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Cost-Effectiveness of Face-to-Face Smoking Cessation Interventions: A Dynamic Modeling Study

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ABSTRACT

Objectives: To estimate the cost-effectiveness of five face-to-face smoking cessation interventions (i.e., minimal counseling by a general practitioner (GP) with, or without nicotine replacement therapy (NRT), intensive counseling with NRT, or bupropion, and telephone counseling) in terms of costs per quitter, costs per life-year gained, and costs per quality-adjusted life-year (QALY) gained.
Methods: Scenarios on increased implementation of smoking cessation interventions were compared with current practice in The Netherlands. One of the five interventions was implemented for a period of 1, 10, or 75 years reaching 25% of the smokers each year. A dynamic population model, the RIVM chronic disease model, was used to project future gains in life-years and QALYs, and savings of health-care costs from a decrease in the incidence of 11 smoking-related diseases over a time horizon of 75 years. This model allows the repetitive application of increased cessation rates to a population with a changing demographic and risk factor mix. Sensitivity analyses were performed for variations in costs, effects, time horizon, program size, and discount rates.
Results: Compared with current practice, minimal GP counseling was a dominant intervention, generating both gains in life-years and QALYs and savings that were higher than intervention costs. For the other interventions, incremental costs per QALY gained ranged from about 1100€ for telephone counseling to 4900€ for intensive counseling with nicotine patches or gum for implementation periods of 75 years.
Conclusions: All five smoking cessation interventions were cost-effective compared with current practice, and minimal GP counseling was even cost-saving.
Keywords: bupropion, cost-effectiveness, counseling, dynamic modeling, nicotine replacement therapy, smoking cessation.

Introduction

Smoking is a leading cause of preventable morbidity and mortality. It incurs high costs to the society. The World Bank estimated that 6% to 15% of total health-care costs were attributable to smoking in high-income countries [1].

For many smokers, it is hard to quit smoking on will power alone. Only 3% to 7% of the smokers who attempt to stop smoking on will power are still abstinent after 1 year [2,3]. A wide range of policy measures and therapies is available to increase this rate, varying from price increases by taxation, media campaigns, or self-help manuals, to intensive individual counseling combined with pharmaceutical therapies. For smoking cessation interventions administered by medical professionals, the percentage of sustained quitters ranges from 7% to 24% [4–6].

Reviews of the cost-effectiveness of smoking cessation interventions [7–9] show that the costs of these interventions are relatively low compared with the resulting gains in terms of avoided mortality, morbidity, and costs of care for smoking-related diseases. Costs per life-year gained varied between about 200€ and 10,000€ when converted into Dutch currency using purchasing power parity rates [10] and updated to the year 2000 with consumer price indices. The majority of studies reported cost-effectiveness ratios around 2500€ per life-year gained [7–9,11–23]. These figures should be interpreted very carefully, because the transfer of results from economic studies between countries is diffi-

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cult. None of these studies included savings in costs of care from avoided smoking-related morbidity or took account of the fact that former smokers may restart smoking after more than 12 months of continuous abstinence.

The present study aims to examine cost-effectiveness for a specific set of smoking cessation interventions, i.e., face-to-face smoking cessation interventions administered by professionals with proven effectiveness in terms of cessation rates. Five different cessation interventions (i.e., minimal counseling by a general practitioner (GP) with, or without nicotine replacement therapy (NRT), intensive counseling with NRT, or bupropion, and telephone counseling) were compared with current practice to report cost-effectiveness ratios for different implementation periods. The selection of interventions was driven by the fact that the study was initiated by the Dutch Public–Private Partnership to reduce tobacco dependence to support them in developing Dutch smoking cessation guidelines for healthcare professionals. Therefore, we selected interventions that are currently applied in The Netherlands. A computer simulation model was used to project the future gains in life-years, QALYs, and the savings in health-care costs that result from a decrease in the incidence of smoking-related diseases, over a time horizon of 75 years. The strength of the model is that it is dynamic, allowing us to apply increased cessation rates on a repetitive basis to a population whose mix of age, sex, and smoking prevalence changes annually.

Methods

Smoking Cessation Interventions

This study focused on face-to-face smoking cessation interventions, administered by medical professionals or educated smoking cessation counselors. They had to have a proven effectiveness in terms of cessation rates from international meta-analyses [4–7] or Dutch trial data [24,25] and had to be currently available in The Netherlands. Based on these criteria, the following smoking cessation interventions were analyzed:

1. MC: Minimal counseling by a GP and/or a GP-assistant in one or two consultations with a total length of 12 minutes [24,26].
2. MC + NRT: Minimal GP counseling in combination with nicotine patches or gum (NRT) for a period of 8 weeks [5].
3. IC + NRT: Intensive counseling by a trained counselor in combination with NRT for a period of 12 weeks. We assumed the counseling would be performed by a trained lung nurse for a total of 90 minutes plus a 2-minute stop advice from a lung physician [5,27].
4. IC + Bupr: Intensive counseling by a trained lung nurse, plus a 2-minute stop advice by a lung specialist in combination with bupropion for a period of 9 weeks [4,27].
5. TC: Telephone counseling as currently provided by the Dutch Foundation on Smoking and Health (STIVORO), consisting of one intake call of 30 minutes and 6 follow-up calls, each lasting up to 15 minutes, based on a (computerized) questionnaire completed by the potential quitters [6,25,28].

