

Special Article

ASSOCIATION OF THE CALIFORNIA TOBACCO CONTROL PROGRAM WITH DECLINES IN CIGARETTE CONSUMPTION AND MORTALITY FROM HEART DISEASE

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**ABSTRACT**

**Background** The California Tobacco Control Program, a large, aggressive antitobacco program implemented in 1989 and funded by a voter-enacted cigarette surtax, accelerated the decline in cigarette consumption and in the prevalence of smoking in California. Since the excess risk of heart disease falls rapidly after the cessation of smoking, we tested the hypothesis that this program was associated with lower rates of death from heart disease.

**Methods** Data on per capita cigarette consumption and age-adjusted rates of death from heart disease in California and the United States from 1980 to 1997 were fitted in multiple regression analyses. The regression analyses included the rates in the rest of the United States and variables that allowed for changes in the rates after 1988, when the tobacco-control program was approved, and after 1992, when the program was cut back.

**Results** Between 1989 and 1992, the rates of decline in per capita cigarette consumption and mortality from heart disease in California, relative to the rest of the United States, were significantly greater than the pre-1989 rates, by 2.72 packs per year per year ( $P=0.001$ ) and by 2.93 deaths per year per 100,000 population per year ( $P<0.001$ ). These rates of decline were reduced (by 2.05 packs per year per year [ $P=0.04$ ], and by 1.71 deaths per year per 100,000 population per year [ $P=0.03$ ]) when the program was cut back, beginning in 1992. Despite these problems, the program was associated with 33,300 fewer deaths from heart disease between 1989 and 1997 than the number that would have been expected if the earlier trend in mortality from heart disease in California relative to the rest of the United States had continued. The diminished effectiveness of the program after 1992 was associated with 8300 more deaths than would have been expected had its initial effectiveness been maintained.

**Conclusions** A large and aggressive tobacco-control program is associated with a reduction in deaths from heart disease in the short run. (N Engl J Med 2000;343:1772-7.)

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IN 1988, the voters of California approved Proposition 99, which increased the tax on cigarettes by 25 cents per package and allocated 5 cents of the new tax for an antitobacco educational campaign,<sup>1</sup> resulting in the creation of the largest tobacco-control program ever undertaken. This program combined the effects of the tax increase with an aggressive media campaign, which attacked the tobacco industry and stressed clean indoor air,<sup>2</sup> and with community-based programs promoting clean indoor air and policies designed to foster a smoke-free society.<sup>3,4</sup> This program,<sup>5-9</sup> as well as similar programs in Florida,<sup>10</sup> Massachusetts,<sup>11,12</sup> and Oregon,<sup>13</sup> accelerated the decline in the number of cigarettes smoked and in the prevalence of smoking.<sup>14</sup>

Several studies have estimated the effects of the California Tobacco Control Program on the prevalence of smoking or on per capita and total consumption. Pierce et al.<sup>6,7</sup> estimated that before the implementation of the California Tobacco Control Program, the prevalence among adults of smoking was falling at about the same rate in California as in the rest of the United States (by 0.74 percent per year in California and by 0.77 percent per year in the rest of the United States); in the early 1990s, when the program was most effective, the rate of decline in the prevalence of smoking accelerated (to 1.06 percent per year), whereas it slowed in the rest of the United States (to 0.57 percent per year). In December 1988, before the program was implemented, the prevalence of smoking in California was 89 percent of that in the rest of the United States; by December 1996, it was 80 percent. In addition, the number of packs smoked among persons who continued to smoke fell more rapidly in California than in the rest of the United States after the California program was initiated.<sup>7</sup> Lightwood and Glantz<sup>8</sup> estimated that the program accelerated the rate of decline in the absolute prevalence of smoking by 1 percent per year, whereas there was no change

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in the rate of decline in the rest of the United States. Siegel et al.<sup>9</sup> reported similar rates of decline in the prevalence of smoking in California during the late 1980s (before the program was implemented, in 1989), with the prevalence falling much faster during the early 1990s in California than in the rest of the United States (by 0.39 percent per year in California vs. 0.05 percent per year in the rest of the United States). Thus, there is a strong consensus that the California program accelerated the decline in cigarette smoking.<sup>14</sup>

