The Cost-Effectiveness of Raising the Legal Smoking Age in California

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Given evidence that most smokers start smoking before the age of 18 and that smokers who start earlier in life are less likely to quit, policies that reduce or delay initiation could have a large impact on public health. Raising the legal minimum purchase age of cigarettes to 21 may be an effective way for states to reduce youth smoking by making it harder for teens to buy cigarettes from stores and by reducing the number of legal buyers they encounter in their normal social circles. To inform the ongoing debate over this policy option in California, this study provides an evaluation of the cost-effectiveness of raising the state's legal smoking age to 21. Costs and benefits were estimated from a societal perspective using a dynamic computer simulation model that simulates changes to the California population in age, composition, and smoking behavior over time. Secondary data for model parameters were obtained from publicly available sources. Population health impacts were estimated in terms of smoking prevalence and the change in cumulative quality-adjusted life years (QALYs) to the California population over a 50-year period. Economic impacts were measured in monetary terms for medical cost savings, cost of law enforcement, and cost of checking identification. Compared to a status quo simulation, raising the smoking age to 21 would result in a drop in teen (ages 14–17) smoking prevalence from 13.3% to 2.4% (82% reduction). The policy would generate no net costs, in fact saving the state and its inhabitants a total of $24 billion over the next 50 years with a gain of 1.47 million QALYs compared to status quo. This research should prove useful to California's policy makers as they contemplate legislation to raise the state's legal smoking age. ***Key words:*** *adolescent smoking; prevention; tobacco-sales laws; youth access laws; smoking uptake; enforcement; cost-effectiveness; system dynamics.* ***(Med Decis Making 2005;25:330–340)***

California is currently considering legislation that would increase the state's legal smoking age from 18 to 21 years old.[1] Bill AB221, currently being debated in the state assembly, would prohibit the sale of all tobacco products to individuals under the age of 21. It would also require the State Department of Health Services to conduct random checks of tobacco outlets to ensure compliance.

If the bill passes, California would be the 1st state in the nation with a smoking age limit of 21. Other states such as Colorado,[2] Maine,[3] Massachusetts,[4] and North Dakota[5] have considered raising their legal age, but none has done so to date. Alabama, Alaska, and Utah have a legal smoking age of 19, and all other states have a legal age of 18.

Because no state has increased its legal smoking age to 21, there is no direct evidence of raising age limits on youth smoking. Advocates of the new law point to the burden of smoking: 1.8 million of today's youth in California will become regular smokers as adults, with 574,000 of them eventually dying of tobacco-related illness,[6] and the state's medical costs and productivity losses due to tobacco use exceed $13 billion annually.[7] Because approximately 90% of adult smokers begin smoking by 18 years of age,[8] it may be that targeting youth is the best way to reduce overall smoking prevalence in the long term. Tengs, Osgood, and Lin[9] demonstrated that the population health gains from preventing initiation in youth are likely to be 7 times greater than encouraging cessation among adults after they are already addicted to tobacco.

A key question is whether increasing the legal smoking age will be effective in curbing youth smoking. Cer-

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tainly, retailer compliance with the present law is imperfect and many youth under the age of 18 succeed in purchasing cigarettes from stores.[10] However, there is evidence that the ease with which minors are able to purchase cigarettes varies by age.[11]

Detractors argue that because youth obtain cigarettes from a variety of sources, tobacco regulation would not prevent smoking initiation in youth. It is important to consider that more than 80% of current underage cigarette acquisition is from sources other than stores.[10] In 2003, nearly a fourth of underage youth borrowed cigarettes from their peers. An additional 30% of underage smokers gave money to a peer to buy cigarettes for them. Seven percent of young people get cigarettes by stealing or from vending machines, and an increasing number acquire cigarettes via Internet Web sites. Although we expect acquisition through peers to drop dramatically due to the age gap between teenagers and 21-year-olds, some peer effects will most likely persist. Even with increased surveillance and enforcement, we will most likely see some increases in all these pathways as a result of raising the legal smoking age. Critics also cite that an individual state passing legislation may not result in significant effects on teenage consumption because of cross-border issues. In an interstate area, a youth can simply travel to a nearby state that maintains the lower age limit to purchase tobacco. California is generally not such an area, and we can expect this effect to be minor.

