Benefits of Smoking Cessation for Longevity

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Objectives. This study determined the life extension obtained from stopping smoking at various ages.

Methods. We estimated the relation between smoking and mortality among 877 243 respondents to the Cancer Prevention Study II. These estimates were applied to the 1990 US census population to examine the longevity benefits of smoking cessation.

Results. Life expectancy among smokers who quit at age 35 exceeded that of continuing smokers by 6.9 to 8.5 years for men and 6.1 to 7.7 years for women. Smokers who quit at younger ages realized greater life extensions. However, even those who quit much later in life gained some benefits: among smokers who quit at age 65 years, men gained 1.4 to 2.0 years of life, and women gained 2.7 to 3.7 years.

Conclusions. Stopping smoking as early as possible is important, but cessation at any age provides meaningful life extensions. (*Am J Public Health.* 2002;92:990–996)

Despite the reductions in smoking prevalence that have been achieved since the first surgeon general's report on the consequences of smoking in 1964, smoking remains the leading cause of preventable death in the United States.[1,2] Approximately 45 million Americans and more than 1.2 billion people worldwide continue to use tobacco.[3] A health message commonly provided to smokers as encouragement to quit is that it is never too late. Smoking cessation has well-documented health benefits.[4] Research has shown that for persons who stopped smoking for a relatively long time, the health benefits experienced—as measured both by relative risk (RR) of mortality in comparison with lifelong nonsmokers and by risk of lung cancer—increased in proportion to the number of years since cessation.[4,5] Recent estimates from Great Britain show that about 90% of the excess mortality attributable to cigarette smoking can be avoided if persons stop smoking before middle age.[6]

Life extension associated with smoking cessation may be a more tangible means of representing the reduction of mortality risk associated with quitting at various ages, compared with reductions in the relative or cumulative risk of death. The objective of this article is to quantify, with US-specific data, the benefit to a smoker of stopping smoking earlier rather than later in terms of life expectancy relative to never smokers and continuing smokers. Such estimates are needed to provide a sounder scientific basis for public health messages and clinical advice given to smokers about the effect of smoking cessation earlier in life on life expectancy. Furthermore, such messages need to be as simple as possible to have maximal effect.

Our goals were to identify the life-years that could be saved by stopping smoking at various ages and to determine whether even elderly smokers could reap benefits in terms of life years saved from smoking cessation. We used data from the Cancer Prevention Study II to construct a mortality-prediction model that included detailed information on smoking status and other potential confounding variables.[4,5] We used relative risk of death by smoking category to predict mortality among 35-year-old Americans in 1990 under differing scenarios of age at smoking cessation. We compared life expectancy under the various cessation scenarios with life expectancy for persons aged 35 years in 1990 who had never smoked and for those who continued to smoke.

A major benefit of our study in comparison with past work was its use of the Cancer Prevention Study II to obtain relative risks of smoking. The Cancer Prevention Study II sample was large enough (>10 million life-years of follow-up) to allow detailed modeling of the effect on mortality both of smoking duration and of age at smoking cessation; such controls would not be possible with a smaller database because of small-cell problems. Furthermore, the Cancer Prevention Study II database is somewhat more nationally representative than the Framingham Heart Study database,[7] and in contrast to the British Doctors Study database,[8] it pertains to the United States and includes a much broader population than that study's single group of professional workers. These other databases are the leading alternatives from which one could obtain relative risk estimates. Finally, we projected mortality decreases after cessation with the 1990 census population and the relative risks obtained from the Cancer Prevention Study II, which provides a realistic estimate of the benefits of smoking cessation on longevity in the American context and allowed us to compare our results with recent findings from Great Britain.[6]

