Scandinavian Journal of Public Health
http://sjp.sagepub.com/

The potential of smoking cessation programmes and a smoking ban in public places: Comparing gain in life expectancy and cost effectiveness

Betina Højgaard, Kim Rose Olsen, Charlotta Pisinger, Hanne Tønnesen and Dorte Gyrd-Hansen

Scand J Public Health 2011 39: 785 originally published online 5 October 2011
DOI: 10.1177/1403494811421416

The online version of this article can be found at:
http://sjp.sagepub.com/content/39/8/785

Published by:
SAGE
http://www.sagepublications.com

Scandinavian Journal of Public Health, 2011; 39: 785–796

ORIGINAL ARTICLE

The potential of smoking cessation programmes and a smoking ban in public places: Comparing gain in life expectancy and cost effectiveness

BETINA HØJGAARD[1,2], KIM ROSE OLSEN[3], CHARLOTTA PISINGER[4], HANNE TØNNESEN[5] & DORTE GYRD-HANSEN[1,2]

[1]*Danish Institute for Health Services Research, Denmark,* [2]*Institute of Public Health – Health Economics Unit, University of Southern Denmark, Denmark,* [3]*Research Unit of General Practice, Institute of Public Health, University of Southern Denmark, Denmark,* [4]*Research Centre for Prevention and Health, Denmark,* [5]*WHO Collaborating Centre, Bispebjerg Hospital, Copenhagen, Denmark*

Abstract

Background: Interventions aimed at reducing the number of smokers are generally believed to be cost effective. However as the cost of the interventions should be paid up front whereas the gains in life years only appear in the future – the budgetary consequences might be a barrier to implementing such interventions. *Aims:* The aim of the present paper was to assess the long-term cost effectiveness as well as the short-term (10 years) budget consequences of cessation programmes and a smoking ban in enclosed public places. *Methods:* We develop a population-based Markov model capable of analyzing both interventions and assess long-term costs effectiveness as well as short-term budgetary consequences and outcome gains. The smoking cessation programme model was based on data from the Danish National Smoking Cessation Database (SCDB), while the model of the smoking ban was based on effect estimates found in the literature. *Results:* On a population level the effect of a smoking ban has the largest potential compared with the effect of smoking cessation programmes. Our results suggest that smoking cessation programmes are cost saving and generate life-years, whereas the costs per life-year gained by a smoking ban are 40,645 to 64,462 DKK (100 DKK = €13.4). These results are conservative as they do not include the healthcare cost saving related to reduced passive smoking. ***Conclusions:* Our results indicate that smoking cessation programmes and a smoking ban in enclosed public places both in the short term and the long term are cost-effective strategies compared with the status quo**.

Key Words: *Costs and cost analysis, preventive health services, public health, smoking*

Background

Cost-effectiveness data provide input to policy-makers about whether a given intervention is worth implementing compared to alternative uses of health-care resources. Many cost-effectiveness analyses (CEAs) of smoking interventions are based on "local" smoking interventions provided for a limited, often highly motivated, population of smokers [1,2]. Some studies report the short-term effect only (<1 year) and/or apply intermediate outcome measures such as quit rates instead of e.g. life years gained [2], which reduces the usefulness of the evaluations as input to policy.

The goal of public health interventions is to improve the overall health status of the population. Consequently, the relevant output of a CEA must be estimates of the long-term population effect and cost effectiveness. A population perspective encompasses consequences beyond those that affect the target group (in this case smokers), as it includes non-smokers and smoking incidences in the population. Hereby, the population perspective can illustrate the relative ability of the interventions to contribute to significant health improvements in the population at large. More narrow approaches do not allow for such direct comparisons of effectiveness.

Correspondence: Betina Højgaard, Danish Institute for Health Services Research, Dampfaergevej 27-29, PO Box 2595, DK – 2100 Copenhagen Ø, Denmark. E-mail: beh@dsi.dk

(Accepted 2 August 2011)

DOI: 10.1177/1403494811421416

It has been estimated that approximately 14,000 annual deaths in Denmark are due to active smoking and 2,000 annual deaths are due to passive smoking [3]. Several intervention strategies have been used to reduce smoking. Two of them are smoking cessation programmes and a smoking ban in public places. The two interventions differ in three important areas: 1) the size and composition of the target group, 2) the extent to which participation is voluntary, and 3) the level of the intervention costs.

Around 10,000 smokers (*c.* 1%) of the approximately one million Danish smokers participate each year in smoking cessations programmes – 80-90 % of all Danish smoking cessation units are registered with the Danish National Smoking Cessation Database (SCDB). The enrolled units are primarily based at pharmacies, municipalities, hospital wards, midwifery clinics, general practices, and dentists. Almost all of the instructors have participated in a three-day standardized smoking cessation training course. Hence the content and theoretical underpinnings of the interventions are quite similar. The interventions offered by the different cessation units are group- and individual courses. In the group courses 8–15 smokers meet with the counsellor for five to six sessions of two hours each over one and a half months, while in the individual courses it is five sessions for at total of two hours. The courses are based on counselling, social support, and pharmacotherapeutic treatments. The rates of continued abstinence from smoking have been estimated to be 16% after 12 months [4]. English studies have reached similar or lower rates [5], even when the authors include only the four-week quitters at the 12-month follow-up [6].

A smoking ban in enclosed public areas was introduced in Denmark in August 2007. The existing literature from other countries documents a relation between smoking bans in public places and a fall in the smoking prevalence [7–13]. The magnitude of the effect of a smoking ban on smoking prevalence varies markedly (0.26–5.9 percentage points per year) [8,9,11,12,14]. The differences are likely explained by country differences, time, social norms' perspective, eventual local bans, and the fact that a smoking ban was sometimes introduced concurrently with other interventions targeting smoking, e.g. a higher price on tobacco.

The effect of a smoking ban on passive smoking has in the literature primarily been assessed on the basis of observed reductions in heart diseases (e.g. myocardial infarction and coronary heart disease) [15]. In the USA the reduction in heart disease as a result of reduced passive smoking has been estimated to lie in the range of 8% and 47% [16–20]; in Canada it is 13% [14], and in Europe it is 11–17% [7,21–23]. The effect of a smoking ban on pulmonary diseases, cancer, and the use of medicine has not been investigated.