Perhaps the only historical evidence of the effectiveness of age restrictions in reducing drug use comes from studies of alcohol. Wagenaar and Toomey[12] reviewed 132 studies on alcohol use in youth in states where the legal drinking age was increased to 21. O'Malley and Wagenaar,[13] using data from the Monitoring the Future Survey, found that states that consistently had a drinking age limit of 21 from 1976 to 1987 had lower levels of youth drinking than states that had a legal age limit of 18 at some point during the same time period. Specifically, after controlling for other potential confounding factors, high school seniors in those states with an age limit of 18 had an 8.1% higher prevalence of alcohol use in the past 30 days. Smart and Goodstadt[14] found that states where the age limit was *reduced* from 21 to 18 showed an *increase* in the prevalence of drinking among youth. Tobacco differs from alcohol in numerous respects, including the ease with which it can be found in settings that youth frequent (convenience stores vs. bars and liquor stores), and possibly the balance of reasons for its consumption (addictive vs. social motives). However, this research does offer evidence that age limits have influenced patterns of use for one type of drug and may be effective for tobacco as well.

Although changing the legal smoking age is likely to prevent initiation in some youth, in others, it may simply delay initiation. This too would have population health implications because there is evidence that people who start smoking in their teens are more likely to become lifelong addicted smokers than those who start later in life.[8,15] Studies have shown that smoking is a long-term addiction. The median cessation age for those who start smoking as adolescents is 33 years for males and 37 years for females.[16] Moreover, smokers who initiate later in life are more likely to quit.[17] Increased enforcement of access laws may also help protect young adolescents from experimenting with cigarettes by strengthening societal antitobacco norms.[18]

Raising the legal smoking age may even be politically viable. In 2002, citizens interviewed in a national phone poll supported increasing the legal smoking age to 21 by nearly a 2 to 1 ratio.[19] In a California poll conducted in the same year, 58% of likely voters said that they would support such a policy. Interestingly, support for raising the legal smoking age cut evenly across political party lines, with 58.3% of Democrats and 58.0% of Republicans demonstrating support.[20]

Although substantial benefits may accrue in terms of improved population health, costs of implementation and enforcement will offset benefits to some degree. To help public officials to make informed decisions regarding tobacco policy, we assess the cost-effectiveness of raising the legal smoking age in California from 18 to 21 from a societal perspective.

METHODS

Model Overview

To estimate the cost-effectiveness of increasing California's legal smoking age, we developed a dynamic computer simulation model using software Vensim 5.1 from Ventana Systems Inc.[21] It is a flexible model that can be used to estimate the cost-effectiveness of any intervention or state/national policy that reduces tobacco use. The model schematic is shown in Figure 1. The model is described in more detail elsewhere[22,23] and thus it is described only briefly here.

We began by initializing the model with the number of people in the California population in the year 2003 from US Census estimates[24] and divided the population into cohorts according to age, gender, and smoking status (current, former, or never smoker).[7,25,26] The model then simulates annual transitions such as birth,

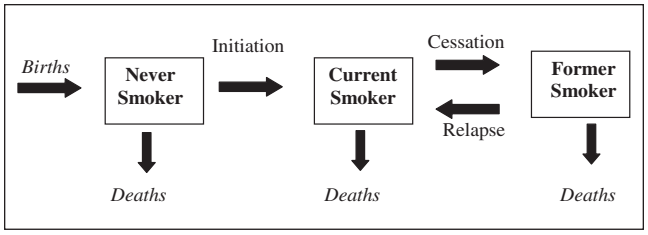

Figure 1 Model schematic.

death, aging, net migration, and changes in smoking behavior in the California population over 50 years.

Three types of smoking behavior change are simulated: initiation (the transition from being a never smoker to being a current smoker), cessation (current to former smoker), and relapse (former to current smoker). Data used to estimate annual behavior change probabilities (initiation, cessation, and relapse) were obtained from various sources[27–29] and vary by age and gender. Additionally, because of evidence that youth who start smoking later in life have an increased probability of subsequent cessation,[17] we adjusted cessation probabilities so that they also varied by age of initiation.