METHODS

Cancer Prevention Study II Analyses

The Cancer Prevention Study II is an ongoing prospective study in a cohort of 1.2 million US adults (676 306 women and 508 351 men) that was begun in the fall of 1982.[9–11] American Cancer Society volunteers recruited participants for the study. Participants were at least 30 years of age and were from all 50 states, the District of Columbia, and Puerto Rico. Because Cancer Prevention Study II subjects were recruited by American Cancer Society volunteers, who are more middle class than the U.S. population as a whole, they were also more likely to be college-educated, middle class, and White compared with the general U.S. population.[12] Often, volunteers recruited their friends and work colleagues to participate. For example, 30% of the Cancer Prevention Study II sample had a college degree, compared with 13% of the 1990 census population, and 93% of the Cancer Prevention Study II respondents were White, compared with 80% in the 1990 census.

Each participant completed a confidential, 4-page mailed questionnaire on smoking habits, alcohol intake, marital status, education, and other characteristics. We excluded partici-

pants who provided incomplete data on smoking habits or men who reported ever smoking a pipe or cigar (138 609 men and 72 459 women). We also excluded people who reported being sick at enrollment (34 824 men and 61 522 women), because they may have changed their smoking habits (by quitting smoking or smoking fewer cigarettes) as a result of their illness; their inclusion in the study most likely would have underestimated the mortality benefits of smoking cessation and would dilute the public health message that our article develops regarding what smokers can expect by way of life extension if they quit smoking at a given age. Analyses were based on the remaining 877 243 participants (334 918 men and 542 325 women).

Deaths occurring between date of enrollment and December 31, 1996, were ascertained through personal inquiries from American Cancer Society volunteers in September 1984, 1986, and 1988 and through automated linkage to the National Death Index in December 1989, 1991, 1994, and 1996.[13] By the end of 1996, 20% of the original respondents had died, and follow-up for 0.2% had been truncated in September 1988 because of insufficient data to link to the National Death Index. We obtained death certificates or multiple cause-of-death codes for 98.6% of all deaths. The underlying cause of death was coded according to the *International Classification of Diseases, 9th Revision.*[14] Our analysis included 149 351 deaths from all causes. Person-years at risk were accrued from month of enrollment through the last date in the study: the end of follow-up (December 31, 1996), date of death, or date lost to follow-up (because of insufficient information for National Death Index linkage), whichever occurred first. This resulted in 7.2 million female person-years and 4.3 million male person-years.

Deaths from all causes were identified from 1982 through December 31, 1996.

Estimation Strategy With Cancer Prevention Study II Data

We estimated the relative risk of death by smoking status, age, and sex using a Cox proportional hazards model, which was implemented using multiple logistic regression estimated by maximum likelihood methods.[15] Age was controlled for in 1-year increments, with age younger than 40 years truncated at 40 and age older than 90 years truncated at 90. Models were estimated separately for men and women and for persons younger than age 70 years and those 70 years or older. Smoking status at the baseline survey was initially assumed to remain constant throughout the study period.

Current smokers were stratified by 10-year age increments: younger than 50, 50 to 59, 60 to 69, 70 to 79, and 80 years or older. Former smokers were stratified by 10-year age increments (as for current smokers) and years of cessation (cigarette abstinence: for 3 to 5, 6 to 10, 11 to 15, and 16 years or more). Those who had quit less than 3 years before baseline were combined with current smokers in the analyses because they have similar mortality rates and because relapse among recent quitters is high.[4] Age and number of years as a former smoker were treated as time-dependent covariates and were advanced for each year in the study. For example, smokers who quit in 1978 and who were alive in 1983 were considered former smokers, 3 to 5 years after cessation, in 1983. The following year, the same people would be categorized with former smokers, 6 to 10 years after cessation.

Alcohol consumption was categorized into 5 groups: teetotalers, up to 2 drinks per day, 3 to 4 drinks per day, 5 or more drinks per day, and missing information on drinking. Education had 4 categories: less than high school, high school graduate, some college, and college graduate or more. Other variables were race (non-White vs White), marital status (married vs not), and self-reported history of cancer. All covariates other than age were modeled as dummy variables using the categories shown in Table 1 (see Table 3 note).