Reducing the use of tobacco is the operational goal of any tobacco-control program, but the ultimate goal is to reduce the diseases that smoking causes. We wanted to determine whether the reductions in tobacco use in California were associated with measurable reductions in deaths caused by tobacco. Whereas the excess risk of death from cancer or lung disease associated with smoking changes slowly after people stop smoking,<sup>15,16</sup> the excess risk of heart disease declines rapidly.<sup>8</sup> The relative risk of hospitalization for myocardial infarction associated with smoking is reduced by half within the first year after the cessation of smoking, and within three to five years it is nearly the same as the risk among persons who have never smoked.<sup>8</sup> Because of this rapid reduction in risk, one would expect to begin to see changes in the rate of mortality from heart disease within a year after changes in cigarette use. We hypothesized that rates of death from heart disease would decline more quickly in California than in the rest of the United States after the implementation of the California Tobacco Control Program, paralleling the changes in cigarette use.

## METHODS

### Data

Because the tobacco-control program reduced both the prevalence of smoking and the consumption of cigarettes among persons who continued to smoke,<sup>7</sup> we selected per capita cigarette consumption, reflected by per capita cigarette sales,<sup>17</sup> as our measure of the program's effect on smoking.

We obtained the age-adjusted death rates for diseases of the heart (codes 390 through 398, 402, and 404 through 429 of the *International Classification of Diseases, 9th Revision*<sup>18</sup>), which includes ischemic heart disease, rheumatic fever and rheumatic heart disease, hypertensive heart disease, diseases of the endocardium, and all other forms of heart disease. Ischemic heart disease accounts for approximately 70 percent of all these deaths. We obtained data on age-adjusted rates of death from heart disease and population data from the National Center for Health Statistics (NCHS),<sup>18-20</sup> for the United States, and from the Center for Health Statistics of the California Department of Health Services (DHS), for California.<sup>21,22</sup> Both these sources provide population and age-distribution data that are updated yearly. We used the DHS data for California rather than the NCHS data because the DHS population data are generated by the California Department of Finance, and the estimates provide a better measure of annual migration (based on driver's licenses) than do the national estimates (based on tax returns). In addition, the DHS mortality data provide a more accurate measure of deaths that occur in California; the NCHS data for California include deaths of California residents outside California. Since California residents residing outside the state are not influ-

enced by the California Tobacco Control Program, it is more reasonable to use the DHS statistics to assess the effects of the program on people residing in California.

We estimated the rates of cigarette consumption and of death from heart disease for the United States excluding California, on the basis of the overall U.S. rates, the rates in California, and the yearly resident populations of California and the United States. Figure 1 shows the rates of per capita cigarette consumption and age-adjusted rates of death from diseases of the heart in California and in the rest of the United States from 1980 to 1997.

### Statistical Analysis

To test our hypothesis that the California Tobacco Control Program was associated with reductions in the rates of cigarette consumption and mortality from heart disease, we had to model not only the effects of the program, but also the fact that in 1992 Governor Pete Wilson suspended the antismoking media campaign until a lawsuit forced him to reinstitute it late that year.<sup>1,2,23</sup> In addition, beginning in 1993, Wilson seriously cut back the program, toned down the advertisements, and changed the focus from the general public to teenagers.<sup>1,6,24</sup>

To account for these events, we modeled the changes in rates of per capita cigarette consumption and age-adjusted rates of death from heart disease in California as a linear function of the rates in the United States with California excluded, allowing for changes in the slope with time, starting in 1988 and in 1992 (see Table 1 for the equation). By including the rate for the rest of the United States in the regression model, we controlled for changes in cigarette consumption and mortality from heart disease due to trends over time, national changes in risk factors, and advances in treatment. We chose 1988 as the first break point in the analysis to allow for any alteration in the rate of change in cigarette consumption or mortality from heart disease in California the year the tobacco-control program was implemented (1989). We chose 1992 as the second break point to allow for possible effects of the changes in the program that began in 1992.