Over the course of 50 years, we simulated the removal of some members of the California population due to death and emigration and the addition of population members via birth and immigration. Mortality rates varied by age, gender,[30] and smoking status.[28] Fertility rates varied by age.[31] We obtained data on net migration, capturing both immigration into the state and emigration from the state, from the California Department of Finance.[32]

Calibration

The accuracy of the model was tested by a calibration process in which model results were compared against reliable external estimates of 1) total population size,[33] 2) current smoker prevalence,[34] and 3) life expectancy (by age, gender, and smoking status).[35,36]

The population calibration run began in 1995 and produced results very similar to external estimates in 2025 (46.35 million from the model to 46.04 million from external estimates) and 2050 (55.53 million from model, 54.78 million external). The adult smoking prevalence calibration ran from 1995 to 2003 and resulted in an estimate of 17.1%, almost identical to the external estimate. Simulated life expectancies, after some adjustments to mortality rate parameters in the model, corresponded closely with external estimates from actuarial projections. As an example, the model estimates that the average 45-year-old female current smoker would live an additional 33.94 years. This compares well with external life expectancy estimates of 33.89 years.

Cost Estimates

We incorporated 3 types of costs. These included the costs of enforcement, checking purchaser identification, and medical care. The costs associated with enforcing the new law include salaries for adult inspectors, underage shoppers, and supervisors as well as the expense of tracking inspection results, administering civil fines, handling legal challenges in court, liability insurance, transportation, and the maintenance of office space, equipment, and supplies. DiFranza and others[37] estimated that these costs would annually amount to $150 per retail outlet for an enforcement level of 4 annual inspections per outlet. Precise figures of the number of retail outlets selling tobacco in California were not available; following DiFranza's work, we estimated 2.2 outlets per 1000 population members or 73,700 outlets for the state of California. Currently, inspection levels are low at approximately 2000 inspections per year.[38] Rigorous enforcement would require that each of the 73,700 outlets would undergo 4 inspections annually for a total of 294,800 inspections per year. We use a discount rate of 3% to discount all costs. Using these figures, and after inflating inspection costs from 2001 to 2003 dollars, we estimate that the cumulative cost of rigorously enforcing a new age 21 law would be $311 million over 50 years.

Second, we included the costs incurred by retailers who would have to increase the frequency with which they check identification to verify age. To estimate the additional cost of ID checking due to increasing the legal smoking age to 21, a number of elements were assembled into a formula. We estimated that the average time to do an ID check was 15 s, and the average hourly wage for cashiers in California was $9.46 in 2001 dollars.[39] In this way, we calculated the cost of each ID check. To estimate the number of purchases that entail an additional ID check under a mandated legal smoking age of 21, the smokers were divided into 3 age groups. Packs per year consumed by each adult smoker (18 years and older) were estimated from Centers for Disease Control and Prevention data.[6] California's 2002 per capita cigarette consumption (for all adult residents, including smokers and nonsmokers) of 35.8 packs per adult was divided by the 2002 California adult smoking prevalence (16.4%) to estimate a cigarette consumption rate of 218 packs per adult smoker for the year. No single estimate of cigarette consumption among youth smokers (age 14 to 17) was available.

We assumed youth consumption at 50% of the adult consumption, arriving at a cigarette consumption rate of 109 packs per teen smoker per year. The percentage of store purchases for underage smokers was the US average of 18.9%[10] of total underage cigarette acquisition, which represents the additional checks at 100% enforcement. Current ID checks for 18 to 20 age group were assigned the arbitrary value of 50%, indicating 50% additional checks at 100% compliance when legal smoking age is raised to 21. The last age group, smokers between 21 and 24, was assumed to have no current ID checks, requiring additional checks for 100% of sales after implementation of raising the legal smoking age to 21. Underage individuals were assumed to purchase only single packs. Smokers age 18 to 20 were assumed to purchase 25% of cigarettes consumed in cartons and the remaining 75% in single packs. Smokers 21 and older were assumed to purchase half of the cigarettes consumed in cartons and the remaining half in single packs. The incremental cost of additional ID checks for all groups can be estimated by sequentially multiplying the age group population by the frequency of purchases, percentage of total purchases that received additional ID checks under the raised smoking age legislation, and the per check cost.

Third, we incorporated the costs of medical care into the model. Average medical costs for youth came from the Medical Expenditure Panel Survey. Medical costs for adults, by age group, gender, and smoking status, were obtained from Hodgson[40] who combined data from several sources. Hodgson identifies 4 categories of medical expenses, that is, 1) Medicare, 2) Medicaid, 3) out of pocket (direct costs), and 4) other private cost (insurance), and adds them to come up with total medical care costs. He obtained data on the costs of hospital and physician services from the National Health Interview Survey and information on nursing home expenditures from the National Nursing Home Survey and NHANES Epidemiologic Follow-up Study. He also used the National Medical Care Utilization and Expenditure Survey and Medicare data. As one example, Hodgson estimated that the average cumulative medical costs for male smokers over the age interval 55–65 was $20,420, whereas the costs for male never smokers of the same age were $9,830.