The impact of different intervention scenarios on the future costs and the gain in life-years and QALYs were studied. All scenarios were compared with current practice. The intervention scenarios assumed an increased implementation of one of the five smoking cessation interventions for a period of 1, 10, or 75 years. The interventions were assumed to reach 25% of the smokers each year. This percentage was based on the percentage of smokers in the preparation state (ready to make a serious attempt at quitting), which has been estimated at 26% [29,30].

Current Practice

Current practice was defined as the mix of all current initiatives to stop smoking, including the above-mentioned five interventions, and will power alone. The estimated current use of the five selected interventions in The Netherlands is shown in Table 1. For example, 0.36% for MC means that currently 0.36 per 100 smokers in The Netherlands receive minimal counseling by the GP. Annually, about 1.3% of smokers used one of the five selected interventions.

In the chronic disease model, prevalence rates of current and former smokers among the Dutch population by sex and 5-year age class were based on yearly population monitoring studies of STIVORO between 1997 and 2000 [28,31–34]. Start, cessation, and restart rates in the current practice scenario were estimated for each 5-year age and sex class from 10 to 14 years of age to the age class more than 85 years. These estimates were based on STIVORO data (1998–1999) [32,33] and three Dutch cohort studies [35–37]. Men start smoking between 10 and 29 years of age and women between 10 and 24 years of age. Start rates in other age categories were zero. The cessation rates approximate 12-month continuous abstinence

Table 1 Percentage of smokers that used the smoking cessation interventions as a percentage of the total number of smokers in The Netherlands in 2000 (4.5 million) [44]

Intervention	Percentage of smokers using the intervention	Data to estimate the percentage of smokers using the intervention
TC	0.026	In 2001, 1.2 thousand smokers were reached by telephone counseling at STIVORO [28]
MC	0.36	30% of the GPs provided minimal GP counseling [63]
		76% of the Dutch population contacted their GP at least once a year [44]
		The average number of contacts for minimal GP counseling was estimated at 0.75 per week per GP, of which roughly 71% was a first consultation [64]
		35% of the GPs provided minimal counseling without advice to use NRT [64]
MC + NRT	0.66	65% of the GPs often to always advised to use NRT in combination with minimal counseling [64]
IC + NRT	0.16	27% of the lung physicians provided intensive counseling [65]
		The average number of contacts for counseling by a lung physician was estimated at 3.1 per week per physician [65]
		52% of the lung physicians often to always advised to use NRT in combination with intensive counseling [65]
IC + Bupr	0.14	48% of the lung physicians often to always advised to use bupropion in combination with intensive counseling [65]

IC + Bupr, intensive counseling combined with bupropion; IC + NRT, intensive counseling combined with nicotine patches or gum; MC, minimal GP counseling; MC + NRT, minimal GP counseling combined with nicotine patches or gum; TC, telephone counseling.

rates. They increased with age from 0.007 in women aged 10 to 14 years to 0.051 in women aged 70 years and older, and from 0.007 in men aged 10 to 14 years to 0.049 in men aged 60 years and older. The average smoking cessation rate of the current practice scenario across all age groups and sexes was 0.034 or 3.4%. Restart rates in the model reflect former smokers starting to smoke again after having been abstinent in the previous year. Restart rates rise with age to a maximum of 0.099 for men aged between 40 and 44 years and a maximum of 0.114 for women aged between 40 and 44 years, after which they fall by age. By assumption, no relapse exists among men older than 74 years and women older than 79 years. The average restart rate was 0.042.

Intervention Scenarios

Effectiveness in terms of cessation rates was expressed as 12 months prolonged abstinence rates. These rates were obtained from randomized controlled trials as included in Cochrane meta-analyses [4–6] and from Dutch trials [24,25], which were summarized in a review by Willemsen et al. [38]. In calculating these rates, participants with missing follow-up data were treated as smokers. Table 2 lists these abstinence rates for the different smoking cessation interventions. These rates were not age-specific. To compute age- and sex-specific cessation rates for the intervention scenarios, for each intervention, the ratio of its abstinence rate and the average current practice cessation rate of 3.4% were calculated. For example, the ratio of MC and current practice is 7.9/3.4, which is about 2.3. Then, the age- and sex-specific current practice cessation rates were multiplied by this ratio. During the increased implementation period of either 1, 10, or 75 years, 25% of all smokers were given the smoking cessation intervention and had increased cessation rates and 75% kept current practice cessation

Table 2 Twelve months continuous abstinence rates for current practice and for the different smoking cessation interventions with 95% confidence intervals for the sensitivity analyses

Intervention	Abstinence rate (%)	95% CI*	Ratio of intervention abstinence rate to CP abstinence rate	Source
CP	3.4			STIVORO data and three Dutch cohort studies [28,31–37]
TC	7.6	6.9–8.3	2.2	9 international RCTs [6,38] and 1 Dutch evaluation study [25]
MC	7.9†	4.7–11.1	2.3	1 Dutch randomized controlled trial [24]
MC + NRT	12.7	11.9–13.5	3.7	17 international RCTs [5,38]
IC + NRT	15.1	14.1–16.1	4.4	26 international RCTs [5,38]
IC + Bupr	17.2	14.0–20.4	5.1	4 international RCTs [4,38]

*For the sensitivity analyses.

