Future Burden and Costs of Smoking-Related Disease in the Netherlands: A Dynamic Modeling Approach

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ABSTRACT

Objectives: In this article, we explore the future health gain of different policy measures to reduce smoking prevalence: health education campaigns specifically aimed at keeping (young) people from starting to smoke, campaigns aimed at persuading smokers to quit, and tax measures.
Methods: We drew up different policy scenarios based on evaluations of several health promotion campaigns. Implementing these into the dynamic multistate models, we simulated smoking prevalence, loss of life-years, and costs for several decades into the next century.

Results: In the short run, campaigns aimed at potential "quitters" appear to be most effective in terms of health gain. However, their effect fades away after several decades, while campaigns aimed at young "starters" or tax measures in the end yield a larger and more lasting decrease in smoking attributable disease burden.
Conclusion: Dynamic modeling is very useful tool in calculating costs and effects of preventive public health measures.
Keywords: cost of illness, dynamic modeling, public health, scenario analysis, smoking.

Introduction

As in most developed countries, in the Netherlands the burden of disease attributable to smoking is substantial. In 1997, cigarette smoking caused approximately 23,000 deaths in the Netherlands, primarily caused by lung cancer, coronary heart disease, stroke, and chronic obstructive pulmonary disease (COPD). In the *Tobacco Paper: Tobacco Control Policy,* the Dutch government awards a high priority to the discouragement of tobacco smoking to reduce the smoking-related burden of disease [1]. However, in spite of this tobacco paper, firm policy measures have failed to appear, whereas smoking prevalence among 10- to 14-year-old youths is gradually increasing from 8% in 1990 to 14% in 1996 for boys and from 6% to 12% for girls [2]. An increasing smoking prevalence among teenagers implies an increasing burden of smoking-related diseases in the future.

To describe the impact of increasing smoking prevalence over time in terms of future burden and costs of smoking-related diseases, a dynamic multistate model is needed [3–6]. These types of models are able to integrate aging of the population, trends in smoking prevalence, and trends in disease-specific incidence for four smoking-related diseases. More specifically, the model takes account of competing death risks. We developed a dynamic multistate model, and as an example, we explored the public health gain of different policy measures to reduce smoking prevalence in terms of disability-adjusted life-years (DALYs) and costs.

Methods

Model and Data
A dynamic multistate model describes the development over time of demography, smoking prevalence, and smoking-related disease in the Netherlands [7–10]. Four smoking-related diseases are considered: lung cancer, coronary heart disease, stroke, and COPD. In the model, the Dutch population, which is divided into birth cohorts, is followed from 1994. To understand the model, imagine a person born in a given year. In each fol-
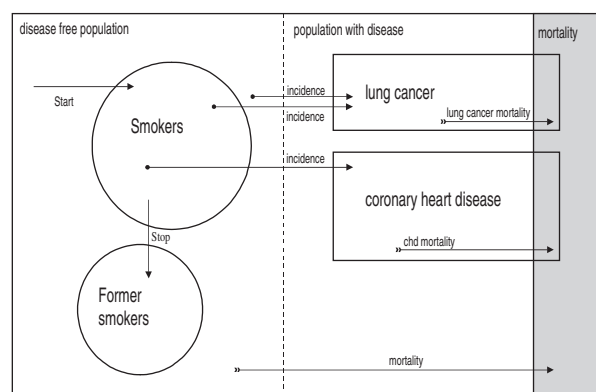
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Figure 1 Basic structure of the multistate model.

Table 1 Relative risks for smokers and former smokers, men and women

Disease	Age (years)	Smokers		Former smokers	
		Men	Women	Men	Women
Lung cancer	35–59	27.21	14.77	11.09	4.53
	60–69	30.71	14.70	11.25	5.05
	70–79	27.23	11.28	9.43	4.50
	80+	13.40	7.31	6.55	2.95
Coronary	35–59	3.36	3.61	1.99	1.61
heart	60–69	2.06	2.43	1.44	1.14
disease	70–79	1.49	1.63	1.19	1.18
	80+	1.23	1.00	1.04	1.00
Stroke	35–59	3.64	6.34	1.12	1.33
	60–69	2.48	2.64	1.19	1.22
	70–79	1.77	2.22	1.15	1.22
	80+	1.09	1.00	1.00	1.00
COPD	50–69	13.57	12.29	11.18	8.26
	70+	9.76	8.92	7.43	5.94