The method for determining the increase of medical cost over the simulated period was an autoregressive moving average model as introduced by Box and Jenkins.[41] We forecasted medical Consumer Price Index (CPI) and medical cost data and adjusted the medical cost data by the medical CPI to obtain all costs in 2003 U.S. dollars.

Health Outcomes

We measured gains in health with quality-adjusted life years (QALYs). The QALY measure, recommended by the US Task Force on Cost-Effectiveness in Health and Medicine,[42] combines improvements in length of life and health-related quality of life (QOL) into a single measure. For example, 10 years of life at 0.85 (or 85%) quality would result in 8.5 QALYs. Quality-of-life data for current, former, and never smokers by age group and gender were obtained from the Quality of Well Being (QWB) scale (RM Kaplan, personal communication, September 1999). The health-related quality of life values range between 0.94 and 0.66 for never, current, and former smokers (by age, group, and gender). Current smokers reported lower health-related quality of life than former smokers, who reported lower health-related quality of life than never smokers. For example, the QOL values for males in the 40 to 44 years of age group are 0.82, 0.88, and 0.90 for current, former, and never smokers, respectively. The QOL values for females in the same age group and smoking status are 0.83, 0.87, and 0.88, respectively. Health-related quality-of-life values decrease with increase in age.

Scenarios Simulated

Because California is among the 1st states in the United States to seriously discuss increasing the legal smoking age to 21, there is no direct evidence of the impact of changing the law on patterns of tobacco use. Consequently, we assumed that the legislation would affect smoking rates primarily through its impact on smoking initiation in youth, but we considered a range of plausible scenarios regarding the magnitude of this assumed impact.

In the 1st set of scenarios, depicted in Figure 2, we assumed that increasing the legal smoking age by 3 years, from 18 to 21, would have the effect of rendering underage youth 3 additional years from being legally able to smoke. To simulate this effect, we "shifted" the initiation distribution accordingly. That is, we assumed that following a change in the law, an 18-year-old would have the initiation rate of a 15-year-old, a 17-year-old would have the initiation rate of a 14-year-old, and so on. We assumed that adults age 21 and older would maintain their current initiation rates.

In a 2nd group of scenarios, we made a different assumption. Depicted in Figure 3, we assumed that, following a change in the law, the age- and gender-specific probability of smoking initiation would decrease by some percentage for those under the age of 21. We varied this percentage from 10% to 50%.

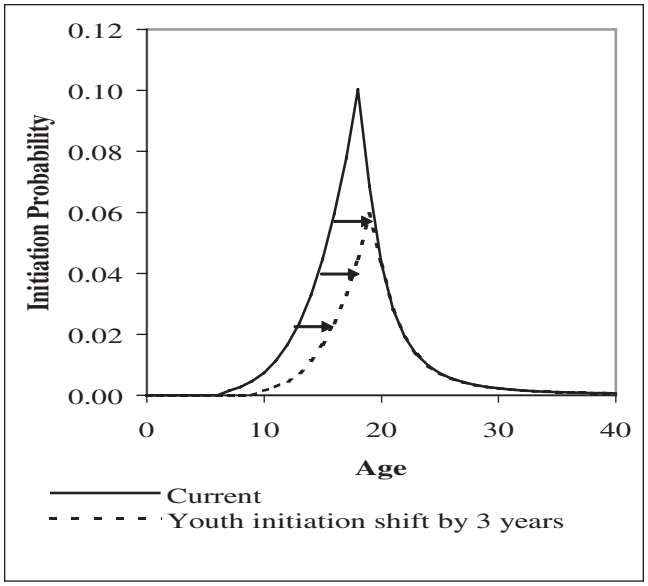

Figure 2 Initiation probability distribution assuming a 3-year shift after increasing the legal smoking age from 18 to 21.