†Cessation rate in trial: 8.2%. 9% used minimal GP counseling in combination with nicotine gum; cessation rate for minimal GP counseling only: $8.2 - (0.09 \times 11.0) / 0.91 = 7.9\%$.

CP, current practice; IC + Bupr, intensive counseling combined with bupropion; IC + NRT, intensive counseling combined with nicotine patches or gum; MC, minimal GP counseling; MC + NRT, minimal GP counseling combined with nicotine patches or gum; TC, telephone counseling.

rates. This percentage was kept constant at 25% of smokers in each year during the implementation period. After the implementation period the cessation rates returned to current practice levels. Start and restart rates in the intervention scenarios were equal to current practice start and restart rates.

Intervention Costs

We have calculated direct health-care costs from a societal perspective, indicating that these direct cost estimates were based on estimates of real resource use. We have not included productivity costs. All costs were expressed in euros, for the start year 2000. Table 3 presents the calculated costs of the different smoking cessation interventions. For current practice, resource use was based on Dutch empirical data [24,26–28,39,40]. For the intervention scenarios, resource use was based on practice guidelines, and, for the duration of pharmaceutical therapies, on the original international trials underlying the effectiveness data. Thus, the costs of an "optimal" implementation of the smoking cessation interventions consistent with the effectiveness figures were estimated. For the unit costs of minimal GP counseling, we used the standard cost of a GP consultation from the Dutch manual for costing in economic evaluations [41]. This standard cost included overhead and costs of assistants. We assumed that one GP consultation lasts 10 minutes and calculated costs per minute. Material costs for self-help manuals were added separately [24,26]. For the pharmaceutical costs in the intervention scenarios, we used average costs per defined daily dose (DDD) based on data from the Dutch Foundation for Pharmaceutical Statistics [39]. Costs of adverse effects were assumed to be negligible [42]. For

Table 3 Cost per smoker of the components of smoking cessation interventions for the current practice scenario and for the intervention scenarios (euros, year 2000 price level)

Intervention		Current practice scenario Volume	Unit price	Total cost per quit attempt
TC	Counselor time (min)	60	0.58*	**35**
MC	GP time (min)	6.5	1.70	11
	Self-help manuals	1	1	1
	Total			**12**
MC + NRT	GP time (min)	6.5	1.70*	11
	Self-help manuals	1	1	1
	Prescriptions NRT	1.6	20	32
	Total			**44**
IC + NRT	Chest physician time (min)	2	3.3*	7
	Lung nurse time (min)	110	1.9*	204
	Prescriptions NRT	1.6	20	32
	Total			**243**
IC + Bupr	Chest physician time (min)	2	3.3	7
	Lung nurse time (min)	110	1.9	204
	Prescriptions Bupr	1.5	47	71
	Total			**282**
Intervention		Increased intervention scenarios Volume (min–max)†	Unit price	Total cost per quit attempt
TC	Counselor time (min)	120 (90–150)	0.58	**70**
MC	GP time (min)	12 (3–12)	1.70	20
	Self-help manuals	1	1	1
	Total			**21**
MC + NRT	GP time (min)	12 (3–12)	1.70	20
	Self-help manuals	1	1	1
	DDDs NRT‡	65 (49–141)	2.18§	142
	Total			**163**
IC + NRT	Chest physician time (min)	2	3.3	7
	Lung nurse time (min)	90 (40–110)	1.9	167
	DDDs NRT‡	80 (70–93)	2.18§	175
	Total			**349**
IC + Bupr	Chest physician time (min)	2	3.3	7
	Lung nurse time (min)	90 (40–110)	1.9	167
	DDDs Bupr¶	63 (49–84)	2.53§	160
	Total			**334**

*Including overhead.
†For the sensitivity analyses.
‡One DDD equals 14 mg for patches; one DDD equals 30 mg for gum.
§Total price, including a mark-up of 5.67€ to cover pharmacist fees.
¶One DDD equals 300 mg for bupropion.
IC + Bupr, intensive counseling combined with bupropion; IC + NRT, intensive counseling combined with nicotine patches or gum; MC, minimal GP counseling; MC + NRT, minimal GP counseling combined with nicotine patches or gum; min, minutes; TC, telephone counseling.

intensive counseling and telephone counseling, the salary of a counselor (respiratory nurse, or trained telephone counselor, respectively) per unit of time was used. The salary costs included material costs and overhead [28]. In addition, the standard costs of a lung physician consultation [41] were used to find the costs of a 2-minute stop advice. Material costs for self-help manuals were added separately [27]. Minimum and maximum estimates of resource use were used in the sensitivity analyses.

