The Role of Public Policies in Reducing Smoking
The Minnesota SimSmoke Tobacco Policy Model

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Background: Following the landmark lawsuit and settlement with the tobacco industry, Minnesota pursued the implementation of stricter tobacco control policies, including tax increases, mass media campaigns, smokefree air laws, and cessation treatment policies. Modeling is used to examine policy effects on smoking prevalence and smoking-attributable deaths.

Purpose: To estimate the effect of tobacco control policies in Minnesota on smoking prevalence and smoking-attributable deaths using the SimSmoke simulation model.

Methods: Minnesota data starting in 1993 are applied to SimSmoke, a simulation model used to examine the effect of tobacco control policies over time on smoking initiation and cessation. Upon validating the model against smoking prevalence, SimSmoke is used to distinguish the effect of policies implemented since 1993 on smoking prevalence. Using standard attribution methods, SimSmoke also estimates deaths averted as a result of the policies.

Results: SimSmoke predicts smoking prevalence accurately between 1993 and 2011. Since 1993, a relative reduction in smoking rates of 29% by 2011 and of 41% by 2041 can be attributed to tobacco control policies, mainly tax increases, smokefree air laws, media campaigns, and cessation treatment programs. Moreover, 48,000 smoking-attributable deaths will be averted by 2041.

Conclusions: Minnesota SimSmoke demonstrates that tobacco control policies, especially taxes, have substantially reduced smoking prevalence and smoking-attributable deaths. Taxes, smokefree air laws, mass media, cessation treatment policies, and youth-access enforcement contributed to the decline in prevalence and deaths averted, with the strongest component being taxes. With stronger policies, for example, increasing cigarette taxes to $4.00 per pack, Minnesota's smoking rate could be reduced by another 13%, and 7200 deaths could be averted by 2041.
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Introduction

During the past 35 years, Minnesota has played a major role in U.S. tobacco control. In 1975, Minnesota became the first state to pass a statewide law that limited indoor smoking in most public places.[1] This ground-breaking law set the stage for future tobacco control at the state level.[2] Ten years later, the Minnesota Department of Health launched the first state-funded tobacco control program with a portion of the cigarette tax proceeds.[3] In 1994, the state of Minnesota and Blue Cross Blue Shield of Minnesota filed a lawsuit against cigarette manufactures and related trade associations accusing them of failing to disclose information about the dangers and addictive qualities of cigarettes. The 1998 settlement of that lawsuit provided funds to the state health department and Blue Cross Blue Shield of Minnesota. In addition, a separate nonprofit organization, ClearWay Minnesota[SM], was established with a mission to create programs and services (QUITPLAN®) to reduce the harm caused by tobacco in Minnesota.

By 2001, almost all Minnesota residents had tobacco-cessation treatment covered as an insurance benefit by their health plans or, if they lacked insurance, quitline counseling, and cessation medication were covered by ClearWay Minnesota. Around the same time, statewide mass media campaigns began promoting ClearWay Minnesota services. In 2007, a comprehensive statewide

smokefree law was passed. Minnesota has consistently spent above average on tobacco control relative to other states.[4] In addition, at $1.58 per pack in 2011, Minnesota was ranked in the top half of states for cigarette taxes.[5]

The purpose of this paper is to estimate the effect of tobacco control policies in Minnesota on smoking prevalence and smoking-attributable deaths using the SimSmoke simulation model. SimSmoke simultaneously considers a broader array of public policies than other models[6] and has been validated in other states[7–9] and countries.[10,11] Specifically, both the impact of past policies and the potential impact of additional policy changes on smoking prevalence and smoking-attributable deaths are estimated.

Methods

SimSmoke[12,13] projects smoking prevalence and smoking-attributable deaths over time and estimates the effect of tobacco control policies on those rates. A discrete time, first-order Markov process is employed to project future population growth through fertility and deaths, and to project smoking rates through smoking initiation, cessation, and relapse.

SimSmoke begins in the baseline year 1993, with the population divided into current, never, and former smokers and distinguished by age and gender (because of the different smoking patterns). The baseline year was chosen because a large-scale survey was available for that year and policies were stable.