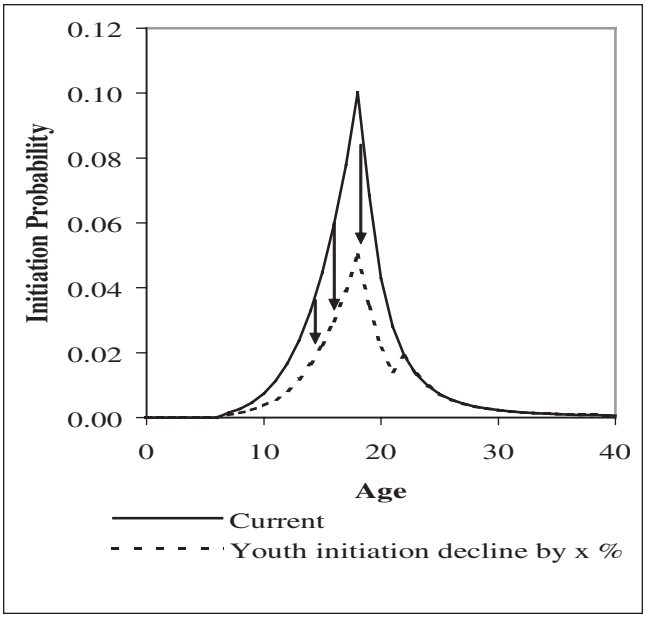

Figure 3 Initiation probability distribution assuming an x% decrease after increasing the legal smoking age from 18 to 21.

These 2 groups of scenarios are similar in that both assume that increasing the legal smoking age will affect smoking initiation rates in youth. Furthermore, both assume that decreasing smoking prevalence in youth will, as youth age, ultimately impact the prevalence of smoking among adults. This intergenerational impact occurs for 2 reasons. First, reducing initiation in youth will, as youth age, result in a decrease in smoking prevalence among adults. Second, for those youth who continue to smoke into adulthood, their probability of cessation will be higher if they started smoking later in life.

The 2 groups of scenarios differ, however, in the nature of the assumed impact. In the 1st group, the distribution of age-specific initiation probabilities is assumed to shift to the right, whereas in the 2nd group, the distribution is assumed to shift in the downward direction. Figures 2 and 3 portray these assumptions.

Using the baseline parameter estimates described above, we ran the simulation over a 50-year period. First, we ran the model assuming no change in the legal smoking age. Second, we ran the model assuming that the legal smoking age was increased to 19, 20, or 21. For each model run, we estimated the total cumulative costs and total cumulative QALYs that would accrue to the entire California population over that period. Costs and QALYs were discounted back to the present at 3% as recommended by the Panel on Cost-Effectiveness in Health and Medicine.[42] We then calculated the difference in cost and QALYs between the 2 model runs to estimate the incremental cost-effectiveness of increasing the legal smoking age.

RESULTS

Table 1 shows smoking prevalence estimates of our simulation model if the legal age remains 18 (status quo), and if the age limit is increased to 21, 20, or 19. The 1st 2 rows show the current prevalence in 2003 and the expected prevalence in 2053, under the status quo. If there is no increase in the legal smoking age in California, and there are no additional efforts to reduce smoking beyond the status quo, overall smoking prevalence is expected to remain fairly consistent at around 17% over 50 years. The difference in smoking prevalence estimates for 2003 and 2053 under the status quo scenario is the result of a dynamic interaction of several model variables that are changing over 50 years, for example, mortality, fertility, and net migration.

If the legal smoking age is increased to 21, and if that resulted in a 3-year shift in the probability of initiation, smoking prevalence is expected to decrease dramatically in all age groups. The percentage of youth ages 14 to 17 who smoke is likely to decrease to 2.4% from status quo prevalence levels of 13.3% in the same age group in 50 years, a substantial drop of 82%. The percentage of young adults ages 18 to 20 who smoke would decrease to 7.9% from status quo prevalence

Table 1 Estimated Prevalence of Smoking before and after Raising the Legal Smoking Age in California Given Alternate Age Limits and Assumptions about the Impact on Smoking Initiation