Only one study has investigated the effect of a smoking ban on progression to establish smoking in adolescents [24,25]. The study found that youths (12–17 years of age) living in towns with a strong smoking regulations for restaurants had significantly lower odds for progressing to established smoking (odds ratio, 0.60; 95% confidence interval, 0.42–0.85) compared to those living in towns with weak regulations. Two other studies indicate that more extensive bans on smoking in public places reduce or discourage teenage smoking [26,27]. So far it has not been possible to document any effect of the Danish law on the number of acute myocardial infarctions or smokers [28].

Aims

The objective of the present study was to assess the population-level costs, effects, and cost effectiveness of two different smoking cessation interventions – smoking cessation programmes and a ban on smoking in enclosed public places – compared to no intervention. In this paper a smoking ban in enclosed public places is defined as a total ban, without Danish law exceptions. One of the primary exceptions is that smoking is allowed in pubs less than 40 m^2.

Methods

Model structure

A state transition model (Markov model) was used to estimate costs and gain in life-years due to the two interventions compared with the status quo (no intervention). The software program TreeAge Pro Healthcare 2009, release 1.0.2 was used to develop the Markov model with cycles of one year from the age 0 years to death or the age of 100 years. Half cycle correction was applied to both cost and outcome. The model was based on Danish risk data. We estimate the effects of the intervention under the assumption that the intervention is present during the whole lifetime of the individual. This implies that smokers can participate in a smoking cessation programme more than once over their lifetime, if the first attempt was not successful.

Four Markov states were included in the model, as follows: "Never smoker", "Smoker", "Ex-smoker", and "Death". The structure of the model, which was applied for the evaluation of both interventions, is

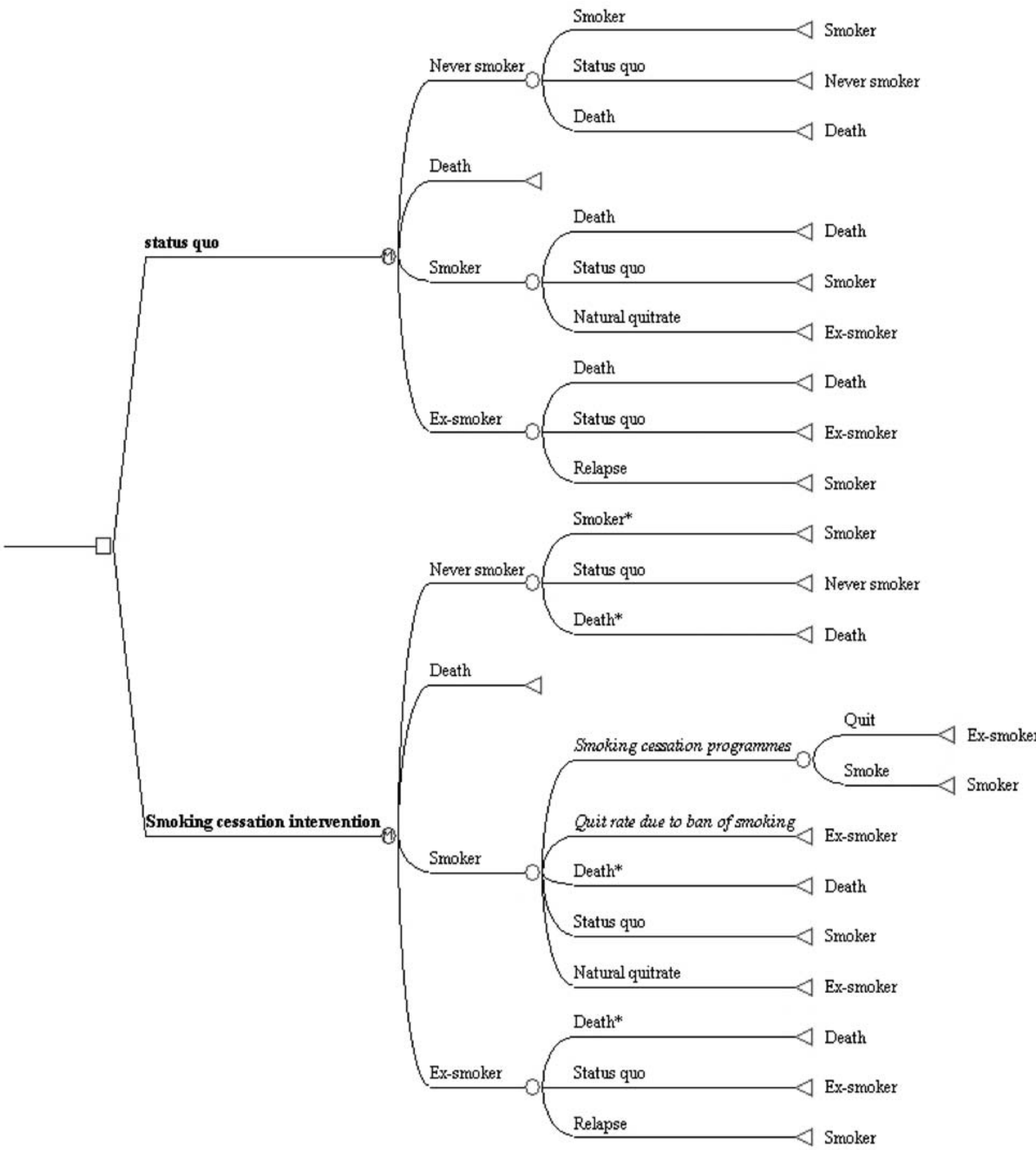

Figure 1. Model schema.
*Indicates different transiton probabilities for the two interventions. Arms marked in italics were only included in the respective evaluations.

depicted in Figure 1. This implies the same status quo arm and identical transition probabilities in the interventions arm except for the states which reflect the intervention effects (marked with * in the figure). The "smoking cessation programmes" and the "quit rate due to ban on smoking" arms (marked in italics) were included only in the respective evaluations.

We use a discount rate of 3.5% per annum for both costs and health effects, which follow the recommendations of the National Institute for Health and

Clinical Excellence (NICE) [29]. Monetary units are expressed in year 2008 Danish Crowns (DKK).

Sensitivity analysis

Uncertainty related to the precision of the effect estimate was handled by performing and presenting three analyses – a worst, base, and best case scenario – based on the most pessimistic, the most probable, and the most optimistic assumptions about the effect of the intervention. In addition, the results' sensitivity to the applied discount rate of 3.5% was investigated by varying the rate between 0% and 5%.

