Original Investigation

Tobacco Control and the Reduction in Smoking-Related Premature Deaths in the United States, 1964-2012

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IMPORTANCE January 2014 marks the 50th anniversary of the first surgeon general's report on smoking and health. This seminal document inspired efforts by governments, nongovernmental organizations, and the private sector to reduce the toll of cigarette smoking through reduced initiation and increased cessation.

OBJECTIVE To model reductions in smoking-related mortality associated with implementation of tobacco control since 1964.

DESIGN, SETTING, AND PARTICIPANTS Smoking histories for individual birth cohorts that actually occurred and under likely scenarios had tobacco control never emerged were estimated. National mortality rates and mortality rate ratio estimates from analytical studies of the effect of smoking on mortality yielded death rates by smoking status. Actual smoking-related mortality from 1964 through 2012 was compared with estimated mortality under no tobacco control that included a likely scenario (primary counterfactual) and upper and lower bounds that would capture plausible alternatives.

EXPOSURES National Health Interview Surveys yielded cigarette smoking histories for the US adult population in 1964-2012.

MAIN OUTCOMES AND MEASURES Number of premature deaths avoided and years of life saved were primary outcomes. Change in life expectancy at age 40 years associated with change in cigarette smoking exposure constituted another measure of overall health outcomes.

RESULTS In 1964-2012, an estimated 17.7 million deaths were related to smoking, an estimated 8.0 million (credible range [CR], 7.4-8.3 million, for the lower and upper tobacco control counterfactuals, respectively) fewer premature smoking-related deaths than what would have occurred under the alternatives and thus associated with tobacco control (5.3 million [CR, 4.8-5.5 million] men and 2.7 million [CR, 2.5-2.7 million] women). This resulted in an estimated 157 million years (CR, 139-165 million) of life saved, a mean of 19.6 years for each beneficiary (111 million [CR, 97-117 million] for men, 46 million [CR, 42-48 million] for women). During this time, estimated life expectancy at age 40 years increased 7.8 years for men and 5.4 years for women, of which tobacco control is associated with 2.3 years (CR, 1.8-2.5) (30% [CR, 23%-32%]) of the increase for men and 1.6 years (CR, 1.4-1.7) (29% [CR, 25%-32%]) for women.

CONCLUSIONS AND RELEVANCE Tobacco control was estimated to be associated with avoidance of 8 million premature deaths and an estimated extended mean life span of 19 to 20 years. Although tobacco control represents an important public health achievement, efforts must continue to reduce the effect of smoking on the nation's death toll.

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January 2014 marks the 50th anniversary of the first surgeon general's report on smoking and health.[1] The report inaugurated efforts to reduce cigarette smoking and its effects on health. Those efforts by governments, voluntary organizations, and the private sector—education on smoking's dangers, increases in cigarette taxes, smoke-free air laws, media campaigns, marketing and sales restrictions, lawsuits, and cessation treatment programs—have comprised the nation's tobacco control efforts. Recently, Warner et al[2] documented an important reduction in cigarette consumption associated with tobacco control. This report estimates how many individuals in the United States have gained additional years of life from 1964 through 2012 as a result of tobacco control-influenced decisions to quit smoking or to never start.

The Cancer Intervention and Surveillance Modeling Network (CISNET) estimated 800 000 lung cancer deaths avoided between 1975 and 2000 as a result of tobacco control.[3] CISNET used a common set of smoking history and mortality parameters in population cancer models to estimate the expected difference in the number of lung cancer deaths between smoking rates under actual tobacco control and under no tobacco control, ie, if smoking behavior subsequent to 1964 had not been affected by tobacco control.[4,5] These results were extended to consider all deaths rather than just lung cancer deaths and expand the examined time period from 1975-2000 to 1964-2012 to estimate the number of early deaths avoided and life-years saved that were associated with reduced cigarette smoking during this period. The relationship between tobacco control and life expectancy was also estimated.