			Smoking Prevalence			
Age Limit	Year	Scenario Assumption	Ages 14–17 (%)	Ages 18–20 (%)	Ages 21+ (%)	All Ages (%)
18	2003	Status quo	15.4	16.8	16.7	16.6
18	2053	Status quo	13.3	17.3	17.0	16.4
21	2053	Initiation probability distribution shifted by 3 years	2.4	7.9	12.6	11.7
21	2053	Initiation probability decreased by:				
		10%	6.6	15.8	16.2	15.5
		30%	5.2	12.7	14.6	13.9
		50%	3.8	9.4	12.9	12.1
20	2053	Initiation probability distribution shifted by 2 years	3.5	10.5	13.9	13.0
20	2053	Initiation probability decreased by:				
		10%	6.6	15.9	16.3	15.6
		30%	5.2	12.9	14.9	14.1
		50%	3.8	9.7	13.4	12.5
19	2053	Initiation probability distribution shifted by 1 year	5.1	13.6	15.4	14.5
19	2053	Initiation probability decreased by:				
		10%	6.6	16.0	16.5	15.8
		30%	5.2	13.4	15.3	14.5
		50%	3.8	10.7	14.1	13.2

levels of 17.3% in 50 years. Adults over age 21 would also experience a decline in smoking prevalence over 50 years. Although 17% are expected to smoke with no change in the law, this will likely drop to 12.6% if the legal smoking age is increased to 21. We also simulated a scenario where increasing the legal smoking age to 21 may result in a 10% to 50% decline in the probability of initiation in those under age 21. This scenario also results in a decrease in smoking prevalence. For example, a 30% decline in probability of initiation results in decreasing the smoking prevalence from status quo levels of 13.3% among those in the 14 to 17 year age group to 5.2% and from 17.3% among those in the 18 to 20 year age group to 12.7%.

Also shown in Table 1 are smoking prevalence levels if the legal smoking age is increased not to 21 but to 20 or 19. Note that the declines in prevalence levels are relatively less, for example, if the legal smoking age is increased to 19, and if that resulted in a 1-year shift in the probability of initiation, smoking prevalence is expected to decrease in all age groups. We also considered if the legal smoking age were decreased to 20 or 19 and resulted in a 10% to 50% decline in the probability of initiation in those who would be under age. For example, with a 30% decline in the probability of initiation in youth under age 19 (vs. legal age remaining at 18), the smoking prevalence is reduced from 13.3% to 5.2% among those in the 14 to 17 year age group, from 17.3% to 13.4% for those in the 18 to 20 year age group, and from 17% to 15.3% among those 21 and older.

Table 2 shows cumulative cost and population health impacts over 50 years. The 1st row describes the results that might be anticipated with no change in the law. The following rows contain the expected outcomes assuming the legal smoking age is changed, under various assumptions about the nature and degree of impact on smoking initiation.

We estimate that if the current modest levels of enforcement continue for 50 years, the cumulative costs of enforcement, discounted back to the present at 3%, would be approximately $2 million. At present levels of retailer compliance, the cost of checking ID for the next 50 years would be $17 million. Cumulative medical costs for the entire California population are estimated to be $3,723,940 million. We estimate total costs,

Table 2 Cost-Effectiveness of Raising the Legal Smoking Age in California to 21 Given Alternate Assumptions about the Impact on Smoking Initiation (2003 US dollars)

Scenario Assumption	Cumulative Cost of Enforcement (millions)	Cumulative Cost of ID Checking (millions)	Cumulative Medical Costs (millions)	Total Cumulative Costs (millions)	Total Cumulative Life Years (millions)	Total Cumulative QALYs (millions)	Incremental Costs (compared with status quo) (millions)	Incremental Life Years (compared with status quo) (millions)	Incremental QALYs (compared with status quo) (millions)
Status quo	$2	$17	$3,723,940	$3,723,959	1231.22	1072.75	—	—	—
Initiation probability distribution shifted by 3 years (age 21)	$311	$39	$3,699,530	$3,699,880	1231.73	1074.22	–$24,079	0.51	1.47
Initiation probability distribution shifted by 2 years (age 20)	$311	$36	$3,706,540	$3,706,887	1231.58	1073.81	–$17,072	0.36	1.06
Initiation probability distribution shifted by 1 year (age 19)	$311	$32	$3,714,830	$3,715,173	1231.41	1073.31	–$8,786	0.19	0.56
Initiation probability decreased by (age 21):									
10%	$311	$60	$3,719,570	$3,719,941	1,231.31	1,073.01	–$4,017	0.09	0.26
30%	$311	$51	$3,710,490	$3,710,852	1,231.51	1,073.55	–$13,106	0.29	0.80
50%	$311	$42	$3,700,920	$3,701,273	1,231.71	1,074.11	–$22,686	0.49	1.36

Note: QALYs = quality-adjusted life years.

