined	High	25	15	9	5	4	20	13	8	5	4
	Middle	30	19	11	7	6	30	21	13	9	7
	Low	35	26	17	12	9	37	27	18	12	9
Levelling-up	High	25	18	13	12	11	20	15	12	11	10
	Middle	30	21	15	12	11	31	23	17	13	11
	Low	35	27	20	14	12	37	29	21	15	12

Initiation: 50% decrease in initiation rate by 2020; cessation: 50% in cessation rates by 2020; combined: combines initiation and cessation scenarios; levelling-up: convergence towards the 2005 initiation and cessation rates of the highly educated by 2020.

scenario, smoking prevalence hardly differed between educational groups from 2040 onwards.

Educational inequalities in lung cancer incidence were observed in Denmark in 2004 with higher rates among persons with a lower level of education (Fig. 1). Rates for highly educated women remained low until the age of 70. Under the baseline scenario, age-standardised (using the 2005 Danish population) lung cancer incidence rates decreased from 140 (per 100,000 person years) in 2004 to 77 in 2050, from 128 to 53 and from 84 to 35 among men with low, medium or high levels of education, respectively (Fig. 2). The decrease is proportionally smaller for men with a low level of education compared with men with medium and high levels of education. The decrease in lung cancer incidence rates was less

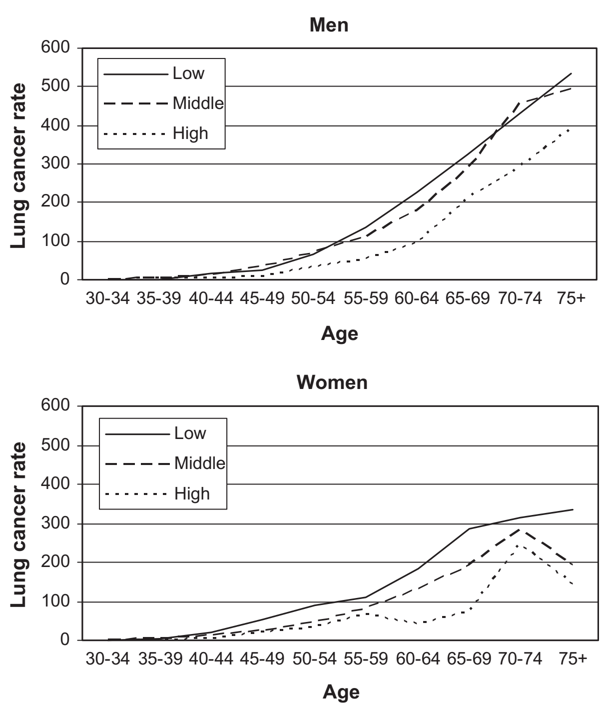

Fig. 1 – Age-specific lung cancer incidence rate (per 100,000 person years) in Denmark in 2004 by sex and education level.[7]

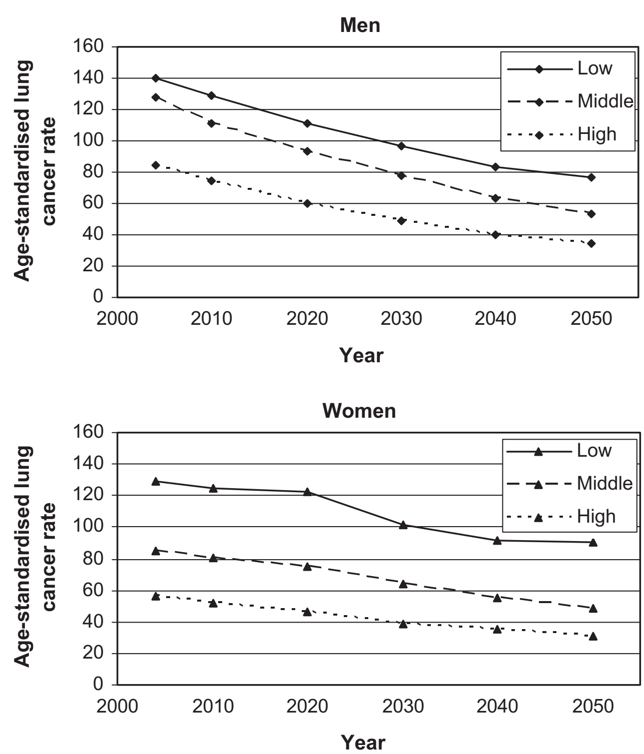

Fig. 2 – Age-standardised lung cancer incidence rates (per 100,000 person years) in 2004, 2010, 2020, 2030, 2040 and 2050 by sex and education level. Baseline scenario.