Population and Smoking Model

Minnesota population data and U.S. birth rates by age and gender were obtained for 1993.[14] Mortality rates[15] by age and gender were averaged from 1999 to 2005.

Baseline estimates of smoking status by age and gender for Minnesota were obtained from the 1992/1993 Tobacco Use Supplement (TUS) of the state-representative Current Population Survey.[16] Smokers are defined as individuals who had smoked more than 100 cigarettes in their lifetime and were currently smoking either daily or on some days. Former smokers (distinguished by years since quit) have smoked 100 lifetime cigarettes but were not currently smoking, and never smokers were those who had not smoked 100 cigarettes in their lifetime.

Because of empirical challenges in measuring initiation and cessation and in order to ensure internal consistency, net initiation rates for each age were measured as the difference between the 1993 smoking prevalence at that age and the rate at the previous age. Because prevalence continued to rise until age 24, initiation in the model occurs through age 24. Quit rates were obtained from the 1992–1993 TUS, measured as those who quit in the last year as a percentage of smokers 1 year ago. Previously published literature[17,18] were used for relapse rates, which were distinguished by age, gender, and years quit.

Death rates by age, gender, and smoking status were calculated from death rates, smoking rates, and relative risks. The number of current and former smokers at each age was multiplied by their respective excess risk and summed to obtain total smoking-attributable deaths. Assuming that relative risks in Minnesota are similar to the U.S., total mortality relative risk estimates for current and former smokers were taken from the U.S. Cancer Prevention Study II.[19,20]

Policy Specifications

The policy effect parameters were based on reviews of the literature and the advice of an expert panel, updated to reflect Minnesota studies. The size of policy effects are assessed in terms of relative (percentage) reductions applied to smoking prevalence in the year the policy was implemented, and applied to initiation and cessation rates in future years unless otherwise specified. The model allows for synergies between media campaigns and other policies, but otherwise assumes that the effect of a second policy is reduced by 1 minus the effect of the first policy if another policy is simultaneously implemented. Table 1 summarizes policies and effect sizes.

The effect of implementing a new policy in SimSmoke depends on the prior level of that policy, so that the level of policies for each year is required. Data on policy levels were inputted for the years 1993 through 2011.

Taxes. Minnesota applies taxes and fees on cigarettes at the wholesale level on a per unit basis, that is, the number of cigarettes sold. The 2011 state cigarette taxes and fees were $1.58 and consisted of an excise tax ($0.48); a health-impact fee ($0.75); and a tax in lieu of general sales tax ($0.35). Although a small number of cigarette brands (generics) manufactured by companies who were not part of the lawsuit settlement pay an additional $0.35 per pack fee, $1.58 was used as the tax rate. Minnesota prices (1993–2011) were measured by a retail price index weighted by brand sales that includes generic cigarettes,[21] and deflated using the consumer price index. Prices rose slowly from 1993 to 1997, before increasing following the national tobacco settlement in 1998, and in 2005 following a $0.75 state health-impact fee, and in 2009 following a $0.62 federal tax.

Smokefree policies. SimSmoke models restrictions in worksites, restaurants, bars, and other public places, and associated compliance.[22] Prior to the statewide smoking ban (1993 to 2007), Minnesota is considered to have had weak smokefree policies, because there were only limited restrictions in some public places (retail stores, supermarkets, and transit).[23] In 2000, the first Minnesota town passed a smokefree restaurant ordinance. By 2007, five counties and ten cities had enacted ordinances representing about 38% of the state population. In 2007, a comprehensive state law was enacted, which banned smoking in all workplaces, including bars and restaurants. The 2010 Minnesota Adult Tobacco Survey (MATS)[24] found at least one exposure to smoke in the last 7 days occurred for 34% of the population in the community at large and for 9% of the Minnesota population at work. Based on exposure from this and earlier MATS surveys, compliance is set at 50% in 1993, increasing to 70% in 2007, and to 80% since 2008.