Bias Caused by Smoking Cessation After Baseline

In estimating the relative risk of current and former smoking, we initially assumed that no changes in smoking status occurred during the follow-up period from 1982 to 1996; as a result, smoking status may have been misclassified for at least a portion of the study for current smokers who quit or for former smokers who relapsed during follow-up. Both types of misclassification could lead to underestimation of the benefits of smoking cessation. Misclassification of current smokers who quit could dilute the effect of current smoking on mortality, whereas misclassification of former smokers who relapsed could inflate the relative risk of former smoking.

We subsequently conducted sensitivity analyses to estimate the extent to which changes in smoking status would cause underestimation of the true risk in continuing smokers. For this estimation, we used follow-up information on smoking status, which was available in 1992 for a fraction of the cohort.[12] Among participants in the 1992 survey who had been current smokers in 1982, 56.8% of the men and 52.7% of the women were no longer smoking, whereas 3.0% of the male and female former smokers had relapsed. The subsample (n=184 194) that participated in the 1992 survey was a self-selected group that was more highly educated, was older, and included a higher proportion of White persons compared with the baseline Cancer Prevention Study II cohort.[12] Smoking prevalence also was lower in the 1992 subsample (7% vs 20%).

We computed annual rates of cessation and relapse by age and sex. For example, among men who were aged 55 years in 1982, the annual cessation rate was 0.0705, and the annual relapse rate was 0.0042. We calculated a "true" relative risk for current smoking, correcting for misclassification due to cessation among the current smokers over the follow-up period. Because the rate of relapse among former smokers was so low, we did not adjust for it in our calculations. We estimated the proportion of current smokers who quit for each year of follow-up. Next, we used these proportions and the observed person-years for current smokers to calculate the number of person-years contributed by each smoking group (e.g., continuing smokers, former smokers who had quit 3–5 years previously). Then, we constructed an equation in which the observed relative risk for current smoking equaled the average "true" relative risk for current smoking plus the observed relative risk for former smoking weighted by the person-years in each group. Solving for the "true" relative risk corrected for misclassification due to change in smoking status.

TABLE 1—Demographic and Other Characteristics: Cancer Prevention Study II, 1982–1996

	Men Cigarette Smoking Status			Women Cigarette Smoking Status		
	Never	Current	Former	Never	Current	Former
No. of people	117 518	91 637	125 763	320 010	113 732	108 583
%	35.1	27.4	37.6	59.0	21.0	20.0
All-cause deaths	20 508	25 383	28 749	43 613	18 856	12 242
Lung cancer	342	4645	2448	831	3323	934
Cancers other than lung	5609	5517	7270	13 697	4852	4351
Coronary heart disease	5866	5950	7688	9675	3169	2078
Stroke	1440	1152	1621	3966	1263	808
Chronic obstructive pulmonary disease	186	1500	1200	404	1334	498
Other causes	7065	6619	8522	15 040	4915	3573
Age at baseline, mean	56.7	54.5	58.5	57.4	53.5	54.9
White race, %	94.1	93.1	96.3	93.4	93.1	96.0
Married, %	93.6	92.7	95.9	76.6	74.0	80.7
History of cancer, %	3.7	3.4	5.1	7.5	7.4	9.0
Education, %						
< High school	11.7	17.9	14.5	13.9	11.8	7.2
High school graduate	19.8	24.4	21.3	33.0	33.1	26.3
Some college	23.2	29.9	28.8	28.2	33.0	33.8
≥ College	45.3	27.8	35.4	25.0	22.0	32.8
Current smoking patterns, %						
< 20 cigarettes/day	. . .	23.7	. . .	. . .	39.3	. . .
20 cigarettes/day	. . .	29.4	. . .	. . .	33.8	. . .
≥ 21 cigarettes/day	. . .	47.0	. . .	. . .	26.9	. . .
Former smoking patterns, %						
1 y since quitting	. . .	. . .	6.3	. . .	. . .	6.6
2 y since quitting	. . .	. . .	3.4	. . .	. . .	3.5
3–5 y since quitting	. . .	. . .	9.7	. . .	. . .	10.2
6–10 y since quitting	. . .	. . .	15.3	. . .	. . .	15.5
11–15 y since quitting	. . .	. . .	18.8	. . .	. . .	18.6
≥ 16 y since quitting	. . .	. . .	46.4	. . .	. . .	45.6
Smokeless tobacco use, %						
Current	2.3	3.1	5.1	. . .	. . .	. . .
Former	0.7	3.5	4.2	. . .	. . .	. . .
Current alcohol consumption, %						
None	24.2	12.0	13.7	23.8	16.2	16.8
1–2 drinks/day	31.9	37.4	41.2	23.8	38.7	44.0
3–4 drinks/day	4.6	12.0	9.7	1.8	7.4	5.7
≥ 5 drinks/day	3.2	11.0	6.7	1.1	3.9	2.7
Missing	36.0	27.7	28.8	49.6	33.8	30.8