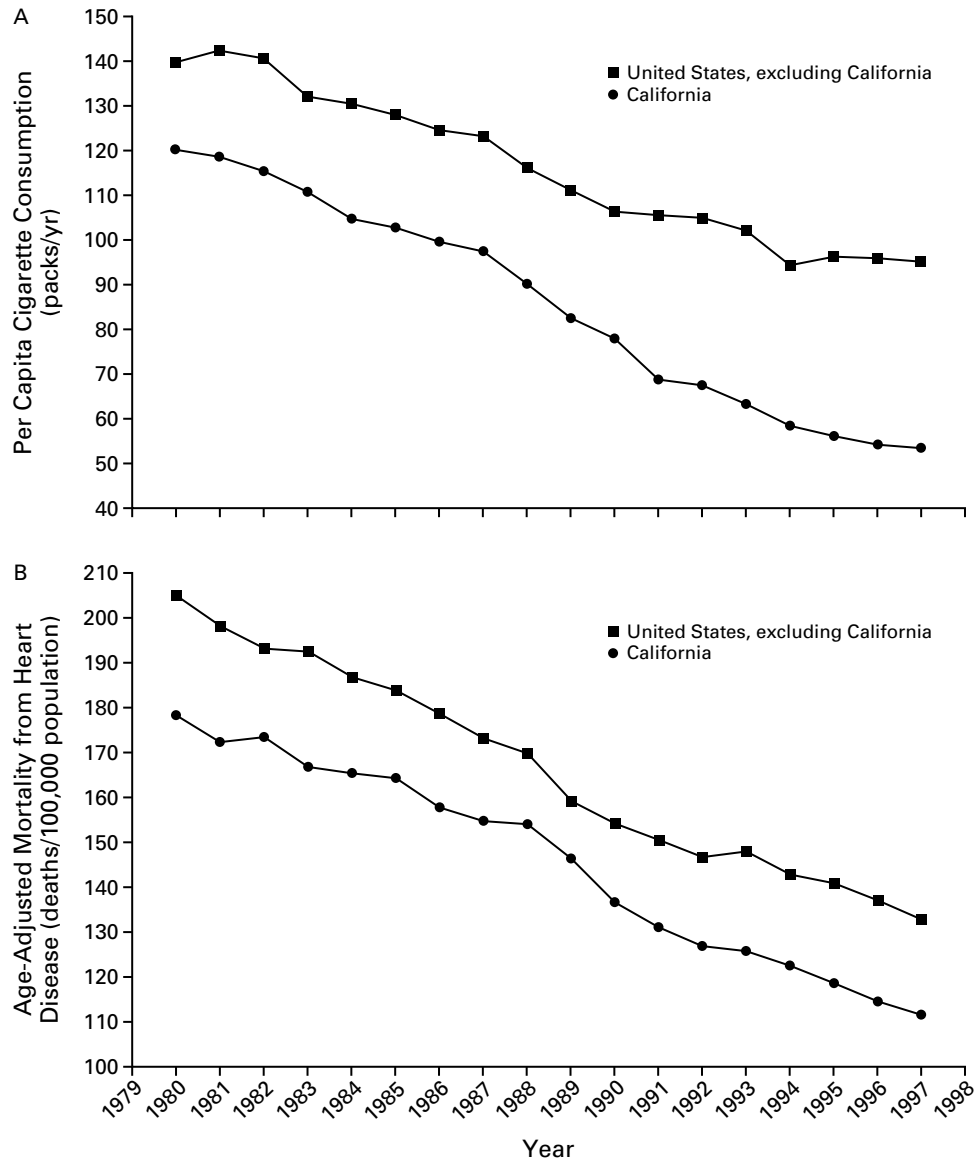
We examined the reasonableness of the break points in our hypothesized model for age-adjusted rates of death from heart disease by conducting a forward stepwise regression, which included candidate variables with breaks at 1988, 1989, 1990, 1991, 1992, 1993, and 1994. This procedure confirmed that 1988 and 1992 were the best break points for this analysis.

We estimated cigarette sales and deaths from heart disease that were prevented by the tobacco-control program by summing over time the difference between the actual rate in California and the predicted rate in the absence of the program, multiplied by the population of California. Likewise, we estimated the number of excess deaths associated with the diminished effectiveness of the California program after 1992 by summing over time the difference between the actual death rate in California and the predicted rate had the effectiveness of the program observed between 1989 and 1992 been maintained, multiplied by the population of California.