Table 4 – Age-adjusted lung cancer incidence rates[a] (IR) and rate ratios (RR) by scenarios, calendar year, sex and education level.

Scenario	Education	MEN								WOMEN							
		2020		2030		2040		2050		2020		2030		2040		2050	
		IR	RR	IR	RR	IR	RR	IR	RR	IR	RR	IR	RR	IR	RR	IR	RR
Baseline	High	60	1	49	1	40	1	35	1	46	1	39	1	35	1	31	1
	Middle	93	1.55	78	1.59	63	1.56	53	1.52	75	1.63	64	1.65	55	1.59	49	1.58
	Low	111	1.85	97	1.98	83	2.06	77	2.24	123	2.67	102	2.65	92	2.67	90	2.89
Initiation	High	60	1	49	1	40	1	33	1	46	1	38	1	34	1	29	1
	Middle	93	1.55	78	1.59	62	1.55	49	1.50	75	1.63	63	1.65	54	1.59	46	1.57
	Low	111	1.85	96	1.97	82	2.04	71	2.16	123	2.67	102	2.65	90	2.65	84	2.84
Cessation	High	60	1	46	1	35	1	28	1	46	1	37	1	31	1	27	1
	Middle	93	1.55	73	1.60	55	1.57	44	1.57	74	1.63	60	1.64	48	1.59	42	1.58
	Low	110	1.85	90	1.98	71	2.06	62	2.19	122	2.67	96	2.62	80	2.63	73	2.76
Combined	High	60	1	45	1	34	1	27	1	46	1	36	1	30	1	25	1
	Middle	93	1.55	73	1.60	54	1.56	41	1.51	74	1.63	60	1.64	47	1.58	39	1.55
	Low	110	1.85	90	1.97	70	2.04	57	2.09	122	2.67	96	2.62	78	2.60	68	2.69
Levelling-up	High	60	1	49	1	40	1	35	1	46	1	39	1	35	1	31	1
	Middle	93	1.55	78	1.59	62	1.53	50	1.46	75	1.63	63	1.64	54	1.55	46	1.48
	Low	111	1.85	96	1.95	78	1.94	66	1.90	123	2.67	99	2.62	87	2.53	79	2.53

Initiation: 50% decrease in initiation rate by 2020; cessation: 50% increase in cessation rates by 2020; combined: combines initiation and cessation scenarios; levelling-up: convergence of initiation and cessation rates towards the 2005 characteristics of the highly educated by 2020.
[a] Per 100,000 person years, 2005 Danish population was used as standard. Sex-specific weighting was used.

pronounced among women. Female lung cancer incidence rates were seen to decrease only after 2020 among women with a low level of education and there were only slight decreases in incidence rates between 2004 and 2020 for women with a medium level of education. From 2004 to 2050, the incidence rates were expected to decrease from 129 to 90, from 85 to 49 and from 56 to 31 among women with low, medium and high levels of education, respectively (Fig. 2). In 2004, the gradient was more pronounced among women (ratio IR low/high = 2.30) than among men (ratio = 1.67). The rate ratios remained stable for men and women with a medium level of education over the whole period whereas those ratios increased for men and women with a low level of education (Table 4).

Table 4 shows the projected incidence rates and rate ratios under the different scenarios for the years 2020, 2030, 2040 and 2050. The difference in incidence rates between the baseline scenario and the alternative scenarios becomes evident from 2030 onwards. For the initiation scenario, the incidence rates differed from those observed under the baseline scenario in 2050, especially for men and women with a low education level. The lung cancer rates are substantially lower in the cessation and the combined scenarios for all educational groups. In 2050, the difference in incidence rates between the baseline and the combined scenario was greater for men with a lower education level (20 per 100,000 person years) or women with a lower education level (22 per 100,000) than for the other educational groups.

In terms of rate ratios for educational differences in lung cancer incidence, the most favourable situation was observed for the levelling-up scenario, where rate ratios remained stable over the period. Rate ratios were observed to slightly increase for all other scenarios.

4. Discussion

We investigated time trends in educational differences in lung cancer incidence under different scenarios aimed at reducing tobacco consumption, either by increasing cessation or lowering levels of initiation. The effect of the alternative scenarios became noticeable from 2030 onwards, compared with the baseline scenario. The largest decrease in lung cancer rates was observed in the cessation and in the combined scenarios. No decrease in relative inequality was observed over the whole period for all scenarios except for the levelling-up scenario.