Estimation of Smoking-Specific Mortality Rates in the United States

US census vital statistics data allow stratification of all-cause death rates by age, race, and sex but not by smoking status. To estimate mortality by smoking status, we first calculated the relative risk of death from all causes for stratified age, race, sex, and smoking-status groups in the Cancer Prevention Study II. We then multiplied these relative risks by the observed mortality rate in the United States for the corresponding age, race, and sex group in 1990 and divided by a factor (representing the weighted average of the category-specific relative risks) to obtain estimated US mortality rates for each age, race, sex, and smoking-status group.

Projecting Mortality by Cessation Scenarios

We projected smoking-specific mortality rates in the 1990 census population of men and women who were aged 35 years in

TABLE 2—Smoking Cessation Scenarios for Mortality Projections

Scenario	Population	Change in Smoking Behavior
Base case (smoke until death)	35-year-olds, 1990	All 35-year-old smokers smoke until death
Stop smoking at 35	35-year-olds, 1990	All smokers stop smoking at age 35 and never relapse
Stop smoking at 45	35-year-olds, 1990, who lived to age 45	All smokers who survive to age 45 stop at age 45 and never relapse
Stop smoking at 55	35-year-olds, 1990, who lived to age 55	All smokers who survive to age 55 stop at age 55 and never relapse
Stop smoking at 65	35-year-olds, 1990, who lived to age 65	All smokers who survive to age 65 stop at age 65 and never relapse
Population smoking behavior	35-year-olds, 1990	No change from observed 1990 rates of smoking, initiation, cessation, and relapse
Preventing smoking	35-year-olds, 1990	No 35-year-old in 1990 ever smoked cigarettes

1990[16] under alternative scenarios in which all smokers quit at a particular age (we used ages 35, 45, 55, and 65). For cessation at ages 45, 55, and 65 years, we used only those persons aged 35 years in 1990 who survived to ages 45, 55, and 65, respectively. Projected mortality under each scenario was compared with the projected mortality if all current smokers had continued to smoke (Table 2). We also projected mortality among persons aged 35 years assuming that the smoking behavior rates (prevalence, initiation, cessation, relapse) for each stratified age, sex, and education group from the 1991 National Health Interview Survey and the National Health and Nutrition Examination Survey I held true, as well as assuming that no person aged 35 years in 1990 had ever smoked cigarettes.[17,18]

To make the projections, we constructed hypothetical life tables split by age, sex, race, and smoking-status subgroups, a general approach that has been used by others.[19–22] The only way in which the scenarios outlined in Table 2 and above differed was in the alteration of smoking behavior (e.g., the initial denominator—population aged 35 years—was the same, but an individual had to survive to age 45 years to be included in that analysis). To demonstrate the sensitivity of our findings, we calculated life extension using both uncorrected and corrected relative risk of mortality for misclassification due to change in smoking status.