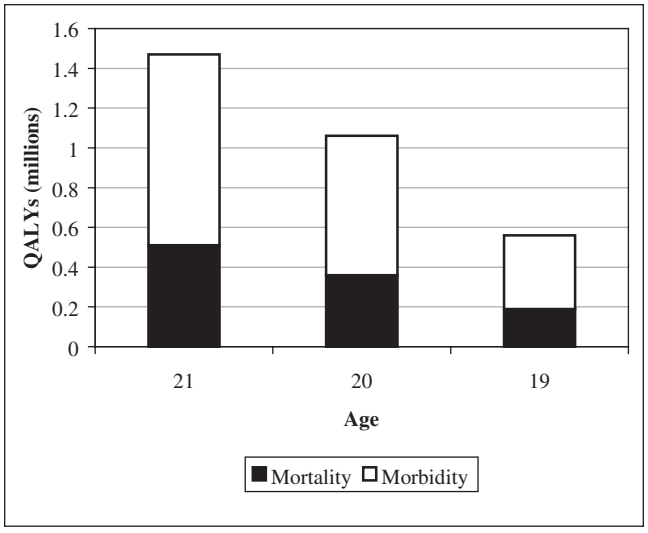

Figure 4 Cumulative gain in quality-adjusted life years (QALYs) by raising the legal smoking age to different levels, showing mortality and morbidity components.

the sum of enforcement, ID checking, and medical costs, at $3,723,959 million. With no change in the legal smoking age, the California population would accumulate approximately 1231 million life years and 1072 million QALYs over this time period.

Table 2 also shows that if the impact of raising the legal smoking age to 21 were to shift the smoking initiation probability distribution by 3 years, then the cumulative cost of more stringent enforcement would increase to $311 million. The cost of checking ID would increase to $39 million, and medical costs would decrease to $3,699,880 million. Relative to the status quo, increasing the legal smoking age to 21 would save $24,079 million. The new law would also result in an estimated gain of 0.51 million life years and 1.47 million QALYs, relative to the status quo. That means that not only would there be a gain in life years and QALYs but also significant cost savings. Figure 4 depicts the mortality and morbidity components of cumulative gain in QALYs resulting from raising the legal smoking age to different levels. It is clear that the morbidity component dominates.

We also estimated the health and economic impacts of increasing the legal smoking age to 19, or 20, compared to 21. For example, raising the age to 19 or 20 would result in cumulative cost savings of $8,786 and $17,072 million, respectively. Although a lower increase in age might be easier to pass through legislation, increasing the legal smoking age to 21 clearly offers the largest gains in QALYs and most cost savings compared to raising the legal smoking age to 20 or 19.

We also estimated the health and economic impacts of a decrease in the initiation probability by various percentages if the legal smoking age is raised to 21. Overall enforcement costs will be the same as under the previous assumption, but ID checking costs would change with the percentage change in smoking initiation. Although a 10% decrease in smoking initiation would only save $4,017 million over the estimated 50 years, a 50% decrease would save $22,686 million. A 30% reduction in initiation levels would save $13,106 million and would result in an estimated gain of 0.29 million life years and 0.80 million QALYs, relative to the status quo.

DISCUSSION

Results in Table 2 indicate that an increase in the legal smoking age to 21 years, compared to 19 or 20 years, will result in the largest decrease in smoking prevalence among teenagers. Note that the gain in QALYs is consistently larger than the gain in life years. Thus, reduction in smoking prevalence not only extends life but also increases the quality of life. Our results further show that smoking prevalence among smokers older than 21 years will also reduce.

Our model provides a relatively conservative estimate of reduction in smoking prevalence. We are only considering changes in initiation resulting from increasing the legal smoking age. Actual impacts might be increased cessation and reduced relapse among smokers who will become underage because of new legislation. If this is the case, we might be underestimating the health benefits and medical cost savings.

The simulation period used in our model is 50 years. Although this period is sufficient to discover the general trend of smoking prevalence among the population, some factors have to be considered when evaluating the results. The length of the simulation is important. A model with a shorter time horizon will not be able to fully capture the health impacts for the population who will not start smoking because of the change in legislation, resulting in reduced medical cost savings. A longer time horizon, such as 100 years, can cover life of an entire generation from birth to death, resulting in increased survival rates, QALYs, and medical cost savings.