In current practice, the estimated intervention costs per quit attempt were 12€ for minimal GP counseling, 44€ for minimal GP counseling with NRT, 243€ for intensive counseling with NRT, 282€ for intensive counseling with bupropion, and 35€ for telephone counseling. For the intervention scenarios, the intervention costs were estimated to be 21€, 163€, 349€, 334€, and 70€, respectively.

For each of the five interventions, intervention costs in the current practice scenario were calculated as the number of smokers times the proportion currently using the intervention times the current practice costs per quit attempt. For example, for MC in the year 2000 this is 4.5 million times 0.36% times 12€. Intervention costs in the intervention scenarios were calculated as the number of smokers times the 25% of smokers that get the intervention times the costs per quit attempt of an "optimal" use of the intervention. For example, for MC in the year 2000 this is 4.5 million times 25% times 21€. The difference between those two calculations was the additional intervention costs. Costs of other interventions than the five that were studied were assumed to remain unchanged.

Model and Input Data

We simulated changes in smoking prevalence rates and the resulting changes in incidence rates of smoking-related chronic diseases, using the Chronic Disease Model [43] that was developed at the National Institute of Public Health and the Environment (RIVM) in Bilthoven, The Netherlands. This dynamic multistate life table model describes the life course of parallel Dutch population cohorts annually over time. The model basically consists of a demographic module that is linked to several disease-specific modules. In contrast with models that follow a cohort of people over time and report the impact of a one-time application of a smoking cessation intervention on morbidity and mortality, the Chronic Disease Model is a dynamic population model. It models yearly changes from aging, birth, migration and mortality based on data from Statistics Netherlands [44]. The prevalence of smoking is not stable either, because the transitions between the three smoking classes of never, current, and former smokers are modeled annually. The net annual cessation rate depends on the changing mix, influenced by interventions and by demographic trends. The disease-specific modules are epidemiological models of risk factor-specific incidence, prevalence, and mortality of several chronic diseases. When estimating mortality, the model takes account of competing death risks, combining the results from the various disease-specific modules with the demographic module. The model has Markov properties. This means that, conditional on sex, age, and risk factor class (never, current, and former smoker), the health states 1 year ahead are independent of the past health states. This implies, for example, that the probability to quit smoking does not depend on the duration of smoking, i.e., within an age and sex group, people have the same probability to quit smoking. The model is further based on the assumption of conditional independence, i.e., conditional on the risk factor class, disease incidence and mortality rates are assumed to be mutually independent. This implies, for example, that given age and sex, the probability for a smoking chronic obstructive pulmonary disease (COPD) patient to get lung cancer is the same as the probability for a smoking person without COPD. Nevertheless, because there are more smokers and former smokers among COPD patients than among non-COPD patients, an average COPD patient has a higher risk of getting lung cancer and, consequently, a higher risk of dying of it. The model was described in more detail elsewhere [43,45,46] and has previously been used to evaluate the effects of hypothetical smoking cessation scenarios [47–50]. Reference [47] contains an online appendix with mathematical details on the model. The current article is the first time the model is used to assess the cost-effectiveness of smoking cessation interventions.

We simulated the effects of increased smoking cessation rates on changes in smoking prevalence and the resulting changes in incidence, prevalence, mortality, and costs of 11 smoking-related diseases, i.e., coronary heart disease (myocardial infarction and other coronary heart disease), stroke, COPD, lung cancer, larynx cancer, oral cavity cancer, esophagus cancer, pancreas cancer, bladder cancer, and kidney cancer. We chose 2000 as the start year of the simulations; Table 4 summarizes the input data for the 11 smoking-related diseases. This comprises data on the incidence, prevalence, and mortality rates of the diseases [45,46], risk ratios for

Table 4 Incidence rates, risk ratios for incidence for current and former smokers and quality-of-life weights of 11 smoking-related diseases, stratified by sex

Disease	Incidence rates (per 1000) [45,46]		Risk ratios for incidence for current and former smokers* [52]				Quality-of-life weights [51,52]	
			Current smokers		Former smokers			
	Women	Men	Women	Men	Women	Men	Women	Men
Acute myocardial infarction	1.7	3.2	3.2	2.9	1.3	1.6	0.71	0.71
Coronary heart disease	2.2	3.1	3.2	2.9	1.3	1.6	0.71	0.71
Stroke	2.3	2.0	3.8	3.3	1.4	1.3	0.39	0.39
COPD	1.4	2.4	11.8	13.1	7.9	10.7	0.69	0.69
Lung cancer	0.23	1.0	14.2	26.8	4.5	10.6	0.57	0.57
Larynx cancer	0.014	0.083	17.8	10.5	11.9	5.2	0.88	0.88
Oral cavity cancer	0.058	0.12	5.6	27.5	2.9	8.8	0.88	0.88
Esophagus cancer	0.042	0.091	10.3	7.6	3.2	5.8	0.27	0.27
Pancreas cancer	0.088	0.092	2.3	2.1	1.8	1.1	0.44	0.49
Bladder cancer	0.065	0.22	1.9	2.9	1.9	2.6	0.89	0.91
Kidney cancer	0.078	0.11	2.0	3.0	1.9	2.1	0.62	0.76

*Never smokers are reference (risk ratios equal 1).

incidence for current and former smokers, and quality of life weights for life-years with these diseases [51,52]. For example, one life-year with lung cancer is equal to 0.57 QALY. Conditional on smoking status, the model calculated the risk of having two smoking-related diseases. To do so, it multiplied age-, sex-, and smoking class-specific prevalence rates. It was further assumed that the quality-of-life weight for a combination of diseases was equal to the worst quality-of-life weight of one of these diseases. Health-care costs for these diseases were obtained from a Dutch cost-of-illness study that allocated total direct costs of health care using a top-down approach [53]. These 11 diseases accounted for 9% of the total costs of health care in The Netherlands in 1999.