Mass media/tobacco control expenditures. A comprehensive statewide media campaign with spending of $10–$12 million was launched in 1998, with an initial focus on youth,[25] but shifting to cessation in 2001. Per capita expenditures were less than $1.00 per capita from 1993 to 1999, increasing to $2.00 per capita in 2000, and at about $6.00 through 2003, and falling to $3.50–$4.00 per capita from 2004 to the present.[4,23] Minnesota was classified as having a low-intensity campaign from 1993 through 1999, increasing to a high-intensity campaign in 2000 and maintained at a medium to high-intensity campaign from 2004 through 2011.

Cessation treatment policies. Soon after the 1998 lawsuit settlement, cessation treatment was provided both through health plan quitlines and QUITPLAN Services (funded by ClearWay Minnesota). The QUITPLAN Helpline began in

Table 1. Policy inputs and effect sizes for Minnesota SimSmoke

Policy	Description	Potential percentage effect[a]
Cigarette taxes		
Cigarette price	The state-level average price for a pack of cigarettes (including branded and generic), including state and federal excise taxes	For each 10% price increase: 6% reduction ages 15–17 years, 3% reduction ages 18–24 years, 2% reduction ages 25–34 years, and 1% reduction ages ≥35 years
Well-enforced and publicized smokefree air laws		
Worksite ban, well-enforced	Smoking banned in all indoor worksites in all areas	6% reduction
Worksite restrictions, weak	Smoking in restricted areas only	2% reduction
Restaurant and bar ban, well enforced	Ban in all indoor restaurants in all areas	3% reduction
Restaurant ban, weak	Smoking in restricted areas only	0.5% reduction
Other places bans	Ban in three of four (government buildings, retail stores, public transportation, and elevators)	1% reduction
Enforcement and publicity	Compliance reflecting norms and government agencies to enforce and publicize the laws	Effect size reduced by 50% if no compliance or publicity[b]
Mass media campaigns		
Highly publicized media campaign	Campaign expenditures meeting the pre-2009 CDC minimum recommended	6% reduction
Moderately publicized media campaign	Campaign expenditures meeting 50% of the pre-2009 minimum recommended	3.6% reduction
Low-publicity media campaign	Campaign expenditures meeting 25% of the pre-2009 minimum recommended	1.2% reduction
Cessation treatment programs		
Comprehensive cessation treatment	A proactive quitline with nicotine replacement therapy, complete treatment coverage through insurance	~4% reduction, 40% effect on quit rates[c]
Youth-access restrictions		
Strongly enforced and publicized	Compliance checks are conducted four times per year per outlet, penalties are potent and enforced, and with heavy publicity and community involvement	20% reduction for those aged 16–17 years and 30% reduction for those aged <16 years
Low enforcement	Compliance checks are conducted sporadically, penalties are weak, and there is little merchant awareness and minimal community participation	2.5% reduction

[a]Unless otherwise specified, the same percentage effect is applied as a percentage reduction in the prevalence in the initial year and as a percentage reduction in initiation rate and a percentage increase in the cessation rate in future years, and is applied to all ages and both genders. The effect sizes are shown relative to the absence of any policy.
[b]Enforcement is measured in terms of compliance, and publicity is based on the media campaign variable.
[c]Effects prevalence and first-year quit rates only

2001, and nicotine replacement therapy (NRT) was made available to the uninsured through the Helpline in 2002.[26,27] Quit success and reach were at the high end of state quitline studies.[28] Full treatment coverage was effectively available to 10% of smokers in 1996, increasing to 50% in 1998. By 2003, with the exception of approximately 10% of residents with insurance but no affordable access to cessation medications, all Minnesotans had access to comprehensive cessation through ClearWay Minnesota services and private health plans.

Youth-access laws. Enforcement of youth-access laws in Minnesota was low from 1993 to 1996 and increased to a high level in 1997, where it remained until 2011.[23] Minnesota has implemented mild vending machines restrictions in 1996 considered to have 25%

of the effect of a complete ban, increasing to the current level of 50% in 1997.