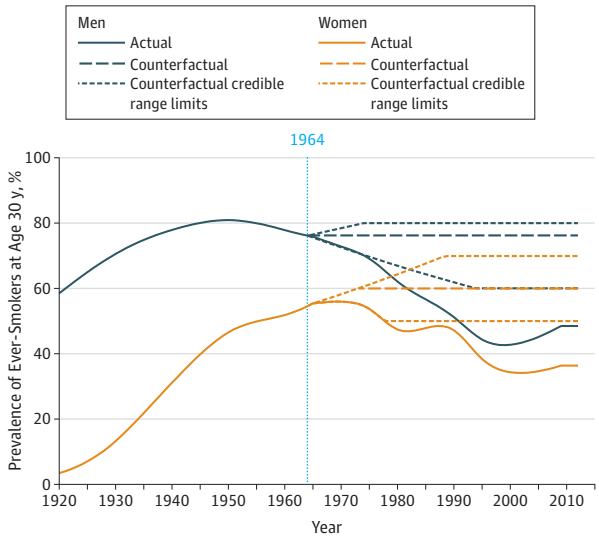
Methods

Smoking histories prior to 1964 were used to estimate likely patterns of smoking in the absence of tobacco control, which are referred to as counterfactual scenarios. In conjunction with national mortality rates and epidemiological studies of smoking and mortality, death rates expected under these counterfactuals were estimated. The differences in premature deaths, and associated life-years gained, under observed smoking rates and those under counterfactual scenarios were used to estimate the benefits associated with tobacco control.

Smoking History Estimation

Holford et al[6] refined the Anderson et al[7] technique, using National Health Interview Surveys (NHIS) for 1965-2009 to estimate smoking prevalence, initiation, and cessation for birth cohorts born after 1864. Thirty-three surveys provided smoking status, 13 of which also provided age at initiation, cessation, and intensity, thereby enabling retrospective construction of smoking histories. Higher mortality among smokers implies that survey participants represent a biased sample of the population born in a given year. The method corrects for this bias,[6] providing ever-smoker (individuals who have smoked ≥100 cigarettes) prevalence for ages 0 to 99 years and birth cohorts from 1864-1980 by 1-year intervals. Conditional cessation probabilities were similarly obtained, yielding cumulative estimates of cessation. Multiplying the cumulative cessation probability by ever-smoker prevalence provided former smoker prevalence, and multiplying by the complement yielded current smoker prevalence. Never-smoker prevalence is 1 minus ever-smoker prevalence. These estimates reflect smoking patterns under actual tobacco control since 1964.

Figure 1. Estimated Ever-Smoker Prevalence at Age 30 Years by Sex

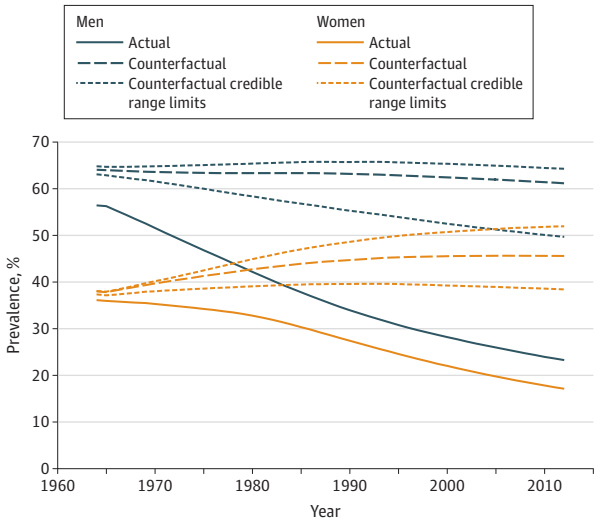


For the no tobacco control counterfactuals, Holford and Clarke's method[4] was modified to estimate smoking prevalence, initiation, and cessation rates that could be expected had the era of tobacco control following the 1964 surgeon general's report[1] not occurred. Ever-smoker prevalence by cohort was considered to develop a plausible range of counterfactuals. Most all initiation has generally taken place by age 30 years, so this provides a useful reference for positing alternative initiation scenarios. **Figure 1** shows ever-smoker prevalence estimates at age 30 years by year and sex.[6]

Male smoking prevalence began to decline before 1964, possibly reflecting awareness of research from the early 1950s showing an association with lung cancer.[8,9] The 1920 birth cohort achieved the male maximum ever-smoking prevalence of about 80% at age 30 years, and a return to this was defined as the upper no tobacco control counterfactual for men. The actual level in 1964 was the primary counterfactual, and a decline to 60% was defined as the lower bound.