Cost-Effectiveness

The additional intervention costs of the intervention scenarios were calculated as the difference in intervention costs between these scenarios and current practice. To calculate net costs, the savings from avoided smoking-related diseases were subtracted from the additional intervention costs. These net costs were divided by the gain in life-years or QALYs to find the costs per life-year or QALY gained. Future costs and effects were discounted at the Dutch standard annual percentage of 4% [54]. The time horizon was 75 years.

Sensitivity Analysis

A series of one-way sensitivity analyses was carried out to investigate the robustness of the cost-effectiveness ratios with regard to variations in cessation rates, intervention costs, discount rates, time horizon, and the percentage of smokers reached by the intervention. Cessation rates were varied by their 95%-confidence limits (see Table 2). Intervention costs were varied from minimum to maximum estimates of resource use (see Table 3). Discount rates on costs and effects of 0%, 3%, and 5% were used, and a discount rate of 4% for costs combined with 0% for effects. The percentage of smokers that was offered the intervention was varied, from 10% to 50% of all smokers. Finally, results were computed for time horizons of 20, 30, and 50 years.

Results

For each intervention applied to a population of 1000 smokers, Table 5 presents the total number of extra quitters, additional intervention costs as well as costs per quitter, compared with the 34 quitters that would be obtained in current practice. Costs per quitter ranged from about 450€ for minimal GP counseling to about 3000€ for intensive counseling with nicotine patches or gum.

Table 6 shows the model estimates of health effects and health-care costs for the Dutch population when the smoking cessation interventions were offered for a period of 1, 10, and 75 years. The table presents in the first two columns cumulative discounted health effects, first the extra life-years gained from a reduced mortality and second the extra QALYs gained. The third column gives the net present value of intervention costs. Combining these, the fourth and the fifth column present intervention costs per life-year and QALY gained, respectively. The sixth column then gives the savings in health-care costs from a reduced prevalence of smoking related diseases. Finally, the last two columns present the cost-effectiveness ratios in terms of costs per life-year or QALY gained.

Table 5 Number of additional quitters, total additional intervention costs, and costs per quitter for the intervention scenarios compared with the current practice scenario for a group of 1000 smokers (euros, year 2000 price level)

Intervention	Additional quitters*	Additional intervention costs† (×1000)	Costs per quitter
TC	42	69	1640
MC	45	20	450
MC + NRT	93	162	1750
IC + NRT	117	348	2970
IC + Bupr	138	333	2410

*Compared with 34 quitters for the current practice scenario.
†Compared with intervention costs of 1130€ for the current practice scenario.
IC + Bupr, intensive counseling combined with bupropion; IC + NRT, intensive counseling combined with nicotine patches or gum; MC, minimal GP counseling; MC + NRT, minimal GP counseling combined with nicotine patches or gum; TC, telephone counseling.

Minimal GP counseling was a dominant strategy compared with current practice, regardless of the implementation period. For minimal GP counseling about 330,000 life-years or 410,000 QALYs were gained with a 75 years implementation period. About 1.4€ billion in health-care costs for smoking-related diseases were saved and these savings were higher than the intervention costs of about 520€ million. The four other interventions yielded higher costs than savings and cost-effectiveness ratios that ranged from 1100€ per QALY for telephone counseling to 4900€ for intensive counseling with NRT. For a 75-year implementation period, the absolute gain in life-years and QALYs and the savings in costs for not having to treat smoking-related diseases were highest, but the intervention costs were also highest. The 1- and 10-year intervention scenarios showed lower total intervention costs as well as lower savings, gains in life-years, and QALYs than permanent implementation. The cost-effectiveness ratios were not very much affected by the duration of the implementation period.

Effects and Costs over Time

The current practice scenario projected a decline in smoking. The percentage of smokers in the Dutch population aged 10 years and older decreased from 32% in 2000 to 25% in 2075. Smoking prevalence increased in older women, but decreased in men of

Table 6 Number of life-years and QALYs gained, total additional intervention costs, intervention costs per LY and QALY gained, total savings in costs of care and cost-effectiveness: costs per life-years gained and costs per QALY gained for the different scenarios cumulative for three different time periods, discounted at 4% for both costs and effects (euros, year 2000 price level)