Calibration, Validation, and the Effect of Tobacco Control Policies

To calibrate SimSmoke, predictions of smoking prevalence by age and gender were compared to corresponding estimates from the CPS–TUS data for 1996 and 1999. Based on those comparisons, the first year cessation rate net of relapse was adjusted downward for ages 24–35, but upward for ages ≥55 years.

To validate the model, SimSmoke predictions were compared to smoking rates from the TUS (1992–1993, 1995–1996, 1998–1999, 2001–2002, 2002–2003, and 2006–2007 surveys), and the MATS (1999, 2003, 2007, 2010).[29] Because rates from the different surveys may reflect their methodology, percentage changes in the rates over time were compared.

To examine the effect of individual and combined policies, the counterfactual scenario of no-policies was first programmed by setting all policies between 1998 and 2011 to their 1993 levels. The difference between predictions of this scenario and predictions with actual policies provides an estimate of the net reduction in smoking prevalence due to all policies implemented since 1993. The contribution of individual policies implemented since 1993 relative to the predicted decline in smoking rates and smoking-attributable deaths from all policies were estimated by examining the effect of implementing each policy relative to the counterfactual. The contribution of a policy is estimated relative to the summed effect of all policies, because the effect of individual policies are interrelated and thus do not sum to the effect of simultaneously implemented policies.
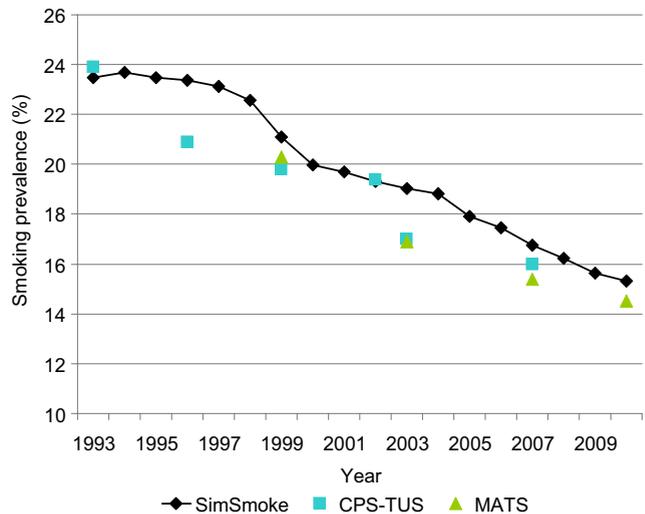
Results

Validation

Smoking prevalence (ages ≥18 years) from SimSmoke and the TUS and MATS are presented in Figures 1 and 2 for men and women, respectively. For both genders,
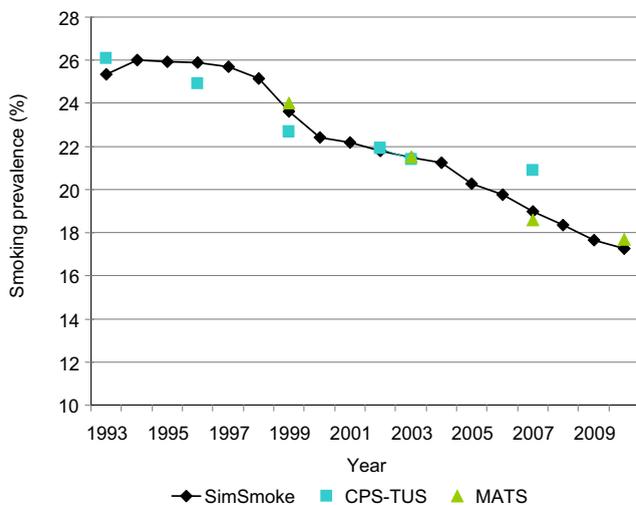
Figure 1. Male smoking prevalence, SimSmoke predictions versus surveys, Minnesota, 1993–2010
CPS-TUS, Current Population Survey-Tobacco Use Supplement; MATS, Minnesota Adult Tobacco Survey

Figure 2. Female smoking prevalence, SimSmoke predictions versus surveys, Minnesota, 1993–2010
CPS-TUS, Current Population Survey-Tobacco Use Supplement; MATS, Minnesota Adult Tobacco Survey

smoking prevalence, as projected by SimSmoke, remained relatively constant from 1993 to 1997, then declined sharply beginning in 1998 with the steep price increase and implementation of a stronger tobacco control campaign. Another more rapid decline is seen following the $0.75 health-impact fee imposed in 2005 and with the 2007 state smokefree air law.