## RESULTS

The model provided an excellent fit to the data for both rates of per capita cigarette consumption and age-adjusted rates of death from heart disease (Table 1 and Fig. 2). All the terms in the model were statistically significant for both per capita cigarette consumption and rates of death from heart disease.

The regression coefficient was 1.09 for the rate of per capita cigarette consumption in California in relation to that in the rest of the United States, indicating that before 1989, the rate of consumption was falling slightly faster in California than in the rest of the United States. After the introduction of the California Tobacco Control Program, there was a signif-



**Figure 1.** Per Capita Cigarette Consumption and Age-Adjusted Rates of Death from Heart Disease from 1980 through 1997 in California and the Rest of the United States.

Rates of per capita cigarette consumption (Panel A) and age-adjusted rates of death from heart disease (Panel B) fell from 1980 to 1997 in both California and the rest of the United States, although at different rates. The rates of decline in both consumption and mortality in California increased when the California Tobacco Control Program was implemented in 1989.

icantly greater rate of decline in per capita consumption in California relative to the rate of decline in the rest of the United States (by 2.72 packs per year per year). Although the rate of consumption continued to decline after the political difficulties that affected the program beginning in 1992, the rate of decline was significantly reduced (by 2.05 packs per year per year).

The changes in age-adjusted rates of death from heart disease, after adjustment for changes in the rates in the rest of the United States, paralleled the chang-

es in per capita cigarette consumption. The regression coefficient was 0.67 for the rate in California in relation to that of the rest of the country, indicating that before 1989, the rate of death in California was about two thirds that in the rest of the United States. The introduction of the California Tobacco Control Program was associated with a significantly greater annual rate of decline in mortality from heart disease in California than in the rest of the United States (by 2.93 deaths per year per 100,000 population per year).

**TABLE 1.** REGRESSION MODELS FOR PER CAPITA CIGARETTE CONSUMPTION AND AGE-ADJUSTED RATES OF DEATH FROM HEART DISEASE IN CALIFORNIA.\*

VARIABLE	ANNUAL RATE OF PER CAPITA CIGARETTE CONSUMPTION	P VALUE	AGE-ADJUSTED ANNUAL RATE OF DEATH FROM HEART DISEASE	P VALUE
Regression coefficient for rate in California in relation to rate elsewhere in the United States ( $b_{US-CA}$ )	1.09 ± 0.07	<0.001	0.67 ± 0.04	<0.001
Effect of tobacco-control program on annual rate ( $b_{after\ 1988}$ )	-2.72 ± 0.65	0.001	-2.93 ± 0.53	<0.001
Change in effect of tobacco-control program on annual rate ( $b_{after\ 1992}$ )	2.05 ± 0.89	0.04	1.71 ± 0.71	0.03
Constant ( $b_0$ )	-35.3 ± 9.2	0.002	39.5 ± 7.9	<0.001
R <sup>2</sup>	0.994		0.994	

\*Plus-minus values are actual values ±SE. The regression equation used was as follows:  $r_{CA} = b_0 + b_{US-CA} r_{US-CA} + b_{after\ 1988} u(1988) + b_{after\ 1992} u(1992)$ , where  $r_{CA}$  and  $r_{US-CA}$  are the rates in California and in the rest of the United States, respectively, and  $u(t)$  is the unit step function (equal to 0 before year  $t$  and 1 starting in year  $t$ ).

Although the death rate continued to decline after 1992, the rate of decline was significantly reduced (by 1.71 deaths per year per 100,000 population per year).

The broken lines in Figure 2 show the predicted rates of per capita cigarette consumption and mortality from heart disease in California had the relation between the rates in California and those in the rest of the United States before 1989 been maintained. The difference between these lines and the actual values (solid circles) for the nine years from 1989 to 1997 indicates that the tobacco-control program was associated with 2.9 billion fewer packs of cigarettes sold (worth \$4 billion to the tobacco industry in pretax sales) and 33,300 fewer deaths from heart disease (as compared with a total of 611,500 deaths from heart disease in California during this period<sup>21,22</sup>).