Intervention	LYs gained* (×10⁴)	QALYs gained† (×10⁴)	Intervention costs‡ (×10⁹)	Intervention costs per LY gained	Intervention costs per QALY gained	Savings of treatment for diseases§ (×10⁹)	Costs per LY gained	Costs per QALY gained
1-year implementation								
TC	1.2	1.6	0.077	6,200	4800	0.053	2000	1500
MC	1.4	1.7	0.023	1,700	1300	0.057	¶	¶
MC+NRT	2.8	3.6	0.18	6,500	5000	0.12	2300	1700
IC+NRT	3.5	4.5	0.39	11,000	8500	0.15	6800	5200
IC+Bupr	4.1	5.3	0.37	8,900	6900	0.17	4700	3600
10-year implementation								
TC	11	14	0.64	5,800	4500	0.46	1600	1200
MC	12	15	0.19	1,600	1300	0.50	¶	¶
MC + NRT	23	30	1.4	6,200	4800	0.98	1900	1500
IC + NRT	29	37	3.0	10,500	8100	1.2	6300	4900
IC + Bupr.	33	43	2.8	8,600	6600	1.4	4400	3400
Permanent implementation								
TC	31	38	1.7	5,700	4600	1.3	1400	1100
MC	33	41	0.52	1,600	1300	1.4	¶	¶
MC + NRT	62	78	3.8	6,100	4800	2.7	1800	1400
IC + NRT	74	94	7.8	10,500	8300	3.2	6200	4900
IC + Bupr	84	110	7.3	8,600	6800	3.6	4300	3400

*Compared with a cumulative total of 412×10^6 life-years from the current practice scenario.
†Compared with a cumulative total of 392×10^6 QALYs from the current practice scenario.
‡Compared with cumulative costs of continued current practice of $120€ \times 10^6$.
§Compared with cumulative costs of care of $142€ \times 10^9$ from the current practice scenario.
¶Minimal GP counseling dominated current practice, due to savings and higher effects.
IC + Bupr, intensive counseling combined with bupropion; IC + NRT, intensive counseling combined with nicotine patches or gum; LYs, life-years; MC, minimal GP counseling; MC + NRT, minimal GP counseling combined with nicotine patches or gum; QALYs, quality-adjusted life-years; TC, telephone counseling.

all ages and in young women. For the youngest age groups of both men and women, the decline was quite small. For the intervention scenarios reaching 25% of the smokers, the percentage of smokers declined to 21% in 2075 for permanent implementation of intensive counseling with bupropion at maximum. For the intervention scenarios of 1- and 10-year implementation periods, effects on the number of smokers gradually disappeared after the intervention stopped because of relapse and new young smokers, and the percentage of smokers in 2075 was 25%, the same as in the current practice scenario. In all scenarios, a lag time between an increased implementation of smoking cessation interventions and the full gain in life-years and QALYs could be observed. After implementation, first the number of quitters increases, decreasing the number of smokers and increasing the number of former smokers. This leads to a reduced incidence of smoking-related diseases and hence a reduced prevalence. In turn, that causes a reduced mortality. Reduced mortality is counted as life-years gained. The combined reduction in prevalence and mortality gives the QALY gain. For 1- and 10-year implementation periods, reductions in mortality reach a top, about 15 and 20 years after implementation, respectively, then the gain compared with current practice declines again, to nearly zero, about 65 years after implementation, so that the full gain is obtained within the model's time horizon.

Sensitivity Analysis

Figure 1 depicts the uncertainty in resource use and effectiveness. It presents gains in total costs, including savings from reductions in the incidence of 11 smoking-related diseases, and QALYs plus uncertainty ranges over resource use and cessation rates, for permanent (i.e., 75 years) implementation of the smoking cessation interventions compared with current practice. Changes in cessation rates led not only to changes in QALYs gained but also to changes in the incidence of smoking-related diseases and hence to changes in total additional costs. This explains why the horizontal confidence lines in Figure 1 were not completely horizontal, but slightly diagonal. The relatively large uncertainty about the effectiveness of minimal GP counseling was reflected by the relatively wide horizontal uncertainty range. Nevertheless, the result that minimal GP counseling is a cost-saving intervention was robust for uncertainties in resource use and effects. The figure shows that uncertainty ranges overlapped, so that the dominance of intensive counseling with bupropion over intensive counseling with NRT was quite uncertain, while that of minimal GP counseling over telephone counseling was also uncertain. Besides, because of the large uncertainty range in costs, it might well be that minimal counseling with NRT was also dominated by either intensive counseling with NRT or intensive counseling with bupropion. Cost-effectiveness ratios became more favorable when the time horizon increased, so that more of the gains were included. Minimal GP counseling was dominant for all time horizons considered. For intensive counseling with bupropion, costs per QALY gained ranged from about 13,000€ for a time horizon of 20 years to 3900€ for a time horizon of 50 years, compared with 3400€ for a time horizon of 75 years. Cost-effectiveness ratios were not sensitive to changes in the percentage of smokers that was offered the intervention, which ranged from 10% to 50% of all smokers. Table 7 shows incremental cost-effectiveness ratios for different discount rates for costs and effects, compared with current practice, for 75-year intervention scenarios. Discounting clearly affected