RESULTS

One in 4 persons was a current smoker at baseline in the Cancer Prevention Study II (men, 27.4%; women 21.0%; Table 1). Former smokers were the largest group among men (37.6%), and never smokers were the largest group among women (59.0%). Amount smoked among current smokers differed substantially by sex, with nearly half of the men being heavy smokers (21 or more cigarettes per day) but only 26.9% of the women smoking this amount. Nearly half of the former smokers had quit 16 or more years before the 1982 survey, and 10% had quit less than 3 years before the survey.

Current smokers had higher all-cause mortality compared with never smokers, regardless of their age or sex (Table 3), and the relative risk of death rose with increasing age, peaking at age 50 to 59 years in men and age 60 to 69 years in women and then declining among older smokers (although absolute risk of death for older smokers remained high). The relative increase in death rates from all causes among smokers was 2.34 (95% confidence interval [CI]=2.21, 2.48) in men younger than age 50 years; 2.82 (95% CI=2.76, 2.88) for those aged 50 to 59 years; 2.80 (95% CI=2.76, 2.84) for those aged 60 to 69 years; 2.52 (95% CI=2.46, 2.58) for those aged 70 to 79 years; and 1.81 (95% CI=1.75, 1.88) for men 80 years and older. A similar pattern of rising and then declining relative risk of death was observed for female smokers.

Death rates among former smokers who were older than age 50 years in 1982 were nearly always higher than the rates among never smokers, regardless of how long before 1982 they had quit smoking. For former smokers younger than age 50 years, the risk of death usually was not different from that of never smokers. Among former smokers, the relative risk of death by years since cessation in 1982 generally rose with increasing age up to age 70 to 79 years and then declined. Alternatively, given a particular age group in 1982, the relative risk of death decreased as the years since cessation increased, showing that cessation at earlier ages reduced mortality. The pattern for women was similar.

Annual death rates of men aged 50 to 59 years who had quit smoking 16 or more years before enrollment were 13% higher than those of never smokers (relative risk [RR]=1.13; 95% CI=1.05, 1.21), rates of those aged 60 to 69 years were 23% higher (RR=1.23; 95% CI=1.19, 1.27), rates of those aged 70 to 79 years were 32% higher (RR=1.32; 95% CI=1.29, 1.35), and rates of those aged 80 years and older were 19% higher (RR=1.19; 95% CI=1.15, 1.23). For women, relative risk of death among those who were long-term quitters (16 or more years since cessation) also remained elevated at ages 60 to 69 years (RR=1.11; 95% CI=1.06, 1.16), ages 70 to 79 years (RR=1.20; 95% CI=1.16, 1.24), and age 80 years and older (RR=1.21; 95% CI=1.17, 1.25). Although we did not directly control for the age at cessation, the intersection of the age and quit duration in 1982 clearly illustrates that smoking cessation at a younger age reduces mortality risk.

Estimation of Misclassification Bias Due to Change in Smoking Status

Correcting for cessation rates increased the relative risk for current smokers by 8% to 28%; the increase was higher in people aged 60 to 79 years. For example, the observed relative risk of death for current smoking among men aged 50 to 59 years in 1982 was 2.82; after correction, the relative risk was 3.11 (Table 4). The adjustment for misclassification fixed the relative risk of death

TABLE 3—Relative Risk Estimates for All-Cause Mortality Associated With Current Smoking or Having Stopped Smoking Before Study Baseline in 1982