Increasing social acceptance of smoking and advertising targeting women tended to increase smoking prevalence in women just when awareness of adverse health effects was taking hold. The rate of smoking among women was increasing at a rate that paralleled that of men about 3 decades earlier.[10] As an upper bound counterfactual, female ever-smoker prevalence at age 30 years was assumed to have continued its upward trajectory, eventually reaching 70%, 10 percentage points below the maximum for men. A more conservative increase to 60% prevalence was defined as the primary counterfactual, and decline to 50% was defined as the lower limit, despite clear indications that this would have been unlikely.

Figure 2. Estimated Prevalence of Current Smokers by Sex



All-Cause Mortality Rates by Birth Cohort and Smoking Status

Rosenberg et al[11] developed methodology for estimating cause-specific cohort life tables by smoking status. As described in the eMethods (in the Supplement), the method was adapted to obtain all-cause cohort life tables by sex and smoking status (never, former, and current) for the 1864-1980 birth cohorts. The methodology uses (1) mortality relative risk estimates by sex and smoking status derived from the first 2 American Cancer Society Cancer Prevention Studies[12,13] and the NHANES (National Health and Nutrition Examination Survey) Epidemiologic Follow-up Studies[14] and (2) smoking prevalence described earlier in this section to partition US all-cause mortality tables[15] by smoking status.

Population Estimates

Population estimates in the United States by single years of age (0-85+) were obtained from US government websites: 1964-1968, US Census[16]; 1969-2011, Surveillance, Epidemiology, and End Results[17]; and 2012, US Census.[18]

Calculation of Premature Deaths

The difference between mortality rates for both current or former smokers and never-smokers measures the avoidable increase related to cigarette smoking exposure. The number of premature deaths is the product of this difference and the corresponding number of current or former smokers (population × smoking prevalence). These were calculated by single year of age, calendar year, smoking status, and sex and summed over the appropriate age range for each year yielding total premature deaths. These were calculated for all ages and for those younger than 65 years. The difference under the actual and no tobacco control scenarios provided a measure of mortality reduction related to tobacco control.

Years of Life Lost

Yearly death rates for a cohort were used to estimate expected years of life remaining given that an individual is alive at a given age (eMethods in the Supplement). All deaths were assumed to occur before age 100 years, the upper limit of reported age-specific death rates. If a rate was not available for a particular age, the value from the nearest cohort was used. Expected years of life remaining estimates years of life lost (YLL) for a premature death. Total YLL is the sum of the product of number of premature deaths and expected years of life remaining for a never-smoker. Total YLL before age 65 years was calculated to examine this outcome of smoking associated mortality on the working-age population.

Life Expectancy

Life expectancy provides an alternative summary measure of mortality rates, and it is commonly used to assess the overall health of a population. It essentially envisions a hypothetical population that experiences a set of age-specific mortality rates that occur in a year and determines the resulting expected length of life after a given age. This was calculated using actual and counterfactual mortality rates beginning at age 40 years to better measure the effect of cigarette smoking and to remove infant and childhood mortality effects.

Results

Figure 2 shows prevalence of current smokers, aged 18 years and older, under the actual and counterfactual scenarios. For men, the actual trend was steadily downward, and although the decrease for women was initially slow, it accelerated after 1980. For the lower male counterfactual, prevalence declined steadily, while the upper and primary estimates were fairly flat initially but declined slightly after 1990. For women, there was a modest increase for the lower counterfactual and greater increases for primary and higher scenarios. By 2012, under the counterfactual scenarios, smoking prevalence would have ranged from 50% to 64% for men and from 38% to 52% for women. Age-specific prevalences are shown eFigures 1-3 in the eResults section of the Supplement.

Table 1 shows the estimated number of premature deaths related to smoking in the United States in 1964-2012 compared with number of deaths estimated under the counterfactual scenarios. (Age-specific mortality rates by smoking status and counterfactual scenario are shown in the Supplement in eFigures 4 and 5, respectively, and eFigure 6 shows the estimated change in population structure under the primary counterfactual.) With tobacco control, the model estimates a total of 17.7 million smoking-attributable deaths between 1964 and 2012. Overall, an estimated reduction of 8.0 million (credible range [CR], 7.4-8.3 million) premature smoking-attributable deaths (subsequently referred to as "lives saved") were associated with tobacco control in 1964-2012 (5.3 million [CR, 4.8-5.5 million] men and 2.7 million [CR, 2.5-2.7 million] women). More than half of these, 4.4 million [CR, 3.8-4.7 million], occurred before age 65 years (3.4 million [CR, 3.0-3.6 million] men and 1.0 million [CR, 0.9-1.1 million] women).