lowing year, this person, if still alive, at certain age, may start smoking and may have one or more diseases. The changes in these characteristics are determined by transitions. As an example, with probability, a 60-year-old smoker may become a 61-year-old nonsmoker and may be diagnosed as a lung cancer patient at the age of 65. The incidence of smoking-related diseases depends on age, gender, and smoking behavior. Data on incidence and mortality of smoking-related diseases together with data on changes in smoking behavior and demographics of the Dutch population resulted in the future number of smoking related patients for the years 1994 to 2050. Figure 1 presents the conceptual structure of the model. The arrows in this figure represent changes in health or smoking behavior.

Demographic data, incidence rates, 1994 prevalence rates, and disease-specific mortality rates were the input data for the model. Demographic data on migration, birth, and total mortality by gender and age were obtained from Statistics Netherlands. To obtain estimates for incidence and prevalence of

smoking-related diseases in 1994 in the Netherlands, data from several general practitioner registrations were combined [11–13]. Mortality rates for smoking-related diseases were estimated as the difference between mortality in the general population and mortality among patients [14]. The 1994 gender- and age-specific incidence and mortality rates were used without time trends for the period 1994 to 2050. Remission from smoking-related diseases was assumed to be zero.

Gender- and age-specific start and stop rates for smoking were estimated from observed trends over the period 1987 to 1994 using age-period-cohort analysis. Smoking-specific incidence rates had to be calculated from the observed gender- and age-specific incidence rates in the population and the relative risks or risk ratios of smokers and former smokers for incidence of smoking-related diseases [15]. The prevalence of smoking for 1994 and start and stop rates are presented in Table 1, and the relative risks for four major smoking-related diseases are presented in Table 2.

Table 2 Smoking-related input data, men and women

Age (years)	Men				Women			
	Proportion* (1994)		Rate		Proportion* (1994)		Rate	
	Never-smoker	Smoker	Start	Quit	Never-smoker	Smoker	Start	Quit
10–14	0.97	0.03	0.072		0.97	0.03	0.023	
15–19	0.76	0.22	0.057	0.041	0.77	0.21	0.047	0.046
20–24	0.59	0.34	0.045	0.041	0.60	0.32	0.031	0.034
25–29	0.49	0.40	0.03	0.034	0.49	0.37	0.02	0.029
30–34	0.42	0.43	0.018	0.028	0.41	0.39	0.012	0.027
35–39	0.37	0.44		0.016	0.40	0.39		0.007
40–44	0.33	0.44		0.019	0.43	0.37		0.009
45–49	0.31	0.43		0.022	0.46	0.34		0.01
50–54	0.30	0.42		0.025	0.50	0.31		0.012
55–59	0.30	0.40		0.029	0.55	0.28		0.013
60–64	0.30	0.38		0.033	0.60	0.24		0.015

*Proportion of former smokers equals 1 minus proportion never-smokers and proportion smokers.

Scenarios

As an example, scenarios on antismoking measures are considered. The Dutch Foundation on Smoking and Health (StiVoRo) has evaluated its own antismoking campaigns over the period 1983 to 1991, including three campaigns specifically aimed at teenagers. The yearly reduction that was achieved among young potential starters varied between 10 and 20%. In a recent meta-analysis of smoking prevention studies a mean reduction of 30% was found in the first year [16]. Based on these studies, we have assumed that a reduction of 20% in the numbers of starters is possible.

A Dutch health education campaign encouraging smokers to quit led to a 14% decrease in smoking prevalence in the first year. Similar effects among smokers have been described in several other evaluation studies [17–20]. We have assumed a 14% reduction in smoking prevalence in the first years and a 2% reduction in successive years.

The effect of tax measures is described in terms of price elasticity: the percentage of change in smoking prevalence per percentage of change in price. Because Dutch data on price elasticity are lacking, we have used data from the United Kingdom [21].

Based on these evaluations, the following alternative scenarios on future smoking prevalence are formulated.