The strengths and limits of Prevent have been thoroughly discussed elsewhere.[12] Projection is a complex exercise that implies approximations, in which one focuses only on a few variables while ignoring the rest. Because any changes in smoking prevalence will start to have a visible impact on lung cancer incidence about 15 years later, long-term projections are the only way to investigate future impacts of smoking reduction on lung cancer incidence. The drawback is that long-term modelling is accompanied by more uncertainties in the estimates, stemming from uncertainties in the baseline trends of smoking or in risk factors not included in the model. Therefore the results can not be interpreted as exact predictions, but have allowed us to assess the effect of different smoking reduction scenarios. A difference in estimated lung cancer incidence between two different scenarios was related to the difference between the two scenarios in terms of smoking prevalence.

As for any modelling exercise, data quality was a major issue as the outcome directly depended on the input data. Lung cancer incidence by educational level was available from a project linking the Danish Cancer Register with education information from Statistics Denmark on an individual level. We had 17 years of historical smoking data from reliable national surveys including information on education with a coding similar to that available for lung cancer data. However, smoking prevalence before the age of 20 was not available by level of education in cross-sectional surveys as education is not completed for most people. As a result, we had to assume that smoking initiation was completed at the age of 20 and that nobody smoked before the age of 20. Consequently, we may have underestimated smoking exposure, and more so among subjects with a low level of education as they take up smoking earlier than their better educated counterparts.[22] Also, we only had information on smoking status, whereas lung cancer risk is also determined by intensity and duration of smoking.[16] However, the amount of cigarettes per smoker does not greatly differ by education level.[23]

We assumed no autonomous trend in lung cancer incidence rates. This means that all changes in lung cancer incidence were driven by changes in tobacco consumption. The literature, however, suggests that smoking does not totally account for socioeconomic inequalities in lung cancer incidence, which may partly be explained by residual confounding from smoking[8,24] and other risk factors including occupational exposures.[25] We conducted additional analyses with an autonomous trend in lung cancer incidence accounting for past exposure to asbestos among men aged 40+ with low and medium levels of education (results not shown). Expected lung cancer incidence rates including this autonomous trend were slightly higher in these educational groups and socioeconomic inequalities were more pronounced. Our main conclusions, however, did not change, probably because smoking is responsible for the majority of lung cancer cases.

The education level of the population is increasing over time. In 2005, slightly more than half of the Danish population had tertiary education (53% of men and 58% of women) whereas 34% of men and 22% of women had vocational education. The share of the population with a low level of education was low and is likely to decrease further in future years. The projected incidence rates for the lowest-level education group would therefore refer to an increasingly smaller group in the future. Despite this, inequalities are likely to be an important problem in future years in Denmark as well, because differences in lung cancer incidence were also observed between the two highest education groups. In addition, studies on time trends in socioeconomic inequality in lung cancer did not report any clear decrease in inequality,[26] even when the measure of inequality accounted for changes in the socioeconomic distribution of the population.[27–29] Furthermore, although the mean education level will increase during the next decades, an important degree of educational stratification will remain within the national population.

The parameters of the baseline scenario should be discussed. Little information is available regarding cessation rates by education in Denmark. Estimates that are available are derived from cross-sectional data, which mix cohort, age and period effects.[30] Danish data on cessation rates, therefore, could not be directly obtained from this study, and we had to use the estimates that were available from an Italian study. We selected male cessation rates as smoking histories strongly differ between Italian and Danish women, but much less so for men. The Italian data indicated higher smoking cessation rates among people with a higher level of education as consistently suggested by indirect estimates for Denmark[31] and elsewhere.[30,32–34] The education-specific cessation rates used were in line with those observed for Spain,[32] Italy[35] or USA.[34]