Validation is conducted from the year 1993 to 2010. From 1993 to 2002, SimSmoke predicts a decline to 14.1% for men compared to 16.1% from the TUS and 17.8% for women compared to 18.8% from the TUS. SimSmoke predicts less well compared to the TUS over the 2002–2007 period and by subperiods and age group (data not shown). SimSmoke performs better compared to MATS, which has a larger sample than the TUS. From 1999 to 2010, SimSmoke predicts a reduction for men of 26.9% compared to 26.3% from MATS, and for women of 27.4% compared to 28.6% from MATS. However, SimSmoke under-predicts the reduction for ages 18–24 years (24.0% vs 37.5% from MATS for men and 22.1% vs 34.9% for women), but over-predicts the reduction for men aged 25–44 (33.7% vs 20%). Predictions are close for women aged 25–44 years (29.9% vs 27.5%) and for ages 45–64 years, men (22.7% vs 27.5%) and women (29.4% vs 24.5%).

The Effect of Past Policies

Tables 2 and 3 present smoking prevalence and smoking-attributable deaths for the status quo (with actual policies in place) and the counterfactual policy scenarios. With the policies implemented after 1993, the 2011 male prevalence was 28.3% lower and the 2011 female prevalence 29.1% lower relative to the counterfactual with all policies held constant at their 1993 level. By 2041, the relative

Table 2. Minnesota SimSmoke predictions of smoking prevalence with policies implemented by 2011 and policies at 1993 levels, %

	1993	1997	2002	2007	2011	2021	2031	2041
MEN								
Smoking prevalence with:								
All policies implemented	25.4	25.7	21.8	19.0	17.0	14.1	12.1	11.1
Policies at 1993 level	25.4	25.8	25.1	24.4	23.7	21.4	19.6	18.8
Percentage prevalence reduction[a] with:								
All policies	—	−0.4	−13.1	−22.1	−28.3	−34.1	−38.3	−41.0
Price only	—	−0.4	−5.2	−9.0	−13.5	−16.4	−19.4	−21.3
Smokefree air only	—	0.0	0.0	−4.6	−6.3	−6.9	−7.5	−7.9
Tobacco campaign only	—	0.0	−6.3	−6.2	−6.2	−5.3	−4.6	−4.0
Cessation treatment only	—	0.0	−1.2	−2.9	−3.8	−4.7	−4.6	−4.8
Youth access only	—	0.0	−0.7	−1.5	−2.2	−3.4	−4.8	−6.1
WOMEN								
Smoking prevalence with:								
All policies implemented	23.5	23.2	19.3	16.8	15.1	13.1	11.6	10.8
Policies at 1993 level	23.5	23.2	22.4	21.8	21.3	20.0	18.8	18.2
Percentage prevalence reduction[a] with:								
All policies	—	−0.1	−13.7	−23.1	−29.1	−34.7	−38.3	−40.7
Price only	—	0.0	−5.8	−9.6	−13.6	−17.0	−19.1	−20.9
Smokefree air only	—	0.0	−0.2	−4.6	−6.1	−7.1	−7.6	−8.2
Tobacco campaign only	—	0.0	−6.7	−6.4	−5.6	−5.0	−4.3	−4.4
Cessation treatment only	—	0.0	−1.3	−2.8	−3.3	−5.0	−5.3	−6.0
Youth access only	—	0.0	−0.7	−1.4	−1.8	−3.0	−3.7	−4.5