	<50 in 1982			50–59 in 1982			60–69 in 1982			70–79 in 1982			≥80 in 1982		
	RR	95% CI	*P*	RR	95% CI	*P*	RR	95% CI	*P*	RR	95% CI	*P*	RR	95% CI	*P*
Men															
Current smoker, 1982	2.34	2.21, 2.48	<.001	2.82	2.76, 2.88	<.001	2.80	2.76, 2.84	<.001	2.52	2.46, 2.58	<.001	1.81	1.75, 1.88	<.001
Former smoker, quit duration in 1982															
3–5 y	1.29	0.88, 1.69	.23	1.93	1.75, 2.10	<.001	2.13	2.02, 2.25	<.001	1.98	1.85, 2.11	<.001	1.12	0.77, 1.46	.52
6–10 y	1.46	1.17, 1.74	.01	1.86	1.74, 1.97	<.001	2.17	2.10, 2.24	<.001	2.08	2.01, 2.14	<.001	1.56	1.43, 1.69	<.001
11–15 y	0.93	0.60, 1.25	.64	1.50	1.38, 1.61	<.001	1.75	1.68, 1.81	<.001	1.92	1.87, 1.98	<.001	1.60	1.51, 1.68	<.001
≥16 y	0.95	0.68, 1.21	.68	1.13	1.05, 1.21	.004	1.23	1.19, 1.27	<.001	1.32	1.29, 1.35	<.001	1.19	1.15, 1.23	<.001
Women															
Current smoker, 1982	1.68	1.56, 1.80	<.001	2.32	2.27, 2.37	<.001	2.51	2.48, 2.54	<.001	2.46	2.42, 2.51	<.001	1.81	1.76, 1.86	<.001
Former smoker, quit duration in 1982															
3–5 y	1.55	1.17, 1.93	<.001	1.76	1.52, 1.99	<.001	2.06	1.89, 2.23	<.001	1.55	1.33, 1.76	<.001	1.64	1.21, 2.08	.03
6–10 y	1.10	0.79, 1.40	.55	1.31	1.15, 1.47	<.001	1.89	1.79, 1.99	<.001	1.80	1.70, 1.90	<.001	1.53	1.35, 1.71	<.001
11–15 y	1.11	0.83, 1.38	.47	1.23	1.09, 1.37	.005	1.59	1.50, 1.67	<.001	1.70	1.62, 1.77	<.001	1.47	1.37, 1.58	<.001
≥16 y	1.12	0.92, 1.31	.26	0.95	0.87, 1.04	.25	1.11	1.06, 1.16	<.001	1.20	1.16, 1.24	<.001	1.21	1.17, 1.25	<.001

Note. RR = relative risk; CI = confidence interval.
Numbers in cells represent the adjusted likelihood of all-cause mortality relative to never smokers.
Only smoking covariates are shown, but the model also controlled for education, alcohol consumption, race, marital status, self-reported history of cancer, and age in 1-year increments. Models were estimated separately for men and women and for persons younger than 70 and those 70 and older.

TABLE 4—Relative Risk Estimates for All-Cause Mortality Among Smokers in 1982, Adjusted for Cessation

	Men		Women	
Age, y	Observed	Adjusted[a]	Observed	Adjusted
<50	2.34	2.57	1.68	1.86
50–59	2.82	3.11	2.32	2.58
60–69	2.80	3.53	2.51	2.89
70–79	2.52	3.12	2.46	3.14
≥80	1.81	1.95	1.81	2.14

Note. Observed relative risks assumed no cessation between 1982 and 1996. See "Methods" section for details.
[a]Adjusted for smoking cessation between 1982 and 1996.

for male current smokers at greater than 3.0 and for female current smokers at greater than 2.5, except for the youngest and oldest age groups of both male and female current smokers.

Benefits of Smoking Cessation

Men who smoked at age 35 years and continued to do so had a life expectancy of 69.3 years, compared with an expectancy of 76.2 years for those who stopped smoking at age 35 years, an increase of 6.9 years (Table 5). After adjustment for the subsequent quit rate among current smokers at baseline, the life extension from cessation at age 35 increased to 8.5 years. Women who smoked at age 35 years and continued to do so had a life expectancy 6.1 years less than did those who quit at age 35; when we adjusted for cessation, the life extension increased to 7.7 years. Quitting earlier had clear advantages in terms of average life-years saved relative to continuing to smoke. However, even among smokers aged 65 years, those who quit at age 65 had an expected increase in life span of 2.0 years for men and 3.7 for women relative to persons aged 65 years who continued to smoke, showing that cessation at any age yields substantial increases in life expectancy.