1. *Reference scenario:* Future smoking prevalence is based on trend extrapolation.
2. *Don't start scenario:* Continuous health promotion aimed at keeping (young) people from smoking; over a 3-year period (1998–2000) the number of starters is reduced by 20%. For the following years, it is assumed that this reduction can be maintained by periodically and supplementary campaigns.
3. *Quit scenario:* Continuous health promotion urges smokers to quit; in the first year (1998) a 14% reduction of the smoking prevalence is achieved. In successive years a reduction of 2% of the smoking prevalence is maintained.
4. *Tax scenario:* Tax measures increase tobacco prices with 50%. Price elasticity is −1.2 for teenagers, −0.08 for adult men, and −0.23 for adult women [21]. Consequently in the first year starting rates are 60% (1.2 times 50% price reduction) lower than the reference value, while quitting rates among male and female smokers are 4% (0.08 times 50% price reduction) and 11.5% (0.23 times 50% price reduction) higher, respectively. Because of inflation, prices among other effects on starting and quitting rates diminish with 3% per year. Because quitting rates have returned to their original value in about 1 year, tax measures primarily have an effect on the smoking behavior of teenagers [22].

Disability-Adjusted Life-Years Gained

Given the model estimates of prevalence and mortality for the four smoking-related diseases for the period 1998 to 2050, we calculated the total number of life-years lost as the sum of the remaining life expectancy at the age of death. Quality-of-life losses for patients were calculated using Dutch disease-specific quality-of-life weight [23,24]. Quality-of-life weights for four smoking-related diseases are presented in Table 3. As an example, for an average lung cancer patient 0.432 per year is lost as a result of lung cancer, which means that 1 year with lung cancer was considered to be equal to 0.568 years in perfect health.

The total amount of DALYs lost because of smoking in a certain year was computed by adding up years of life lost resulting from premature mortality and the prevalence of smoking-related diseases multiplied by the quality of life-weight. The number of life-years saved in the different scenarios is the difference of "reference" DALYs lost and "alternative" DALYs lost.
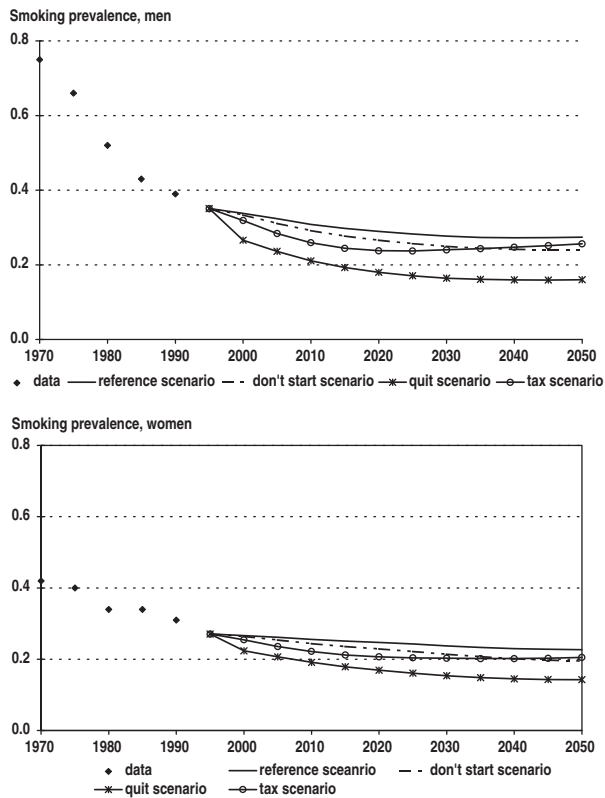
Avoided Costs