The dotted lines in Figure 2 show the predicted rates of per capita consumption and mortality from heart disease in California had there been no reduction in the effectiveness of the program in 1992.<sup>1,6,7,24</sup> This loss of effectiveness was associated with 1 billion excess packs of cigarettes sold (worth \$1.4 billion to the tobacco industry) and 8300 excess deaths from 1993 through 1997 (as compared with a total of 340,800 deaths from heart disease<sup>21,22</sup>).

**DISCUSSION**

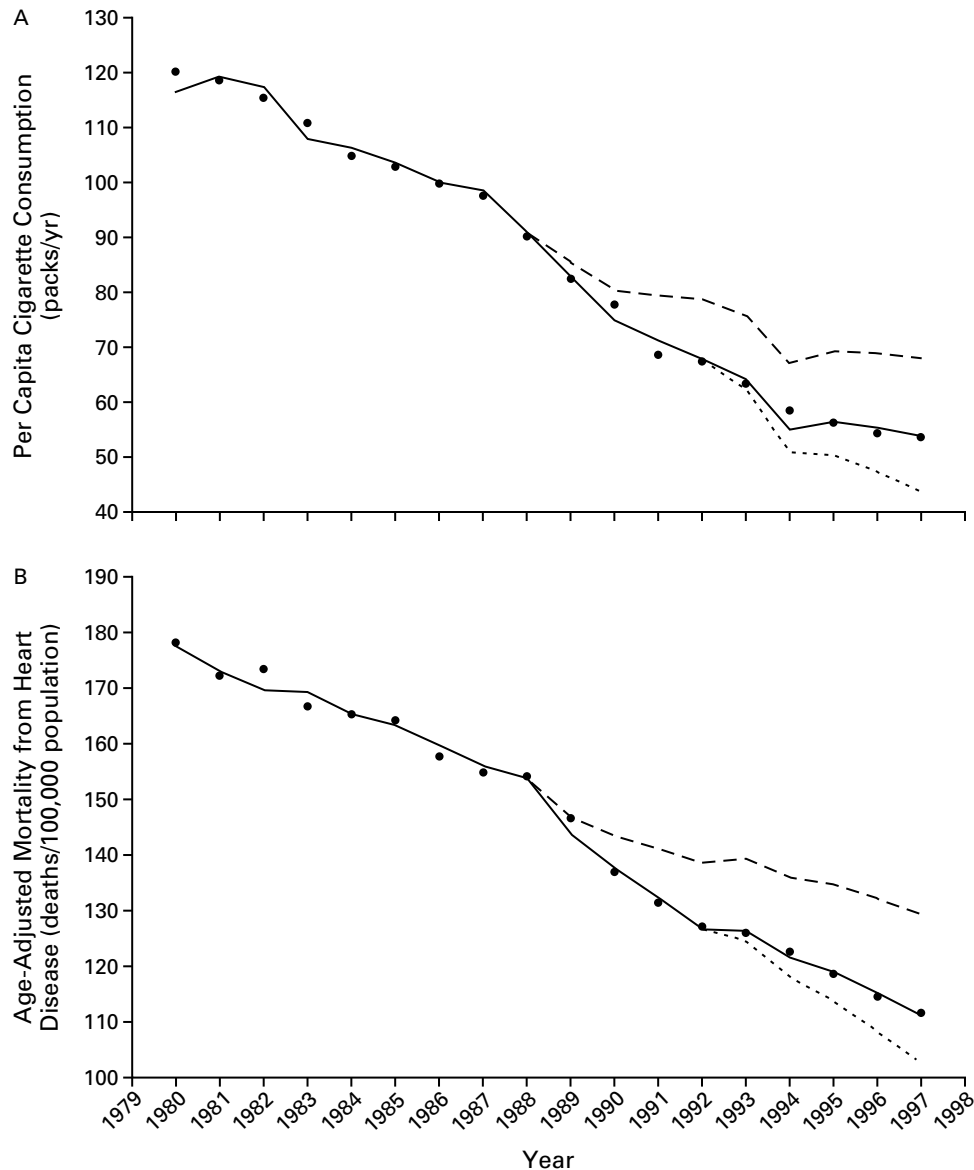
The California Tobacco Control Program has led to significantly larger decreases in the prevalence of smoking and in the rate of per capita cigarette consumption in California than in the rest of the United States.<sup>5-9,14</sup> It has been well established that smoking causes heart disease<sup>25</sup> and that the cessation of smoking quickly reduces the excess risk of heart disease.<sup>8</sup> Our findings are consistent with these facts. Mortal-