DISCUSSION

Our study showed that people live substantially longer when they stop smoking, regardless of the age at which they quit. Most of the excess mortality from smoking could be avoided by quitting smoking at age 35 years, and much of the excess mortality could be avoided by stopping smoking in middle age. Even smokers who quit at age 65 stand to gain 2.0 years of life expectancy among men and 3.7 years among women, relative to those who continue to smoke. These findings reinforce the urgency of emphasizing smoking cessation to all smokers, irrespective of age,

TABLE 5—Life Expectancies, by Smoking Behavior for Men and Women Aged 35 in 1990

	Men			Women		
Smoking Behavior	Expected Survival, y	Unadjusted Gain Relative to Continuing Smoker	Adjusted[a] Gain Relative to Continuing Smoker	Expected Survival, y	Unadjusted Gain Relative to Continuing Smoker	Adjusted Gain Relative to Continuing Smoker
Never smoked	778.2	8.9	10.5	81.2	7.4	8.9
Smoked until death	69.3	. . .	. . .	73.8	. . .	. . .
Quit at age 35	76.2	6.9	8.5	79.9	6.1	7.7
Quit at age 45	74.9	5.6	7.1	79.4	5.6	7.2
Quit at age 55	72.7	3.4	4.8	78.0	4.2	5.6
Quit at age 65	70.7	1.4	2.0	76.5	2.7	3.7
No intervention[b]	72.9	3.6	4.6	77.7	3.9	5.1

[a]Adjusted for cessation rate estimated by resurvey of Cancer Prevention Study II respondents in 1992. See "Methods" section for details.
[b]No intervention means that among 35-year-old smokers in 1990, the age- and sex-specific cessation and relapse rates were as observed in the 1990 National Health Interview Survey and the 1991 National Health and Nutrition Examination Survey I.

and the importance of never assuming that a smoker is "too far gone." Our estimates of the life extension that would accrue from smoking cessation are conservative, principally because some persons who were current smokers in 1982 stopped smoking during the follow-up period used to estimate the relative risk of death from smoking. We were able to partially, but not fully, account for this cessation because the subsample that we used for estimation of cessation was a healthier subgroup of the Cancer Prevention Study II, but it is not clear whether using this subgroup resulted in overestimation or underestimation of quitting relative to the population.

Our estimate of life extension gained from stopping smoking at age 35 years was much larger than that found by Tsevat et al.[22] They used relative risk information from the Framingham study conducted from the 1950s to the 1980s and found that smoking cessation at age 35 years would yield an average life extension of 0.5 to 1.2 years for men and of 0.4 to 0.8 years for women, relative to the life expectancy of persons aged 35 years who continued to show population-based smoking behavior, including some smokers who subsequently stopped smoking. We used a national and much larger sample and found a much higher benefit for smoking cessation at age 35 years than Tsevat and colleagues did: 3.3 to 3.9 additional years for men and 2.2 to 2.6 years for women with the same comparison groups that they used. They did not quantify life expectancy changes relative to a person aged 35 years continuing to smoke until death (which we highlighted in this article) or relative to persons who had never smoked; instead, they compared complete cessation with population-based quit rates.

Our estimate of the effect of never smoking was more similar to that found in the second half (1971–1991) of the British Doctors Study.[23] Doll and colleagues determined that never smokers aged 35 years had a life expectancy that was 8 years longer than that of men aged 35 years who smoked until death (see Figure 6 from the Doll et al. study[23]), compared with about 8.9–10.5 years for men and 7.4–8.9 years for women in our study. Life extension between 1951 to 1971 and 1971 to 1991 increased by more than 3 years in the British Doctors Study. If the survival benefit of smoking cessation continues to increase over time as it did during the British Doctors Study, we likely underestimated the benefit of cessation for life extension, because our study period (1982–1996) was later and our follow-up period was shorter.