[a]Percentage prevalence reduction calculated as the difference in the smoking prevalence with policies at their 1993 level and the smoking prevalence with all policies or a subset of policies implemented divided by the smoking prevalence with policies at their 1993 levels

reduction from the implemented policies reached 41.0% for men and 40.7% for women. With the implemented policies in place, SimSmoke predicted 5932 (3864 male and 2068 female) smoking-attributable deaths in 2011. Under the counterfactual of no new policies since 1993, there were an estimated 6515 smoking-attributable deaths in 2011. With the difference in deaths attributed to the implemented policies, 583 fewer smoking-attributable deaths (376 male and 207 female) were estimated for 2011. Cumulatively, the policies implemented between 1993 and 2011 were estimated to avert 2898 (1875 male and 1023 female) deaths between 1993 and 2011. By 2041, 47,687 deaths (29,989 male and 17,698 female) will be averted.

Effect of Individual Policies

Inflation-adjusted cigarette prices were relatively constant between 1993 and 1997, and then increased through 2011. From increased prices alone, smoking rates were reduced 13.5% through 2011 and 21.1% by 2041. The cumulative deaths averted were 19,062 by 2041. From smokefree laws implemented between 2000 and 2008, smoking rates were 6.2% lower in 2011 and 8.0% lower in 2041, which is predicted to have averted 10,107 deaths by 2041. With a tobacco control media campaign already in effect in 1993 but at a relatively low level, the first major increase in expenditures occurred in 1999, leading to a smoking decline of 5.9% by 2011 and 4.2% by 2041, averting 12,026 deaths by 2041. From cessation treatment policies, smoking rates declined by 3.5% in 2011 and by 5.4% in 2041. A total of 4958 deaths were averted by 2041. The enforcement of youth-access laws reduced prevalence by 1.9% in 2011, because these laws affect only youth. By 2041, prevalence is reduced by 6.0% and 1075 deaths were averted.

Table 3. Minnesota SimSmoke estimates of smoking-attributable deaths and death averted with policies as implemented by 2011 and policies at 1993 levels, *n*

| | 1993 | 2011 | 2021 | 2031 | 2041 | Cumulative | |
						1993–2011	1993–2041
MEN							
Smoking-attributable deaths with:							
All policies implemented	3669	3864	4028	3641	2895	70,111	181,126
Policies at 1993 level	3669	4240	4878	4757	4056	71,985	211,115
Deaths averted[a]							
All policies	—	376	850	1116	1161	1,874	29,989
Price only	—	147	337	446	520	764	12,096
Smokefree air only	—	54	174	260	250	153	6,397
Tobacco campaign only	—	148	240	245	206	810	7,580
Cessation treatment only	—	55	165	233	230	249	5,864
Youth access only	—	2	12	31	68	4	795
WOMEN							
Smoking-attributable deaths with:							
All policies implemented	2075	2068	2233	2277	2025	38,311	104,409
Policies at 1993 level	2075	2275	2708	2940	2788	39,334	122,107
Deaths averted[a]							
All policies	—	207	475	663	763	1,023	17,698
Price only	—	86	189	251	316	459	6,966
Smokefree air only	—	27	95	151	168	78	3,709
Tobacco campaign only	—	80	132	147	145	438	4,446
essation treatment only	—	27	92	149	174	120	3,661
Youth access only	—	1	5	10	24	1	280

[a]Deaths averted calculated as the difference in smoking-attributable deaths with all policies at their 1993 levels and smoking-attributable deaths with all policies or a subset of policies implemented in the SimSmoke model

Figure 3 shows the relative contribution of each policy. Of the reduction in smoking prevalence (for both genders combined) because of tobacco control policies, price increases account for 43.4%, smokefree air laws for 19.9%, cessation treatment policies for 11.3%, youth-access enforcement for 6.3%, and media campaigns for 19.1%. By 2041 (data not shown), the role of price increased to 47.8% and youth access increased to 12%, both because of their relatively large effect on youth.

Discussion

Smoking rates in Minnesota have fallen more than 34% in relative terms since 1993. Allowing for trends in the absence of policy, SimSmoke indicates that policies played a major role in Minnesota's steep decline in smoking rates, leading to a 29% relative reduction between 1993 and 2011 and reaching a 41% reduction by 2041. About 43% of the reduction in prevalence is explained by price increases, with about 20% from smokefree air laws and mass media campaign spending, 6.5% from youth-access laws, and 11% from cessation treatment policies.