Transition probabilities

Table I shows the assumptions and estimates on incidence, natural quit rates, and relapse rates. In the literature it has not been possible to find estimates for the incidence of smoking, and therefore we made qualified estimates on the basis of Danish smoking prevalence rates [30,31]. The annual risk of relapse after not having smoked for 12 months of 0.001754 corresponds to the estimate used in [32], which is based on a compromise of estimates previously identified and/or applied in the literature [33–36]. The probability of enrolling in a cessation programme was estimated by coupling data on the participation frequency (as reported in SCDB) with the number of smokers in Denmark. Every year 0.5% of the male smokers and 1% of the female smokers participate in a cessation programme.

Age-, sex-, and smoking status dependent mortality risks were incorporated into the model. Table II presents relative risks (RR) of dying for smokers, ex-smokers, and never smokers used to convert mortality data from Statistics Denmark into annual mortality rates. According to findings in previous studies [37] it was assumed that the risk of dying for smokers under 35 years was equivalent to that of the general population of the same age.

Table III shows the assumed transition probabilities associated with the two interventions.

Cessation programmes

Owing to the low participation rate in cessation programmes, the impact on passive smoking is supposed to be negligible, and therefore passive smoking is not included in the evaluation of the courses. The quit rates of the cessation programmes were based on data from the SCDB. These gender dependent quit rates were based on self reported abstinence after 12 months. The intention to treat (ITT) estimate was used as the effect estimate in the worst case scenario, while the "real-life" result was used in the best case scenario. The "real-life" result was based only on data about those course participants where attempts had been made for them to be followed-up through questionnaires. The real-life result was higher than the ITT estimate. In population studies, clinical surveys, follow-up registries, and other studies over time the ITT approach and the "real-life" result may both have legitimacy. However, the aim of this analysis was to give an estimate of the real-life effect of smoking cessation courses. The base case effect is expected to lie between the ITT- and the "real-life" result.

Characteristics of the smokers in the SCDB are showed in Table IV.

Table I. Model parameters for smoking behaviour: status quo.

	Transition probability	Source
Smoking incidence		
<11 years	0.0000	Assumption based on prevalence rates [30,31]
11–13 years	0.01	
14–15 years	0.03	
16–20 years	0.0600	
21–30 years	0.0300	
>30 years	0.0000	
Probability of enrolling in a cessation programme (men/women)		
16–24 years	0.003/0.007	Based on data from SCDB[a]
25–44 years	0.005/0.010	
45–64 years	0.007/0.012	
>65 years	0.003/0.004	
Natural cessation parameters		
Annual relapse rate after not having smoked for 12 months	0.001754	Assumption based on [33–36,38]
Natural cessation rate (% of smoking pop.)	0.019	[39]

[a]SCDB, Danish National Smoking Cessation DataBase.

Smoking ban

Compared to the cessation programmes the evidence of the effect of a ban is much more limited. Our estimates were based on the literature of evaluations from other countries. We cannot rule out that the observed effect of smoking bans in the literature is driven by changes in norms related to smoking. Changes in norms may coincide with introduction of a smoking ban, which makes it difficult to identify the effect of smoking bans per se. If a change in norms is the main driver of changes in smoking behaviour, a worst case scenario could be that a smoking ban has no individual impact. This is the assumed worst case scenario in our simulation model (Table III). However, the very fast positive health effects on cardiovascular disease seen in many countries in the world indicate that the effect of the ban is real [7,10,17–19,22].

The primary aim of the smoking ban is to reduce passive smoking. Owing to the use of intermediary effect estimates and the fact that only the short-term effects of a smoking ban have been evaluated, and on cardiovascular disease only, the reduction in the risk of dying as a consequence of reduced passive smoking cannot be derived directly from the literature. Instead the effect on passive smoking was included in the model on the basis of an assumption about the reduction in the number of annual deaths due to passive smoking. It has previously been estimated that around 2,000 Danes die annually because of passive smoking [3].

We used these estimated 2,000 annual deaths [3] to estimate the change in death from passive smoking. We assumed that half of the exposure for environmental tobacco smoke (ETS) was in the home, and half was in public places (work/bars/restaurants etc.). Only the 1,000 annual deaths due to exposure in public places were assumed to be affected by a smoking ban. While the effect on heart disease can already be observed one year after the introduction of a ban [7,16–19,22], the full effect on cancer will first appear after several years. Therefore in the base and best case scenarios it was assumed that in the first 10 years after the smoking ban the number of deaths caused by passive smoking in public places was reduced by 25% (reduced by 250 deaths per year), and thereafter by 50% more – equal to a reduction of 375 deaths per year (Table III). The reduction in the risk of dying due to passive smoking

Table II. Relative risk of dying for smokers, ex–smokers and never smokers.

	Ex–smoker	Light smoker (1–14 grams per day)	Heavy smoker (>14 grams per day)
Men			
35–64 years	1.4	2.1	3.2
65–74 years	1.2	1.6	2.1
75 + years	1.2	1.2	1.3
Women			
35–64 years	1.4	2.2	3.8
65–74 years	1.0	1.5	2.6
75 + years	1.1	1.5	2.1

Reference: Table 5.3.4. in [3].

Table III. Applied effect estimates (transitions possibilities).

Scenarios	Worst	Base	Best	Source
Smoking cessation programmes				
Quit rate (men/women)	0.17/0.153	0.245/0.226	0.32/0.30	Data from SCDB[a]
Smoking ban				
Smoking incidence 11–13 years	No effect	No effect	0.008	In general no effect on the incidence rate was assumed for persons over 16 years. On the basis of [24,25]. A 20% reduction was assumed in the best case scenario.
Smoking incidence 14–16 years	No effect	No effect	0.024	
Quit rate due to ban of smoking	No effect	No effect	0.082 the first year, hereafter 0	The best case estimate was based on [12].
Reduced risk of dying due to reduced passive smoking	No effect	$\leq$10 Markov cycles 250 deaths fewer per year, hereafter 375 deaths fewer per year	$\leq$10 Markov cycles 250 deaths fewer per year, hereafter 375 deaths fewer per year	Assumption, see text (section Smoking ban)

[a]SCDB, Danish National Smoking Cessation DataBase.

Table IV. Characteristics of the smokers in the Danish National Smoking Cessation Database (SCDB) (95% confidence interval).