For health-care costs, we used cost per person estimates from the Cost of Illness in the Netherlands study [25]. By multiplying disease-specific prevalence numbers and disease-specific costs per person the total smoking-related costs can be calculated. Costs to be avoided are difference of costs calculated in the reference scenario and the alternative scenarios.
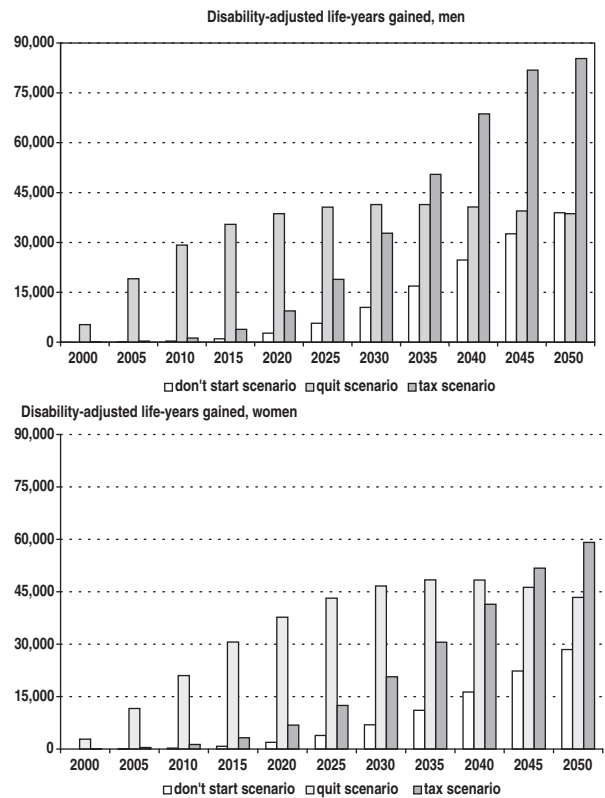
Sensitivity Analysis

In the different scenarios the effect of start and stop smoking rates on DALYs gained and avoided costs is calculated. The different scenarios can be interpreted as sensitivity analysis.

Table 3 Quality-of-life weights used in the model

Disease	Quality-of-life weight
Lung cancer	0.432
Coronary heart disease	0.288
Stroke	0.609
COPD	0.314

Smoking prevalence, men

Smoking prevalence, women

Figure 2 Past and and future smoking prevalence in different scenarios, men and and women.

Disability-adjusted life-years gained, men

Disability-adjusted life-years gained, women

Figure 3 Annual health gain in "alternative" scenarios compared to the "reference" scenario, men and and women.

Results

In the reference scenario the prevalence of smoking among men declines from 35% in 1995 to 29% in 2020 (Fig. 2). After that year the decline almost stalls: in 2050 smoking prevalence is still 28%; for women the smoking prevalence only slightly decreased from 27% in 1995 to 24% in 2030 and 23% in 2050. In the don't start scenario prevalence is reduced to around 24% for males and 20% for females in 2050, while the quitting scenario yields a reduction to less than 16% for males and 14% for females in 2050. In both scenarios the effect is larger for men than for women. The tax scenario reduces smoking prevalence among men to 24% in 2020, after which it slightly increase to 26%; for women there is a reduction to 21% in 2025, after which smoking prevalence remains constant. The former smokers prevalence will rise in the quitting scenario, whereas it decreases in the don't start scenario (Figs. 3 and 4).
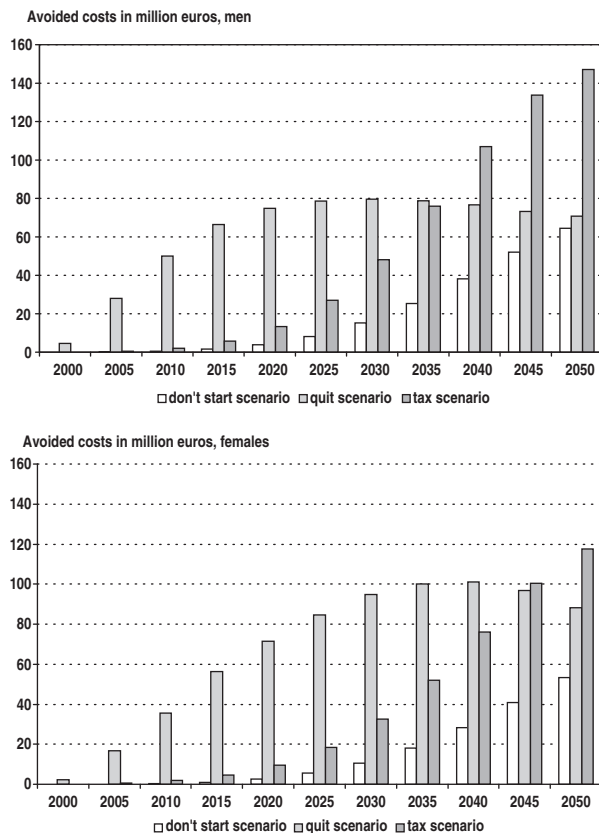
In the don't start scenario, it takes about 15 years to see an effect on the number of DALYs lost each year to smoking-related disease. From that moment on, the health gain of programs aimed at teenagers