Several projection methods have been developed that allow simulation of the effects of changes in disease risk factors on mortality. Examples include the Coronary Heart Disease Policy Model,[19] which used data from the Framingham study; the Canadian Population Health Model[20]; and the PREVENT[21] model, developed initially in Holland. Recently, a dynamic model in the United States was developed that is mechanically similar to our model, although it was designed to project the prevalence of a risk factor (in the United States) and not its effect on mortality.[24] The key difference between models of this type is how the relative risk of death by smoking status (or other risk factor) is determined. Improvements of our projection method relative to other projection methods include the following:

• The characteristics of the Cancer Prevention Study II—namely, the large sample size that allowed us to estimate different cessation effects, by sex, age, and how long ago a former smoker had quit, on total mortality. The Cancer Prevention Study II allowed us to precisely quantify how the relative risk changes the longer a person has refrained from smoking, as opposed to having to assume this risk.

• The Cancer Prevention Study II database is more representative of the US population than are other databases, such as that of the Framingham study, which had virtually no minorities in its initial study cohorts.[7]

• The relative risks of death by smoking status we obtained are unlikely to be substantially confounded. Although the Cancer Prevention Study II cohort contains proportionally more White, educated, and middle class individuals than the US population, these differences would affect the generalizability of absolute mortality rates but not the relative rates we calculated; the same issues would arise if we used another database such as Framingham, so the large sample size that allowed for more precise estimation of the effect of smoking status was the key reason to use the Cancer Prevention Study II. Further-

more, race and education are observable characteristics that we included in our analyses to avoid confounding.

Our work had several limitations. First, we used mortality only as an end point. Smoking cessation also leads to compression of morbidity and improvement in quality of life.[25] Second, we do not know whether the decline in baseline cardiovascular deaths will continue.[26] Lung cancer death rates in lifelong nonsmokers were stable from the Cancer Prevention Study I (1959–1965) to the Cancer Prevention Study II (1982–1988), but this stability could disappear.[5] Third, our analyses did not directly control for duration of smoking or age at quitting, even though we controlled for age directly, and the specification we used did control for age at cessation somewhat. The fact that the relative risk of death for current smokers rises and then falls with increasing age despite the fact that age is highly correlated with duration of smoking suggests that further stratification that directly accounts for these 2 determinants of lung cancer might improve estimates; however, such a specification would result in small-cell problems even with a database as large as that of the Cancer Prevention Study II. Finally, we did not estimate the economic savings from reduced sickness or otherwise associated with smoking cessation, another relevant area of benefit.

Our calculation of the benefits of smoking cessation in terms of life extension agrees with recent findings documented with data from the British population—smoking cessation at any age reduces the risk of mortality, and cessation by age 35 years avoids essentially all of the excess risk of smoking.[6] Our study differs from the British Doctors Study in that it focuses on the US population, illustrating that the significance of the British findings are not specific to Great Britain or to its smoking population. The major take-home message of that study was the decrease in cumulative risk of lung cancer death by age at cessation and the lung cancer mortality avoided, whereas our focus has been on overall life extension associated with smoking cessation at different ages. Although these 2 ways of documenting the benefit of smoking cessation are complementary, we believe that a focus on life extension is a more straightforward way of representing the benefits of smoking cessation to smokers. ■

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Contributors

D.H. Taylor helped conceptualize the study, interpreted findings, and wrote initial drafts and the final draft. V. Hasselblad helped conceptualize the study, completed the mortality projections, and commented on drafts. S.J. Henley estimated statistical models and commented on drafts. M.J. Thun helped conceptualize the study, interpreted findings, and commented on initial drafts. F.A. Sloan obtained the research funding, helped conceptualize the study, and commented on drafts.

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