	All participants at the beginning of intervention $n = 3,628$ (100%)	Participants, who completed 6-month follow-up form $n = 1,979$ (55%)	Participants, who completed 12– months follow-up form $N = 1,877$ (52%)
Female (%)	63 (61.3–64.5)	63 (60.4–64.6)	62 (59.9–64.3)
Mean age	48.6 (48.3–49.0)	49.2 (48.7–49.6)	49.6 (49.2–50.1)
Employed (%)	69 (67.7–70.7)	69 (66.9–70.9)	70 (67.5–71.6)
Age of onset of smoking (mean, years)	16.2 (16.0–16.3)	16.1 (15.9–16.3)	16.3 (16.1–16.4)
Daily tobacco consumption (mean, gram)	19.6 (19.3–19.8)	19.3 (19.0–19.6)	19.0 (18.8–19.3)
Fagerström Test for Nicotine Dependence (mean)	5.5 (5.4–5.5)	5.4 (5.3–5.5)	5.4 (5.3–5.5)
Ever tried to quit (%)	84 (82.6–85.0)	84 (82.3–85.5)	84 (81.9–85.2)
Previous attempts to quit (mean)	3.6 (3.4–3.8)	3.6 (3.3–3.9)	3.7 (3.5–4.0)

Reprinted from Preventive Medicine, Vol 45, N.T. Kjaer, T. Evald, M. Rasmussen, et al. pp. 12–14, Copyright (2007), with permission from Elsevier [4].

was assumed to be evenly distributed between the three groups (non-smokers, smokers, and ex-smokers). Initially we expect to see an effect on cardiovascular disease. Later, we additionally expect a long-term effect on, for example, lung disease and cancer.

Furthermore, in the best case scenario it was assumed that the ban also affects incidence rates and quit rates. On the basis of references [24] and [25], there was assumed to be a reduction of 20% in the incidence rates on youths aged 11–16 years. In accordance with the results in the literature no effect on the incidence rate was assumed for persons aged $\geq$17 years. We found evidence on the effect of a smoking ban on smoking prevalence from Italy and England [9,12]. As Denmark is expected to be more similar to England than Italy the applied quit rate due to a smoking ban was based on the data from England. In England the smoking prevalence declined rapidly for the first nine months following the ban on smoking in indoor public areas [12]. After that there appears to have been a partial rebound. Overall the smoking prevalence was reduced by 2% points from 2007 to 2008 (from 24% to 22%, corresponding to a reduction of 8.2%). Thus a quit rate of 8.2% was assumed (Table III).

Costs

The analysis takes a societal perspective. Costs were divided into intervention costs, change in healthcare consumption, change in non-healthcare consumption, and changes in production value. The intervention costs of cessation programmes were based on a prior estimate based on SCDB data [32] equal to a mean cost of 3,200 DKK per person, in 2003. The intervention costs include participants' self reported out-of-pocket payments for nicotine replacement therapy (NRT) products, the cost of NRT products supplied as part of the courses, and the cost of instructor hours. Previously, subgroup analyses found no subgroup differentiation in intervention cost [33], and therefore the mean cost estimate was used for all age groups and for both men and women.

There are campaign costs in the introduction period of implementing an indoor smoking ban and costs related to law enforcement. These costs are very modest and therefore the intervention cost of an indoor smoking ban was assumed to be zero.

The annual healthcare costs per person for never smokers, smokers, and ex-smokers were based on a Danish study by Reindahl [40]. The applied annual healthcare costs per person distributed according to smoking status, age, and gender are reported in Figure 2.

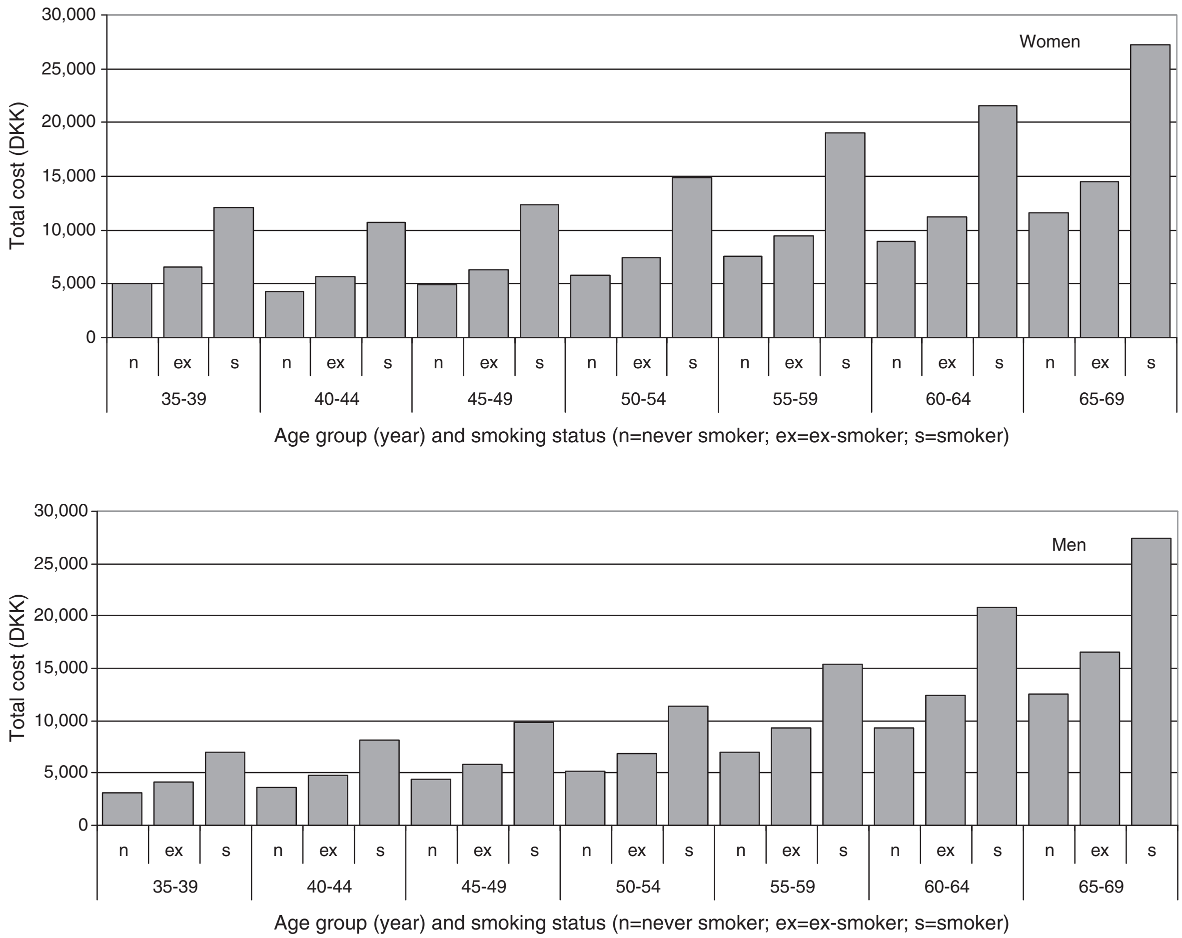

Figure 2. Annual total healthcare costs per person by smoking status, age, and gender. Denmark, 2008.