ity from heart disease decreased significantly more in California than in the rest of the United States after the introduction of the California Tobacco Control Program, and the changes in mortality from heart disease mirrored the changes in per capita cigarette consumption over time.

Furthermore, a simple calculation shows that the changes in the rate of death from heart disease were quantitatively consistent with the changes in cigarette consumption. Values for the risk of death from coronary heart disease that is attributable to smoking range from 40 to 55 percent.<sup>26</sup> In 1997, the rate of per capita cigarette consumption in California was 21 percent lower than the predicted rate had the pre-1989 relation between the rates in California and the rest of the United States been maintained. A 40 to 55 percent reduction of 21 percent is 8 to 12 percent, which is similar to the actual 13 percent difference between the actual rate of death from heart disease in California and the predicted rate had the pre-1989 trend been maintained.

We also analyzed the data separately for persons 25 to 64 years old and those 65 years or older in order to determine whether the primary effects were among the elderly. If so, it would be evidence against our hypothesis that the California Tobacco Control Program led to the changes in mortality from heart disease, because both the prevalence of smoking and the risk of coronary disease that is attributable to smoking decline with age. We found similar effects (after adjusting for the base-line rate of death from coronary heart disease) in the two age groups.

Our conclusions are based on a relatively simple statistical model, and one can never exclude the possibility that the differences we are attributing to the Cal-



**Figure 2.** Rates of per Capita Cigarette Consumption and Age-Adjusted Rates of Death from Heart Disease in California Relative to Rates in the Rest of the United States and Predicted Rates If the Tobacco-Control Program Had Not Been Instituted in 1989 and If It Had Not Been Cut Back in 1992.

The solid lines, which represent the fit of the regression equation to the data (solid circles), show that the program, which was implemented in 1989, was associated with greater reductions in rates of per capita cigarette consumption (Panel A) and mortality from heart disease (Panel B) than the rates predicted on the basis of the relation between the rates in California and those in the rest of the United States before 1989 (broken lines). Had the effectiveness of the program not been reduced starting in 1992, the per capita consumption and death rates would have fallen even faster than they did (dotted lines).

ifornia Tobacco Control Program are due to unknown confounding variables, such as changes in diets or use of hormone-replacement therapy in California that differed from those in the rest of the United States. We consider this situation unlikely for several reasons. First, the changes in rates of death from heart disease paralleled the changes in per capita cigarette consump-

tion in ways that would be expected, given the relation between smoking and heart disease. Second, by using age-adjusted death rates, we accounted for differences in age distribution between the population of California and that of the rest of the United States. Third, by using the death rates in the population outside California as an independent variable in the regression

model with a regression coefficient not constrained to be 1, we accounted for changes in medical practice during the study period (which were substantial in terms of treating heart disease) as well as trends over time in mortality from heart disease that were unrelated to the California Tobacco Control Program. Fourth, the risk of death from heart disease after the cessation of smoking falls over a period of years,<sup>8</sup> not all in one year. As a result, the changes we quantified in our model represent the cumulative effects (strictly speaking, the convolution) of changes in cigarette consumption over time. The slope-change terms in the model were probably an oversimplification required by the fact that we had only one data point per year for a relatively small number of years.

Despite these limitations, our data indicate that well-designed, aggressive tobacco-control programs are associated with major reductions in deaths from heart disease in a short period of time. Our study also shows that scaling back or weakening such programs by limiting them to children, as the tobacco industry and some representatives of the public health community advocate, is associated with an increase in deaths. In view of this fact, public health advocates should redouble their efforts to confront the tobacco industry and its allies in legislatures and elsewhere and insist that effective programs be introduced as rapidly as possible to reduce the number of deaths caused by tobacco.

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