With no change in tobacco control policies, SimSmoke projects a reduction of cigarette smoking prevalence to 11.8% by 2030, less than proposed by the national objective of 12% by 2020. Although Minnesota's tobacco control policies are generally strong, there is room for improvement. For example, if state taxes and fees were increased by $2.40 to $4.00 per pack (2012 taxes are $1.60) and a high-intensity media campaign was sustained, smoking prevalence would drop to 12.0% by 2022 and to 9.5% by 2041, which is 13% below the projected level with current policies maintained. Further, a comprehensive
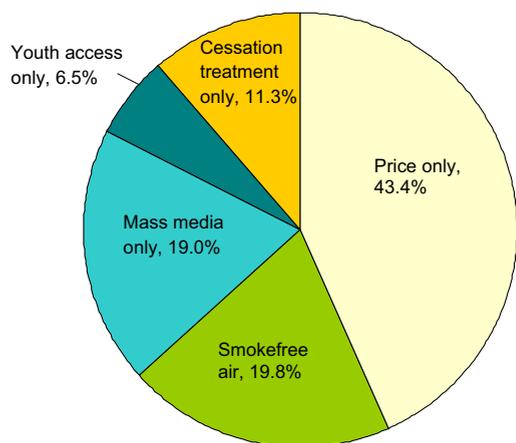
Figure 3. Contribution of each policy to the reduction of smoking prevalence in Minnesota from 1993 to 2011

cessation treatment program that incorporates involvement of the healthcare system and better follow-up could provide substantial additional gains.[28]

SimSmoke also estimates that more than 5900 people in Minnesota will die from smoking in 2011. Based on the policies already implemented since 1993, SimSmoke estimates that 2897 deaths were averted through 2011, increasing to 47,687 cumulative deaths averted by 2041. Increasing the state taxes and fees on cigarettes to $4.00 per pack and implementing a high-intensity campaign is projected to avert an additional 7210 smoking-attributable deaths by 2041. These figures do not include deaths from secondhand smoke or fires caused by smoking, nor the considerable excess medical costs and lost productivity associated with smoking-related health conditions.[30]

The model validated well for prevalence of ages ≥18 years by gender compared to the TUS for 1993–2002 and the MATS data for 1999–2010. The Behavioral Risk Factor Surveillance Survey for Minnesota indicated different trends than the TUS and MATS data. Although the different surveys conducted for Minnesota yield different trends, the MATS data employ the largest sample and seem to provide the most reliable estimates. Besides the validation conducted here, previous applications of SimSmoke to the U.S., Arizona, California, and Kentucky[7–9,13] data have accurately projected trends and turning points in population smoking rates, providing additional validation of the model's assumptions and parameters. Extending Minnesota SimSmoke with updated policy data and validating with new smoking prevalence data as they become available will allow for stronger trend analyses.

The SimSmoke results depend on a set of assumptions and on effect sizes derived from the literature. The impact that an array of tobacco control policies has on different sectors of the population can be exceedingly complex.

The strength of evidence for each of the policies varies.[31,32] The evidence for taxes and smokefree air policies are stronger than the evidence for tobacco control media campaigns, and the evidence for youth-access and cessation policies are weaker and less consistent. Knowledge about the synergistic effect of combined policies is especially limited. SimSmoke also does not explicitly model potential feedbacks through industry practices, social norms and attitudes, or peer and family behaviors.

Conclusion

SimSmoke estimates that tobacco control policies enacted in Minnesota will be responsible for reducing smoking prevalence by 41% and averting 48,000 deaths by 2041. All forms of policy (taxes and price, smokefree air laws, mass media, cessation treatment policies, and youth-access enforcement) contributed to this decline in prevalence and deaths averted, with the strongest component being price and taxes. Based on current trends, smoking rates of 13% are projected in 2020. To further drive down smoking rates and meet the Healthy People 2020 target of 12%, current tobacco policies will need to be continued and cigarette taxes increased.[33]

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