Productivity costs and non-healthcare consumption were included in the model using estimates from a recent Danish study [41]. These estimates are based on the consumption and production patterns of the average Danish citizen for one-year age groups. The estimates may not reflect the potential differences in these patterns across individuals with different smoking status.

There has been some debate within the health economics literature regarding which future cost component should be included [42–48]. In the present study we include all cost consequences, but report these separately to maximise transparency. The results are presented in Danish kroner (100 DKK = €13.41).

Estimation of effects and costs

The model made it possible to apply different approaches to estimating the effects and costs of the intervention. We chose to estimate the consequences both in the short term and the long term.

The short-term analysis estimates the cost and effect after 10 years of the intervention. The estimate was calculated on the basis of the actual Danish population according to the age- and sex distribution. In the shorter term the resources invested will not produce equivalent health effects because the older cohorts will not realize full lifetime effects of the intervention.

The long-term consequences of the interventions – and hereby the full potential of the intervention – were estimated in the long-term analysis. This was done by assuming that the whole population will be under the influence of the intervention for their entire lifetime – a steady state analysis. In practice this was done by estimating the mean cost and effects for an 11 year old individual.

Results

In Table V we present the long-term consequences of the interventions. On a population level the effect of a

Table V. The long-term costs and effects consequences of smoking cessation programmes and smoking ban. In 2008 prices, Danish Crowns. Costs and life-years are discounted with 3.5% (5% discounting; 0% discounting). Three scenarios regarding assumptions.

	Worst	Base	Best
Effect			
Smoking cessation programmes			
Life-years gained	0.0057 (0.0024;0.050)	0.008 (0.0035;0.073)	0.011 (0.0046;0.095)
Days per person gained	2 (1;18)	3 (1;27)	4 (2;35)
Smoking ban			
Life-years gained	0	0.026 (0.009;0.33)	0.031 (0.012;0.37)
Days per person gained	0	9 (3;119)	11 (4;135)
Cost			
Smoking cessation programmes			
Cost of intervention	143 (101;379)	142 (100;375)	141 (100;374)
Healthcare consumption	−395 (−210;−1944)	−572 (−305;−2,811)	−747 (−398;−3,663)
Non-healthcare consumption	706 (306;5,909)	1,022 (444;8,554)	1,334 (579;11,157)
Productivity cost	−537 (−261;−3,421)	−778 (−378;−4,955)	−1,017 (−494;−6,469)
Total	−83 (−64;923)	−186 (−139;1,163)	−289 (−213;3,399)
Smoking ban			
Cost of intervention	0	0	0
Healthcare consumption[a]	0	0	−504 (−282;−2,303)
Non-health care consumption	0	2,969 (1,087;36,968)	3,613 (1,375;42,122)
Productivity cost	0	− 1,293 (−548:−12,137)	−1,849 (−828;−15,389)
Total	0	1,676 (539;24,831)	1260 (265;24,428)
Cost-effectiveness (costs per life-year)			
Smoking cessation programmes	Dominant (Dominant;18,460)	Dominant (Dominant;15,932)	Dominant (Dominant;35,779)
Smoking ban	–	64,462 (59,889;75,936)	40,645 (22,083;66,027)

[a]Healthcare cost savings are underestimated owing to lack of knowledge of cost savings due to reduction in passive smoking.

Table VI. Gained life-years and costs of cessation programmes and smoking bans, for a period of 10 years (3.5% discounting).

Scenarios	Worst	Base	Best
Effect			
Smoking cessation programmes			
Days per person gained	0	0	0
Smoking ban Days per person gained Cost	0	4.7	6.4
Smoking cessation programmes			
Cost of intervention (million DKK)	216	216	215
Healthcare consumption (million DKK)	−215	−311	−393
Non-healthcare consumption (million DKK)	45	70	213
Production	−30	−6	−159
Total costs (million DKK)	16	−31	−124
Smoking ban			
Cost of intervention (million DKK)	0	0	0
Healthcare consumption (million DKK)[a]	0	0	−7,057
Non-health care consumption (million DKK)	0	6,895	9,683
Production	0	−2,428	−4,950
Total costs (million DKK)	0	4,467	−2,324

[a]Healthcare cost savings are underestimated owing to lack of knowledge of cost savings due to reduction in passive smoking.

smoking ban has the largest potential compared to the effect of smoking cessation programmes, 0–11 gained life-days versus 2–4 life-days per citizen (Table V).

Table V indicates that smoking cessation programmes are a dominant strategy relative to a do-nothing strategy (smoking cessation is cost saving and incurs life-year gains) regardless of scenario. A smoking ban, on the other hand, is predicted to incur costs with a cost per life-year gained of between 40,645 DKK and 64,462 DKK. It should, however, be noted that this estimate does not include the healthcare cost saving due to reduced passive smoking. Thus our results suggest that a smoking ban is most likely a cost-effective intervention.

Because only the assumptions about the rate of success differ between the cessation programmes' scenarios and not the number of participants, the cost of the intervention is approximately the same in all three cases. For both interventions the estimated present value of gained life-years is very sensitive to the applied discount rate. This is due to the fact that life-years are gained relatively far into the future. In the case of exclusion of the non-healthcare consumption and productivity gains from the analysis, all the scenarios are dominant (except for the worst scenario of a smoking ban where it is assumed that the ban has no individual effect).

The short-term consequences of introducing the interventions (10 year duration) are reported in Table VI. Introduction of smoking cessation programmes will not produce life-years (of a measurable magnitude) within the time span in any of the scenarios. However we see a reduction in the healthcare costs in all three scenarios, reflecting a positive effect on morbidity in the short term. The total costs show that even in the short term smoking cessation programmes save resources in the base case and best case scenario.