increases rapidly. The short-run health gain in the quitting scenario is substantial but after reaching a maximum of about 40,000 years in 2025 for males and a maximum of about 50,000 in 2035 for females, the annual number of life-years saved is declining again. Cost to be avoided will be almost €80 million for males and €100 million for females. However, in the end the health gain and avoided costs of the don't start scenario will go beyond the yield of the quitting scenario. The tax scenario behaves very similar to the don't start scenario but runs faster, reaches a higher health gain and will catch up with the quitting scenario earlier next century.

In all scenarios a time lag between men and women of about 5 years can be observed. The max-

Table 4 Cost of smoking-related diseases in 1999 in million euros, men and women

Disease	Men	Women	Total
Lung cancer	74.7	29.7	104.4
Coronary heart disease	584.3	344.5	928.8
Stroke	416.9	611.8	1028.6
COPD	328.3	265.6	594.0

Avoided costs in million euros, men

□ don't start scenario □ quit scenario ▣ tax scenario

Avoided costs in million euros, females

□ don't start scenario □ quit scenario ▣ tax scenario

Figure 4 Annual avoided costs in "alternative" scenarios compared to the "reference" scenario, men and women.

imum (absolute) health gain is more or less the same for both men and women.

Discussion

The results of this scenario study suggest that a rather substantial number of health-adjusted life-years are to be saved by programs aimed at reducing smoking prevalence, especially among the young. The application of DALYs to measure the returns provides an indication of the health that is gained more than merely the added years of life [3].

The largest reduction in smoking prevalence is achieved in the quitting scenario. But there is no way in which the WHO Health for All target of 20% smoking prevalence in the Netherlands can be reached in 2000. In the quitting scenario, this goal can be reached in 2015.

The pool of potential quitters is larger than the pool of potential starters. Potential starters are primarily youths from 10 to 30 years of age, whereas most potential quitters are found in older age groups. Therefore, in the short run the health gain

will be largest in the quitting scenario, as potential quitters have a higher disease and mortality risk as well. However, in the long run the health gain of the quitting scenario diminishes, while at the same time the returns of the don't start and tax scenarios are building up as a result of aging of the population.

The quitting scenario shows a time lag of about 10 years between males and females in reaching the maximum health gain or the maximum costs to be avoided. This observation can be explained by the high percentage never smokers in older females. Along with aging of the middle-aged women the health gain and costs to be avoided will increase and reach its maximum.

In the short run, campaigns aimed at adults appear to be most effective in terms of health gain. However, this health gain fades away, while campaigns aimed at starters in the end yield a larger effect.

Obviously the kind of disease modeling reported here requires a fair degree of simplification. For instance, our Dutch model population is made up of never-smokers, smokers, and former-smokers, i.e., groups we assume to be homogenous. Of course in the real world many different types of smoking behavior can be observed. We assume starters and quitters to react alike to health education programs and tax measures, whereas the degree of stubbornness may differ substantially from one smoker to the other. Therefore, especially the long-term response to antismoking campaigns is hard to appraise. Does the pool of smokers that can be "converted" dry up in the course of time, leaving only confirmed smokers? What is the "shelf life" of a tax measure? Will it still matter in a personal decision to quit or to stay away from smoking in the next decades?

Considering these simplifications we think our results should primarily be seen as fairly crude representations of important trends and mechanisms in the real world. Nevertheless, our simulations leave but one conclusion: only rigorous and persistent policies will substantially abate the health problem associated with smoking.

Finally, we conclude that dynamic modeling can be of great help in integrating data from different sources to illustrate the cost and effects of preventive public health policies.

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