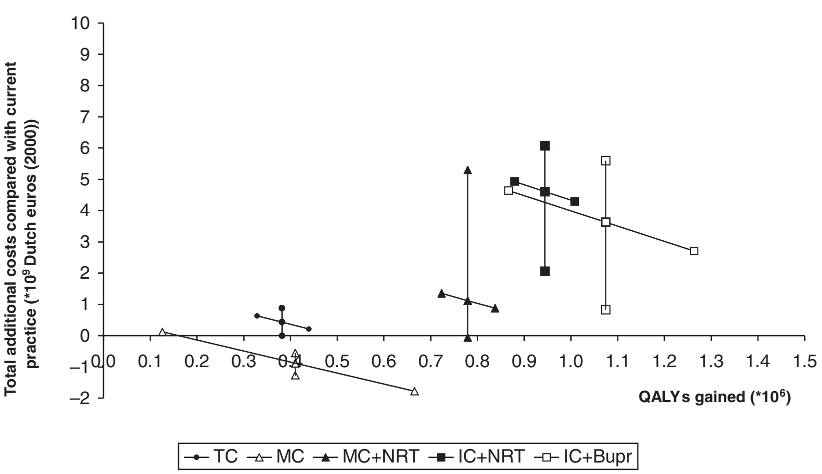

Figure 1 Total additional costs and total quality-adjusted life-years (QALYs) gained for the intervention scenarios compared with current practice with the range in costs and effects based on the sensitivity analyses, cumulative for the years 2000–2075. TC, telephone counseling; MC, minimal GP counseling; MC + NRT, minimal GP counseling combined with nicotine patches or gum; IC + NRT, intensive counseling combined with nicotine patches or gum; IC + Bupr, intensive counseling combined with bupropion.

Table 7 Incremental costs per QALY gained for the intervention scenarios for different discount rates for both costs and effects, cumulative for the time period 2000–2075 (euros, year 2000 price level)

	Costs per QALY for different discount rates			
Intervention	Discount rate for costs and effects 3%	Discount rate for costs and effects 5%	Discount rate for costs 4% and for effects 0%	Discount rate for costs and effects 0%
TC	720	1600	240	10
MC	*	*	*	*
MC + NRT	990	2000	310	210
IC + NRT	4000	5900	1,000	2,300
IC + Bupr	2700	4200	730	1,400

*Minimal GP counseling dominated current practice, due to savings and higher effects.
IC + Bupr, intensive counseling combined with bupropion; IC + NRT, intensive counseling combined with nicotine patches or gum; MC, minimal GP counseling; MC + NRT, minimal GP counseling combined with nicotine patches or gum; QALY, quality-adjusted life-year; TC, telephone counseling.

the cost-effectiveness ratios, reducing the impact of both future savings in health-care costs and future health effects. To illustrate the effect of discounting, a life-year gained 75 years from now weights for full if health effects are not discounted, while it weights for 0.11, 0.053, or 0.026 if health effects are discounted at 3%, 4%, or 5%, respectively. Because health effects occur with a delay, while intervention costs start immediately, the effect of higher discount rates will be that the net present values of health effects, and related savings in health-care costs decrease, while the net present value of intervention costs decreases much less. As a result, cost-effectiveness ratios become worse as the discount rate increases.

Discussion and Conclusions

In conclusion, when assessing the cost-effectiveness of five face-to-face smoking cessation interventions, we found that minimal GP counseling was cost-saving compared with current practice, whereas the cost-effectiveness ratios of minimal counseling plus nicotine replacement therapy, intensive counseling with nicotine replacement therapy, intensive counseling with bupropion, and telephone counseling were quite small. Implementation of these interventions on a permanent basis for 25% of all smokers resulted in estimated cost-effectiveness ratios that ranged from 1400€ per life-year or 1100€ per QALY gained for telephone counseling to 6200€ per life-year or 4900€ per QALY gained for intensive counseling in combination with NRT.

The cost-effectiveness ratios were sensitive to the rate of discount, the time horizon, resource use estimates, and cessation rates. Nevertheless, the cost-effectiveness ratios remained rather low for the variations in the discount rate, time horizon, cessation rates, and resource use that were analyzed in the sensitivity analyses. The ratios did not vary much with the percentage of smokers reached or the length of the implementation period.

For several reasons the ratios above were conservative estimates of the cost-effectiveness. The effects of smoking cessation on the course of diseases were not included, nor were the effects of passive smoking and the effects of smoking cessation by pregnant women on the health of their future infants.

Furthermore, savings from reduced productivity losses were not included. Finally, it should be noted that a large part of the future effects of the intervention efforts during the last 15 to 20 years of the permanent implementation scenario were not taken into account, because these health gains occurred outside the model's time horizon of 75 years. For the 1- and 10-year implementation scenarios, all health gains occurred within the time horizon, and this bias was avoided.