Table VI shows that in the short term a smoking ban can be expected to have an effect on health outcomes in the base and best case scenarios (in the range of 59,911–82,589 life-years). The expected gain per citizen is 4.7 gained life-days in the base case and 6.4 gained life-days in the best case. In the base scenario these gained life-days cost money, while in the best scenario a smoking ban is a dominant strategy.

Discussion

In this study we analyzed and compared two different interventions (cessation programmes and a smoking ban in enclosed public places). Except for the worst case scenario, the health effect of a smoking ban in enclosed public places is estimated as being much larger than the effect of cessation programmes in a general population; the reason being that too few individuals are reached by cessation programmes to incur a measurable reduction in population smoking prevalence.

Smoking cessation programmes appear to be a dominant strategy compared with the status quo (no intervention), regardless of scenario, because life years are gained while costs are saved. In the base and the best scenario of smoking bans the cost per life-year is 64,462 and 40,645 DKK, respectively. As mentioned previously, this is an underestimate due to omitted cost savings related to reduced passive smoking. Clearly, further research into the healthcare costs of passive smoking is warranted.

Generally, it is difficult to precisely isolate health outcomes that are directly attributable to smoking bans. In our worst case we assumed that all changes in smoking behaviour are due to previous changes in norms. A smoking ban has, in addition to reducing the availability of smoking places, a signal effect. Such a signal effect will only be present if norms can be changed further relative to the present state. It is likely that smoking bans are introduced after some changes in norms related to smoking have already taken place. Clearly it is difficult to disentangle the exact causes and effects, because changes in norms and political actions are bound to be closely related. We have attempted to tackle the issue of uncertainty by presenting results based on optimistic and pessimistic model assumptions.

A general issue concerning cost-effectiveness ratios (CE-ratio) of an intervention is that it depends on the populations from which it is estimated. This is the argument for performing sub-group analyses. Similarly the CE-ratio of the interventions may change as the smoking prevalence declines. This depends on whether a decline is followed by a change in the smoking population and thereby a change in the effectiveness of the different smoking cessation interventions, e.g. if it primarily is the least addicted smokers that quit first or those in the worst health state. As we do not know how the composition of the smoking population changes and how different subgroups of smokers respond to the two types of intervention, it is not possible to say whether and how the estimated CE-ratios will change by declining smoking prevalence. In addition, we make the neutral assumption that the effects of the two interventions are independent of each other, and of other interventions, due to a lack of knowledge of these synergistic relationships. There may be a synergistic relationship of different interventions on social norms and/or smoking behaviours affecting the impact of the intervention positively or negatively.

One of the barriers for implementing prevention interventions is that the cost will be here and now, while the gains will be in the future. However, even in the short term smoking cessation programmes save money in the base case and best case scenarios, while a smoking ban saves resources in the best case scenario. In contrast with a smoking ban, smoking cessation programmes will not produce life-years of a magnitude that is measurable in the short term. The explanation is that a smoking ban targets the whole population and therefore has an immediate measurable effect on the mortality risk because of a reduced risk of dying for all individuals due to reduced smoking as well as passive smoking.

To our knowledge no previous publications have reported the population effect and cost effectiveness of a smoking ban. However, the effect of four types of clean air laws (work site, restaurant, school, and other public places) have previously been examined according to changes in prevalence and lives saved, by use of the clean air module of the SimSmoke tobacco control policy simulation model from the United States [49]. The SimSmoke simulation model is a dynamic simulation model based on American demographic data, developed to predict the effect of different smoking policies. Unfortunately, the SimSmoke model does not include the effect on passive smoking and costs.

Another simulation model, the National Institute for Public Health and the Environment (RIVM) Chronic Disease Model (CDM) [50] from the Netherlands, has been used to evaluate the cost-effectiveness of two types of smoking cessation interventions, which to some extent can be compared to our smoking cessation programme. For a 75-year implementation period they found a cost-effectiveness ratio of €4,900 and €3,400 per quality-adjusted life year gained on intensive counselling in combination with nicotine replacement therapy or bupropion, respectively [51]. However, it is difficult to compare our results with these results, because the scenarios differ. In our analysis the situation of no intervention was compared with cessation programmes, while in their analysis current practice was compared to increased implementation of the cessation intervention. Furthermore, in contrast with our model, the researchers only include saving of avoided smoking-related diseases, and thereby ignore healthcare costs unrelated to smoking in life-years gained from smoking cessation.

Compared to the RIVM model, our model is simpler, as it can only be used to assess the effect of smoking interventions, while the RIVM model can be used to assess the public health effects of interventions on other risk factors than smoking. In addition, the RIVM model takes account of demographic changes in the population in all their analysis, while we only take account of demographic changes in the short-term analysis.

The strength of our analysis is that the two interventions are evaluated through use of the same underlying model. The model's validity depends both on the model's structure, the applied data, and the level of evidence. Our study's greatest weakness is the rather low level of evidence of the impact of smoking bans. However, models are an analytical framework that permits the synthesis of evidence that is available at a particular point in time, and the models are therefore only as good as the current evidence permits. Consequently, the results of a smoking ban should be treated with more caution than the results of smoking cessation programmes.

The analyses have several limitations. First, it has not been possible to find estimates for the incidence of smoking in the literature. Instead we had to make qualified estimates on the basis of prevalence rates. We had to use 2005–06 prevalence data, as the newer update data is not as detailed. In 2005 the smoking prevalence was around 29.6% (men 31.6%; women 27.8%) [30]. However, the prevalence has been declining in the last few years by several percentage points [52]. This implies that the health effects of the smoking interventions are overestimated. Secondly, outcome is life years saved, thus ignoring quality-of-life aspects. Thirdly, as we lack information on the healthcare cost for people aged 70 + years it was assumed that their cost profile is identical to the 65 to 69 age group. This probably gives rise to an underestimation of the healthcare costs associated with increased life expectancy, because the last two years of life normally cost more than the preceding years [53], and the mortality is higher for people 70 + years than for the 65 to 69 age group. Fourthly, the applied data of SCDB is based on self reported data without biochemical validation, and attempts were made to follow up only about half of the smokers. Therefore, it cannot be precluded that an overestimation of the success rate has been made. Fifthly, there is a risk that not all the interventions' cost of smoking cessation programmes were included in the analysis. The reason is that these costs were limited to including the cost associated with the interventions' programme. Other costs, such as doctors' cost of persuading and motivating smokers to participate in the courses, were not addressed. In addition, in a perfect model, the economic effect of reduced passive smoking should have been included in the smoking ban model. However, since these effects are largely unknown these were not included in the model. This is the reason for the reported zero healthcare costs in the base case scenario of a smoking ban. Furthermore, constant age-specific productivity costs and non-healthcare consumption regardless of smoking status were applied, as specific smoking status data on this topic do not exist. However, if this assumption is incorrect, and, for example, smokers are less productive than non-smokers due to more sick days, the costs of the interventions will be overestimated.