Tobacco price increase, bans on smoking advertising, smoking bans at schools and anti-smoking education have all been found to affect smoking initiation rates in the population.[35] The most effective policies for smoking cessation were taxation policies and smoking bans: cessation rates were increased by 3–5% with a 10% increase in price and by 12–38% with comprehensive clean indoor air laws.[36] Moreover, little is known about the differential effect of these policies by socioeconomic status (SES), although it has been suggested that bans on TV advertising or anti-smoking education may be more effective in reducing initiation rates among young people from low SES groups.[35,37,38] Although recent evidence suggested that smokers with high and low levels of education benefit equally from the nationwide tobacco control policies,[39] specific policies may have a differential effect by SES on smoking cessation. There is no evidence regarding a differential effect of smoking bans in public places and in the work place.[35,38] Media campaigns are generally shown to have a larger effect on high SES smokers or no differential effect by SES. They may nevertheless be most effective among low SES smokers when implemented as part of more comprehensive tobacco control policies.[37,38,40] Bans on TV advertising may be more successful among low SES smokers.[37] Support for smoking cessation via telephone help lines has been shown to be effective among low SES smokers, especially with a follow-up from the counsellors, whereas the price of nicotine replacement therapy may be a barrier to low SES smokers if not offered freely.[37] Conflicting findings have been reported regarding the effect of price increase by SES, with some observing greater effect among high SES smokers[41] or among low SES smokers.[35] In addition, results may depend on the SES indicator (income, education or occupation) considered[38] or vary over time.[42] Finally, more comprehensive tobacco control policies have been shown to be more effective in increasing the number of smokers who attempt quitting, and who are successful in these attempts.[39]

Denmark has gradually implemented a number of tobacco control policies. Most have been implemented during the 2000s: a smoking ban in schools in 2001, a ban on smoking advertising in 2002, sale of tobacco prohibited to people younger than 16 in 2004 and changed to 18 in 2008, a more general smoking ban in 2007 and a 10% increase in cigarette prices twice in 2010. These policies may be more efficient in decreasing smoking prevalence among young subjects, and more so among low SES groups. These policies have yet to affect lung cancer rates and we can thus expect larger decrease in smoking prevalence, and consequently larger decrease in inequalities in lung cancer rates in future years.

Despite a large decrease in lung cancer incidence rates, we observed that relative inequalities between educational groups would be stable or even increase during the period 2005–2050. This trend fits the general pattern that relative inequalities tend to increase when the occurrence of a health problem in the population decreases.[43] Nonetheless, under all smoking reduction scenarios, a substantial absolute number of lung cancer cases would be avoided, among people with both lower and higher education levels. The lack of decrease in inequalities is also partly due to the definition of the scenarios. The levelling-up scenario, however, showed that relative inequalities in lung cancer incidence would decrease only if special efforts are made to reduce the gap in smoking between groups with high and low levels of education. This scenario, however, also showed that reducing this gap alone does not bring down absolute levels of lung cancer incidence to a great extent, and only in the longer run.

Cancer prevention works on a long-term scale. The incidence rates in the next decade are nearly and completely determined by past smoking exposure. Even though this result may be easily predictable on the basis of the epidemiology of lung cancer, this great inertia is easily forgotten in public health policies. We need scenarios based on population health models like Prevent to demonstrate that some actions take a long time to have their full effect. With regard to smoking, because any change in smoking prevalence is likely to be gradual, any effect of alternative smoking policies on lung cancer incidence is not expected to be noticeable before 2030. As shown by our results, the levelling-up scenario will level out educational differences in smoking prevalence in 2050 only and it will take 20–30 more years before it fully impacts lung cancer rates. Increasing smoking cessation rates among adults will be the most effective way to decrease lung cancer rates within a few decades. Even though lowering initiation rates may be the most effective way to prevent high smoking prevalence among younger generations, the effect on the change in smoking prevalence in the population at large will be visible only on a long time scale. Therefore, the success of anti-smoking policies in decreasing overall levels and socioeconomic inequalities in lung cancer incidence will be evident only on a very long time scale. These policies are, however, likely to show an earlier impact on other diseases such as cardiovascular diseases that have a much shorter latency period.

5. Conclusion

Decreasing socioeconomic inequalities in lung cancer incidence is a major public health challenge. This paper illustrates what could be achieved under different realistic scenarios for smoking reduction. The decrease in socioeconomic inequalities may be modest even after several decades. However, we observed a substantial decrease in lung cancer rates for all educational groups, which means a significant number of lung cancer cases are avoided. Our results also underline the need to implement anti-smoking policies focused both on cessation rates (to bring important benefits to older generations in the shorter term) and initiation rates (to bring even greater benefits to younger generations in the longer term).

Conflict of interest statement

None declared.

Acknowledgements

We thank Susanne Dalton, Institute of Cancer Epidemiology, Danish Cancer Society for providing us with lung cancer incidence by education in Denmark in 2004. This project is funded through the Eurocadet Project (Contract No.: SP23-CT-2005-006528). 'We would like to thank Hans Storm and Brian Koster for their help when exploring the smoking data available for Denmark.'