In contrast, three reasons why our results may overestimate cost-effectiveness ratios must be mentioned. First, the estimates of effectiveness were obtained from clinical trials. If trial populations were a selection of motivated smokers, our cessation rates would be too high. This applies in particular to the more intensive interventions but less to minimal GP counseling with, or without NRT, and telephone counseling, because for the latter interventions, trials were often done in an unselected group of smoking GP patients. The second is that the model did not include a delay effect of smoking cessation, i.e., all quitters received the lower relative risks of disease incidence of former smokers the year after quitting. However, the estimates of the relative risks in our model were conservative. Relative risks of former smokers were estimated as an average of the relative risks of all former smokers regardless of how long ago they had stopped. This implies that for the first years after quitting the reduction in relative risk in our model was too high, while for later years it was too low. Third, in contrast with most cost-effectiveness analyses of smoking cessation, we took savings of avoided smoking-related diseases into account. Health-care costs unrelated to smoking in life-years gained from smoking cessation, for instance, costs of care for dementia, were ignored in our computations. Whether or not costs of care for diseases not related to smoking (so-called unrelated medical costs) that occur during added years of life should be included in cost-effectiveness analyses is a topic of discussion in the literature [55–57]. The current convention in economic evaluation is to ignore unrelated medical costs. Indeed, textbooks and guidelines [54,55] recommend the exclusion of medical costs during life-years gained, unless there is a causal relationship between the intervention and these costs. It was recently argued that it is theoretically more sound to include the survivor costs (i.e., general costs of care that occur during the added years of life) if they present resources that directly produce the utility that is being measured in the denominator of the cost-effectiveness ratio [56]. In practice, most cost-effectiveness analyses exclude unrelated costs of care, partly for reasons of data availability. Given current guidelines and to enable comparison with other cost-effectiveness analyses, in the present study these unrelated medical costs were also excluded.

To have very conservative estimates of the cost-effectiveness ratios, we also computed the ratio of intervention costs to the difference in QALYs or life-years, and presented them in Table 6. Intervention costs per life-year gained varied from about 1,600€ for minimal GP counseling to 10,500€ for intensive counseling combined with NRT for 75-year implementation periods.

Our study differs from other cost-effectiveness analyses of smoking cessation, because we used a dynamic population model. We did not model a closed cohort of smokers until their death, as most studies do [14,16,19,23,58], but estimated effects for the Dutch population. The model included relapse after 12 months continuous abstinence and inflow of new young smokers. Not all smokers who quit in the 1-year scenario would remain nonsmokers for the whole time horizon. This led to higher cost-effectiveness ratios than would be obtained if restart rates were ignored. In addition, the model takes account of the demographic changes in the population and the changes in incidence and prevalence of the risk factor of smoking and the smoking-related diseases.

Furthermore, we could model 10- and 75-year implementation periods and compare these to a 1-year implementation. Our finding that the implementation period did not much affect the cost-effectiveness ratios was partly influenced by the simplifications that had to be made to keep the model tractable and use reliable input data. Cessation rates were assumed constant over time, and smokers, as well as former smokers, were modeled as homogeneous groups with average age- and sex-specific cessation rates and restart rates, respectively, ignoring smokers' individual quit and relapse history. If cessation and restart rates would depend on the number of previous quit attempts, this would influence the outcomes in longer implementation periods. Inclusion of this, however, would strongly complicate the model, while reliable input data were not available.

Despite the methodological differences, our cost-effectiveness ratios were within the range of values found in the literature. Converting all outcomes into Dutch currency for the year 2000, values in the literature varied from 200€ to 10,000€ per life-year gained [8,9,12–23]. Our result that costs per life-year gained of intensive counseling with bupropion were more favorable than those of intensive counseling with NRT was in line with former research [7,9,11].

Comparing the results for the five interventions to each other, two interventions were relatively cheap: minimal GP counseling and telephone counseling. But they were also less effective than the other interventions. The effectiveness of minimal GP counseling was based on a single Dutch trial [24]. This was reflected by the large uncertainty range. We choose this trial instead of a Cochrane meta-analysis on physician counseling [59], because we felt that the 11 studies on minimal counseling included in the meta-analysis did not sufficiently reflect the Dutch minimal GP counseling. The finding that minimal GP counseling is cost-saving, however, was robust. Two other interventions, intensive counseling combined with either NRT or bupropion were more expensive, but they were also more effective. Although their cost-effectiveness ratios were higher than the ratios of minimal GP counseling and telephone counseling, they remained low. For these interventions, costs were more difficult to estimate, because of variations in the duration and intensity of counseling and the duration of NRT use. The costs of one intervention, minimal GP counseling combined with NRT, fell in between. However, its costs were highly uncertain, resulting in an uncertainty range that goes from slight cost savings up to high additional costs. This was in line with results from the Cochrane meta-analysis [5] that stated that the added effect of NRT to low intensity counseling was hard to prove. The trials included in this meta-analysis showed a high variance in the duration of NRT, mainly because of differences in compliance.

The cost-effectiveness ratios, even for the most resource intensive cessation interventions were well below many other commonly recommended medical and surgical interventions. This highlights the cost-effectiveness of smoking cessation interventions, which affects many smoking-related diseases.

How favorable the cost-effectiveness ratios are can be demonstrated by comparing them with other preventive interventions. For example, the Dutch 1998 cholesterol guidelines advise to reimburse cholesterol-lowering therapy up to approximately 20,000€ per QALY [60,61]. The cost-effectiveness of smoking cessation is roughly within the same range as the cost-effectiveness of breast cancer screening in The Netherlands (4000€ per life-year gained) and the cost-effectiveness of the Dutch influenza vaccination program for the elderly (1800€ per life-year gained) [62].

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