The main objective of an economic evaluation is to give valuable information to the policymakers about the cost effectiveness of, for example, treatments and prevention activities. This analysis contributes to the latter. Contrary to many previous cost-effectiveness analyses of smoking interventions, the applied population method in this analysis made it possible to encompass consequences beyond those that affect the target group (e.g. inclusion of passive smoking in the analysis of a smoking ban), estimate the long-term effects, and illustrate the relative ability of the interventions to contribute to significant health improvements in the population at large. Nevertheless, the analysis cannot be better than the quality of the evidence included in the analysis. Therefore, especially in the smoking ban model there is room for improvement. This is once again a general reminder of the importance of detailed effect documentation of prevention activities.

Conclusion

Our results indicate that smoking cessation programmes and a smoking ban in enclosed public places are cost-effective strategies compared to the status quo.

Acknowledgements

We would like to thank Susanne Reindahl Rasmussen for giving access to the lifetime costs of smoking and smoking cessation estimated in her PhD thesis. The authors are grateful to SCDB giving access to data, particularly to National Coordinator Mette Rasmussen for the set-up and collection of the study data.

Funding

This study is an elaboration of a previous work made for the Danish Commission of Prevention. The article is part of BH's PhD. This part of the PhD thesis is supported by the Danish Institute of Health Service Research and Danish Graduate School in Public Health Science.

References

[1] Ruger JP, Emmons KM. Economic evaluations of smoking cessation and relapse prevention programs for pregnant women: a systematic review. SO: Value in Health 2008;11(2):180–90.
[2] Ronckers ET, Groot W, Ament AJ. Systematic review of economic evaluations of smoking cessation: standardizing the cost-effectiveness. Med Decis Making 2005;25(4): 437–48.
[3] Juel K, Sørensen J, Brønnum-Hansen H. Risikofaktorer og folkesundhed i Danmark [Risk factors and public health in Denmark]. København, Danmark: Statens Institut for Folkesundhed [National Institute of Public Health]; 2006.
[4] Kjaer NT, Evald T, Rasmussen M, Juhl HH, Mosbech H, Olsen KR. The effectiveness of nationally implemented smoking interventions in Denmark. Prev Med 2007;45(1): 12–14.
[5] Bauld L, Bell K, McCullough L, Richardson L, Greaves L. The effectiveness of NHS smoking cessation services: a systematic review. J Public Health (Oxf) 2010;32(1):71–82.
[6] Bauld L, Judge K, Platt S. Assessing the impact of smoking cessation services on reducing health inequalities in England: observational study. Tob Control 2007;16(6):400–4.
[7] Cesaroni G, Forastiere F, Agabiti N, Valente P, Zuccaro P, Perucci CA. Effect of the Italian smoking ban on population rates of acute coronary events. Circulation 2008;117(9): 1183–8.
[8] Frieden TR, Mostashari F, Kerker BD, Miller N, Hajat A, Frankel M. Adult tobacco use levels after intensive tobacco control measures: New York City, 2002–2003. Am J Public Health 2005;95(6):1016–23.
[9] Gorini G, Chellini E, Galeone D. What happened in Italy? A brief summary of studies conducted in Italy to evaluate the impact of the smoking ban. Ann Oncol 2007;18(10):1620–2.
[10] Pierce JP, Gilpin EA, Emery SL, White MM, Rosbrook B, Berry CC, et al. Has the California tobacco control program reduced smoking? JAMA 1998;280(10):893–9.
[11] Siegel M, Mowery P, Pechacek TP, Strauss WJ, Schooley MW, Merrit MA, et al. Trends in adult cigarette smoking in California compared with the rest of the United States, 1978–1994. Am J Public Health 2000;90(3):372–9.
[12] West R, Smoking and smoking cessation in England: findings from the Smoking Toolkit Study. Available from: http://www.smokinginengland.info (accessed April 2009).
[13] Weintraub JM, Hamilton WL. Trends in prevalence of current smoking, Massachusetts and states without tobacco control programmes, 1990 to 1999. Tob Control 2002; 11(Suppl II):ii8–ii13.
[14] Lemstra M, Neudorf C, Opondo J. Implications of a public smoking ban. Can J Public Health 2008;99(1):62–5.
[15] Barnoya J, Glantz SA. Cardiovascular effects of secondhand smoke: nearly as large as smoking. Circulation 2005; 111(20):2684–98.
[16] Bartecchi C, Alsever RN, Nevin-Woods C, Thomas WM, Estacio RO, Bartelson BB, et al. Reduction in the incidence of acute myocardial infarction associated with a citywide smoking ordinance. Circulation 2006;114(14):1490–6.
[17] Juster HR, Loomis BR, Hinman TM, Farrelly MC, Hyland A, Bauer UE, et al. Declines in hospital admissions for acute myocardial infarction in New York state after implementation of a comprehensive smoking ban. Am J Public Health 2007;97(11):2035–9.
[18] Khuder SA, Milz S, Jordan T, Price J, Silvestri K, Butler P. The impact of a smoking ban on hospital admissions for coronary heart disease. Prev Med 2007;45(1):3–8.
[19] Sargent RP, Shepard RM, Glantz SA. Reduced incidence of admissions for myocardial infarction associated with public smoking ban: before and after study. BMJ 2004;328:977–80.
[20] Seo DC, Torabi MR. Reduced admissions for acute myocardial infarction associated with a public smoking ban: matched controlled study. J Drug Educ 2007;37(3): 217–26.