REFERENCES

1. Ferlay J, Bray F, Pisani P, Parkin DM. *GLOBOCAN 2002: cancer incidence, mortality and prevalence worldwide IARC CancerBase No. 5*. 2.0 ed. Lyon: IARC Press; 2004.
2. Ferlay J, Parkin DM, Steliarova-Foucher E. Estimates of cancer incidence and mortality in Europe in 2008. *Eur J Cancer* 2010;**46**(4):765–81.
3. Karim-Kos HE, de Vries E, Soerjomataram I, et al. Recent trends of cancer in Europe: a combined approach of incidence, survival and mortality for 17 cancer sites since the 1990s. *Eur J Cancer* 2008;**44**(10):1345–89.
4. Danaei G, Vander Hoorn S, Lopez AD, Murray CJ, Ezzati M. Causes of cancer in the world: comparative risk assessment of nine behavioural and environmental risk factors. *Lancet* 2005;**366**(9499):1784–93.
5. Mackenbach JP, Huisman M, Andersen O, et al. Inequalities in lung cancer mortality by the educational level in 10 European populations. *Eur J Cancer* 2004;**40**(1):126–35.
6. Mackenbach JP, Stirbu I, Roskam AJ, et al. Socioeconomic inequalities in health in 22 European countries. *New Engl J Med* 2008;**358**(23):2468–81.
7. Dalton S, Steding-Jessen M, Engholm G, Schüz J, Olsen J. Social inequality and incidence of and survival from lung cancer in a population-based study in Denmark, 1994–2003. *Eur J Cancer* 2008;**44**(14):1989–95.
8. Menvielle G, Boshuizen H, Kunst AE, et al. The role of smoking and diet in explaining educational inequalities in lung cancer incidence. *J Natl Cancer Inst* 2009;**101**(5):321–30.
9. Hart CL, Hole DJ, Gillis CR, et al. Social class differences in lung cancer mortality: risk factor explanations using two Scottish cohort studies. *Int J Epidemiol* 2001;**30**(2):268–74.
10. Veerman JL, Barendregt JJ, Mackenbach JP, Brug J. Using epidemiological models to estimate the health effects of diet behaviour change: the example of tailored fruit and vegetable promotion. *Public Health Nutr* 2006;**9**(4):415–20.
11. Ekholm O, Hesse U, Davidsen M, Kjoller M. The study design and characteristics of the Danish national health interview surveys. *Scand J Public Healt* 2009;**37**(7):758–65.
12. Soerjomataram I, de Vries E, Engholm G, et al. Impact of a smoking and alcohol intervention program on lung and breast cancer incidence in Denmark: an example of dynamic modeling with Prevent. *Eur J Cancer* 2010;**46**(14):2617–24.
13. Gandini S, Botteri E, Iodice S, et al. Tobacco smoking and cancer: a meta-analysis. *Int J Cancer* 2008;**122**(1):155–64.
14. Leffondre K, Abrahamowicz M, Xiao Y, Siemiatycki J. Modelling smoking history using a comprehensive smoking index: application to lung cancer. *Stat Med* 2006;**25**(24):4132–46.
15. Thun MJ, Henley SJ, Burns D, et al. Lung cancer death rates in lifelong nonsmokers. *J Natl Cancer Inst* 2006;**98**(10):691–9.
16. Blot WJ, Fraumeni Jr JF. Cancers of the lung and pleura. In: Schottenfeld D, Fraumeni Jr JF, editors. *Cancer epidemiology and prevention*. New York: Oxford University Press; 1996. p. 637–65.