This cost-effectiveness analysis is performed from a societal perspective. From Table 2, it is clear that medical cost savings dominate other costs incurred through enforcement or ID checking. Retailers incur the costs of checking ID. The state incurs costs on enforcement and realizes savings in reduced health care expenditures. Although a significant portion of the health care cost

savings will be realized by individuals and other private payers, the reduction in health care costs borne by the state (Medicaid, known in California as Medi-Cal) will still be much higher than the increase in enforcement costs. Hodgson[40] estimates that between 11% and 15% of total smoking-related medical care costs are borne by the state (Medi-Cal). This means that of the $24,079 million saved in the 3-year delay scenario, for example, the state of California saves between $2,649 and $3,612 million over the 50-year span. Medicare (accounting for less than 7% of smoking-related costs) would save up to $1686 million in the same scenario. Individuals' out-of-pocket smoking-related medical expenses (13% to 16% of the total) would drop by $3,130 to $3,853 million, and insurance companies and other private payers (bearing 70% to 72% of smoking-related costs) would save between $16,855 and $17,337 million.

Raising the legal smoking age to 21 may be among a few policy options that result in a gain in QALYs while saving costs. Even if we assume that there are no medical cost savings, the incremental cost per gained life year and QALY is estimated to be $686 and $238, respectively.

Throughout our analysis, we tried several scenarios of increasing the legal smoking age to 19, 20, and 21 years to assess which setting would offer the greatest benefits compared to costs. The decision to increase legal smoking age to 21 compared to 19 or 20 dominates throughout our analysis. Although enforcement and implementation costs are only minimally higher, increasing the legal smoking age to 21 years yields the greatest health benefits and largest cost savings.

Several caveats will aid the reader in interpreting our results. Mortality distributions in the model used for California population were derived from national datasets. If we assume that California is, on average, healthier than the rest of the nation, we would expect the actual mortality distributions to reflect a generally lower mortality in middle age and a higher mortality in later years, relative to the national average. Thus, actual reductions in mortality may be slightly less than model results.

Net migration rates are used in the model for the next 50 years. This estimate is uncertain, because migration predictions become increasingly unreliable over long periods of time. In addition, California migration is special because a large component is international. As such, California migration is very susceptible to changes in local economy and international events that are largely unpredictable.

Although limiting access will reduce the frequency with which underage individuals use tobacco, periodic access through social channels will still be possible. However, periodic access will not be sufficient for underage dependent smokers who need frequent use to maintain addiction. Those who are forced to quit may not relapse at normal rates because of limited access. Drops in initiation may be underestimated as well because the regular exposure required to produce addiction is no longer possible after age 21 implementation.

We compare a change in legal smoking age with a status quo scenario, where no change in tobacco use is expected to occur. We considered the alternative of simulating a modest decline in smoking prevalence under status quo. However, doing so would have made the model unnecessarily complex without improving the results. Because the same forces causing a modest decline under the status quo are likely to also be present following any change in legal smoking age, smoking prevalence would also decline at higher rates with the intervention. Thus, the incremental value of adding "raising the legal smoking age" is likely to remain largely unchanged if we had modeled declines under both scenarios. In the absence of good information about what the future will hold for smoking prevalence, whether use will decrease or increase, we assumed no change. Researchers have used the population dynamics model to predict the decline in smoking over a short period (e.g., from 1995 to 2002).[43] However, due to uncertainties involved, it is difficult to make predictions for a longer time horizon. For the reasons outlined above, our assumption that smoking prevalence will not change appreciably in the status quo condition allows us to present a clear baseline for comparing model outcomes and is unlikely to have an important effect on the results.

In this work, medical care cost dominates the analysis. Any change in health care policy in the future may significantly change the cost of tobacco-related diseases. Readers should be aware that although medical cost increases during the analysis period, the ratio of medical care expenses between smokers and nonsmokers remains the same throughout the analysis period.

We acknowledge that raising the legal smoking age to 21 may lead to the emergence of a black market. To deal with that, law enforcement efforts can be intensified, stricter penalties imposed, and cigarette packaging regulated so that smuggled cigarettes can be distinguished by law enforcement authorities. Of course, we recognize that even with these efforts, some level of "leakage" will always occur. It will be impossible to completely curtail the black market. However, even considering this negative side effect, important population health gains are likely to be realized. Raising the

legal smoking age will likely deter the use of this hazardous product among teenagers. Generations of youth will be discouraged from smoking, disease will be averted, and lives will be saved. These results should aid policy makers as they consider raising the legal smoking age in California.

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