[21] Barone-Adesi F, Vizzini L, Merletti F, Richiardi L. Short-term effects of Italian smoking regulation on rates of hospital admission for acute myocardial infarction. Eur Heart J 2006;27(20):2468–72.
[22] Pell JP, Haw S, Cobbe S, Newby DE, Pell AC, Fischbacher C, et al. Smoke-free legislation and hospitalizations for acute coronary syndrome. N Engl J Med 2008; 359(5):482–91.
[23] Vasselli S, Papini P, Gaelone D, Spizzichino L, De CE, Gnavi R, et al. Reduction incidence of myocardial infarction associated with a national legislative ban on smoking. Minerva Cardioangiol 2008;56(2):197–203.
[24] Siegel M, Albers AB, Cheng DM, Biener L, Rigotti NA. Effect of local restaurant smoking regulations on progression to established smoking among youths. Tob Control 2005; 14(5):300–6.
[25] Siegel M, Albers AB, Cheng DM, Hamilton WL, Biener L. Local restaurant smoking regulations and the adolescent smoking initiation process: results of a multilevel contextual analysis among Massachusetts youth. Arch Pediatr Adolesc Med 2008;162(5):477–83.
[26] Chaloupka FJ, Wechsler H. Price, tobacco control policies and smoking among young adults. J Health Econ 1997; 16(3):359–73.
[27] Wakefield MA, Chaloupka FJ, Kaufman NJ, Orleans CT, Barker DC, Ruel EE. Effect of restrictions on smoking at home, at school, and in public places on teenage smoking: cross sectional study. BMJ 2000;321:333–7.
[28] Aarestrup AK, Due TD, Juel K. Evaluering af loven om røgfri miljøer. Lov nr. 512 af 6. juni 2007 [Evaluation of the law of smoke-free environments. Law number 512 of June 6th 2007]. The Danish National Board of Health; 2009.
[29] National Institute for Health and Clinical Excellence (NICE). Guide to the methods of technology appraisal. London: NICE; 2004.
[30] Ekholm O, Kjøller M, Davidsen M, Hesse U, Eriksen L, Christensen AI, et al. Sundhed og sygelighed i Danmark 2005 og udviklingen siden 1987 [Health and morbidity in Denmark 2005 and trend since 1887]. København, Denmark: Statens Institut for Folkesundhed [National Instiute of Public Health]; 2006.
[31] Rasmussen M, Due P. Skolebørnsundersøgelsen 2006 [The schoolchildren investigation 2006]. København: Forskningsgruppen for Børn og Unges Sundhed. Institut for Folkesundhedsvidenskab. Københavns Universitet.; 2007.
[32] Olsen KR, Bilde L, Juhl HH, Kjaer NT, Mosbech H, Evald T, et al. Cost-effectiveness of the Danish smoking cessation interventions: subgroup analysis based on the Danish Smoking Cessation Database. Eur J Health Econ 2006;7(4):255–64.
[33] Crealey GE, McElnay JC, Maguire TA, O'Neill C. Costs and effects associated with a community pharmacy-based smoking-cessation programme. Pharmacoeconomics 1998;14(3): 323–33.
[34] Cromwell J, Bartosch WJ, Fiore MC, Hasselblad V, Baker T. Cost-effectiveness of the clinical practice recommendations in the AHCPR guideline for smoking cessation. Agency for Health Care Policy and Research. JAMA 1997;278(21): 1759–66.
[35] Song F, Raftery J, Aveyard P, Hyde C, Barton P, Woolacott N. Cost-effectiveness of pharmacological interventions for smoking cessation: a literature review and a decision analytic analysis (Structured abstract). SO: Medical Decision Making 2002;22(Supplement):S26–S37.
[36] Stapleton JA, Lowin A, Russell MA. Prescription of transdermal nicotine patches for smoking cessation in general practice: evaluation of cost-effectiveness. Lancet 1999; 354(9174):210–15.
[37] Doll R, Peto R, Wheatley K, Gray R, Sutherland I. Mortality in relation to smoking: 40 years' observations on male British doctors. BMJ 1994;309:901–11.
[38] Sonnenberg FA, Beck JR. Markow models in medical decision making. Med Decis Making 1993;13:322–38.
[39] Pisinger C, Glumer C, Toft U, von Huth SL, Aadahl M, Borch-Johnsen K, et al. High risk strategy in smoking cessation is feasible on a population-based level. The Inter99 study. Prev Med 2008;46(6):579–84.
[40] Rasmussen SR. The lifetime costs of smoking and smoking cessation. PhD thesis. Copenhagen, Denmark: DSI Institut for Sundhedsvæsen; 2006. Report No.: DSI rapport 2006.01.
[41] Kruse M, Sørensen J, Gyrd-Hansen D. Future costs in cost-effectiveness analysis: an empirical assessment. Scand J Public Health[in press].
[42] Meltzer D. Accounting for future costs in medical cost-effectiveness analysis. J Health Econ 1997;16(1):33–64.
[43] Garber AM, Phelps CE. Economic foundations of cost-effectiveness analysis. J Health Econ 1997;16(1):1–31.
[44] Nyman JA. Should the consumption of survivors be included as a cost in cost-utility analysis? Health Econ 2004;13(5): 417–27.
[45] Gandjour A. Consumption costs and earnings during added years of life – a reply to Nyman. Health Econ 2006;15(3): 315–17.
[46] Richardson JRJ, Olsen JA. In defence of societal sovereignty: a comment on Nyman: the inclusion of survivor consumption in CUA. Health Econ 2006;15:311–13.
[47] Lundin D, Ramsberg J. On survival consumption costs: a reply to Nyman. Health Econ 2008;17(2):293–7.
[48] Liljas B, Karlsson GS, Stalhammar NO. On future non-medical costs in economic evaluations. Health Econ 2008; 17(5):579–91.
[49] Levy DT, Friend K, Polishchuk E. Effect of clean indoor air laws on smokers: the clean air module of the SimSmoke computer simulation model. Tob Control 2001;10:345–51.
[50] Hoogenveen RT, de Hollander AEM, van Genugten MLL. The chronic diseases modelling approach. Bilthoven, The Netherlands: National Institute of Public Health and the Environment (RIVM); 1998. Report No.: 266750001.
[51] Feenstra TL, Hamberg-van Reenen HH, Hoogenveen RT, Rutten-van Molken MP. Cost-effectiveness of face-to-face smoking cessation interventions: a dynamic modeling study. Value Health 2005;8(3):178–90.
[52] Monitorering af danskernes rygevaner 2010 – hele stikprøven [Monitoring of the Danes smoking habits 2010 – the whole sample]. Userneeds Dataleverandør og Analyseinstitut; 2010.
[53] Zweifel P, Felder S, Meiers M. Ageing of population and health care expenditure: a red herring? Health Econ 1999; 8:485–96.