17. IARC. *The burden of cancer caused by asbestos*. IARC Working Group Reports, International Agency for research on Cancer, Lyon; 2010 [in press].
18. Montanaro F, Bray F, Gennaro V, et al. Pleural mesothelioma incidence in Europe: evidence of some deceleration in the increasing trends. *Cancer Causes Control* 2003;**14**(8):791–803.
19. Eurothine. Tackling health inequalities in Europe: an integrated approach EUROTHINE. Final report: Dept. of Public Health, Erasmus University Medical Centre Rotterdam, The Netherlands; 2007.
20. Mendez D, Warner KE, Courant PN. Has smoking cessation ceased? Expected trends in the prevalence of smoking in the United States. *Am J Epidemiol* 1998;**148**(3):249–58.
21. Federico B, Costa G, Ricciardi W, Kunst AE. Educational inequalities in smoking cessation trends in Italy, 1982–2002. *Tob Control* 2009;**18**(5):393–8.
22. Rasmussen M, Due P, Damsgaard MT, Holstein BE. Social inequality in adolescent daily smoking: has it changed over time? *Scand J Public Healt* 2009;**37**(3):287–94.
23. Cavelaars AE, Kunst AE, Geurts JJ, et al. Educational differences in smoking: international comparison. *BMJ* 2000;**320**(7242):1102–7.
24. Mao Y, Hu J, Ugnat AM, Semenciw R, Fincham S. Socioeconomic status and lung cancer risk in Canada. *Int J Epidemiol* 2001;**30**(4):809–17.
25. Menvielle G, Boshuizen H, Kunst AE, et al. Occupational exposures contribute to educational inequalities in lung cancer incidence among men: evidence from the EPIC prospective cohort study. *Int J Cancer* 2010;**126**(8):1928–35.
26. Steenland K, Henley J, Thun M. All-cause and cause-specific death rates by educational status for two million people in two American Cancer Society cohorts, 1959–1996. *Am J Epidemiol* 2002;**156**(1):11–21.
27. Borrell C, Azlor E, Rodriguez-Sanz M, et al. Trends in socioeconomic mortality inequalities in a southern European urban setting at the turn of the 21st century. *J Epidemiol Commun Healt* 2008;**62**(3):258–66.
28. Turrell G, Mathers C. Socioeconomic inequalities in all-cause and specific-cause mortality in Australia. *Int J Epidemiol* 2001;**30**(2):231–9.
29. Menvielle G, Chastang JF, Luce D, Leclerc A. Temporal trends in socioeconomic inequality in mortality in France between 1968 and 1996. Study of educational differences by cause of death. *Rev Epidemiol Sante Publ* 2007;**55**:e1–8.
30. Giskes K, Kunst AE, Benach J, et al. Trends in smoking behaviour between 1985 and 2000 in nine European countries by education. *J Epidemiol Commun Healt* 2005;**59**(5):395–401.
31. Pisinger C, Vestbo J, Borch-Johnsen K, Jorgensen T. Smoking cessation intervention in a large randomised population-based study. The Inter99 study. *Prev Med* 2005;**40**(3):285–92.
32. Schiaffino A, Fernandez E, Kunst A, et al. Time trends and educational differences in the incidence of quitting smoking in Spain (1965–2000). *Prev Med* 2007;**45**(2-3):226–32.
33. Federico B, Costa G, Kunst AE. Educational inequalities in initiation, cessation, and prevalence of smoking among 3 Italian birth cohorts. *Am J Public Healt* 2007;**97**(5):838–45.
34. Gilpin EA, Pierce JP. Demographic differences in patterns in the incidence of smoking cessation: United States 1950–1990. *Ann Epidemiol* 2002;**12**(3):141–50.
35. Main C, Thomas S, Ogilvie D, et al. Population tobacco control interventions and their effects on social inequalities in smoking: placing an equity lens on existing systematic reviews. *BMC Public Healt* 2008;**8**:178.
36. Lemmens V, Oenema A, Knut IK, Brug J. Effectiveness of smoking cessation interventions among adults: a systematic review of reviews. *Eur J Cancer Prev* 2008;**17**(6):535–44.
37. Giskes K, Kunst AE, Ariza C, et al. Applying an equity lens to tobacco-control policies and their uptake in six Western-European countries. *J Public Health Pol* 2007;**28**(2):261–80.
38. Thomas S, Fayter D, Misso K, et al. Population tobacco control interventions and their effects on social inequalities in smoking: systematic review. *Tob Control* 2008;**17**(4):230–7.
39. Schaap MM, Kunst AE, Leinsalu M, et al. Effect of nationwide tobacco control policies on smoking cessation in high and low educated groups in 18 European countries. *Tob Control* 2008;**17**(4):248–55.
40. Niederdeppe J, Fiore MC, Baker TB, Smith SS. Smoking-cessation media campaigns and their effectiveness among socioeconomically advantaged and disadvantaged populations. *Am J Public Healt* 2008;**98**(5):916–24.
41. Regidor E, Pascual C, Gutierrez-Fisac JL. Increasing the price of tobacco: economically regressive today and probably ineffective tomorrow. *Eur J Cancer Prev* 2007;**16**(4):380–4.
42. Franks P, Jerant AF, Leigh JP, et al. Cigarette prices, smoking, and the poor: implications of recent trends. *Am J Public Healt* 2007;**97**(10):1873–7.
43. Scanlan J. Can we actually measure health disparities? *Chance* 2006;**19**(2).