Table 1. Estimated Smoking Attributable Deaths (×1000) Avoided by Tobacco Control (All Ages and Ages <65 Years)

	Actual, No.	Primary Counterfactual		Lower Limit		Upper Limit	
		No.	Saved (%)	No.	Saved (%)	No.	Saved (%)
All Ages							
Men							
1964-1973	2512	2867	355 (12)	2867	355 (12)	2867	355 (12)
1974-1983	2711	3377	665 (20)	3374	663 (20)	3380	668 (20)
1984-1993	2903	3930	1027 (26)	3897	994 (25)	3953	1050 (27)
1994-2003	2744	4257	1514 (36)	4119	1375 (33)	4328	1584 (37)
2004-2012	2271	4028	1758 (44)	3729	1458 (39)	4150	1879 (45)
Total	13 141	18 460	5319 (29)	17 986	4845 (27)	18 678	5537 (30)
Women							
1964-1973	497	526	29 (5)	526	29 (5)	526	29 (5)
1974-1983	834	980	146 (15)	979	146 (15)	980	146 (15)
1984-1993	1148	1590	442 (28)	1584	436 (28)	1591	442 (28)
1994-2003	1155	2064	909 (44)	2028	873 (43)	2074	918 (44)
2004-2012	895	2050	1155 (56)	1935	1040 (54)	2101	1206 (57)
Total	4529	7210	2681 (37)	7053	2524 (36)	7271	2742 (38)
Both							
1964-1973	3009	3393	384 (11)	3393	384 (11)	3393	384 (11)
1974-1983	3545	4357	811 (19)	4353	808 (19)	4359	814 (19)
1984-1993	4052	5520	1469 (27)	5481	1430 (26)	5544	1492 (27)
1994-2003	3899	6322	2423 (38)	6147	2248 (37)	6402	2503 (39)
2004-2012	3166	6079	2913 (48)	5664	2498 (44)	6251	3086 (49)
Total	17 670	25 670	8000 (31)	25 039	7368 (29)	25 950	8279 (32)
Ages <65 Years							
Men							
1964-1973	1335	1593	258 (16)	1593	258 (16)	1593	258 (16)
1974-1983	1214	1615	400 (25)	1612	398 (25)	1618	403 (25)
1984-1993	1041	1613	572 (35)	1580	539 (34)	1636	595 (36)
1994-2003	835	1773	938 (53)	1636	801 (49)	1842	1007 (55)
2004-2012	738	1975	1236 (63)	1708	970 (57)	2069	1331 (64)
Total	5164	8569	3405 (40)	8129	2965 (36)	8758	3594 (41)
Women							
1964-1973	284	306	22 (7)	306	22 (7)	306	22 (7)
1974-1983	366	443	78 (18)	443	77 (17)	443	78 (18)
1984-1993	347	504	156 (31)	498	151 (30)	504	157 (31)
1994-2003	248	548	300 (55)	513	264 (52)	558	309 (55)
2004-2012	198	649	451 (69)	555	357 (64)	699	500 (72)
Total	1443	2450	1007 (41)	2315	871 (38)	2510	1067 (42)
Both							
1964-1973	1619	1900	281 (15)	1900	281 (15)	1900	281 (15)
1974-1983	1580	2058	478 (23)	2055	475 (23)	2061	481 (23)
1984-1993	1389	2117	728 (34)	2078	689 (33)	2141	752 (35)
1994-2003	1083	2321	1238 (53)	2149	1065 (50)	2400	1316 (55)
2004-2012	936	2624	1687 (64)	2263	1327 (59)	2768	1831 (66)
Total	6607	11 019	4412 (40)	10 444	3837 (37)	11 268	4661 (41)

The estimated number of lives saved each year has increased steadily over time. So too has the percentage saved as a fraction of smoking-attributable deaths that are projected (applying the counterfactuals to both men and women) to have occurred in the absence of tobacco control, from 11% in the first decade to 48% (CR, 44%-49%) in 2004-2012. For deaths before age 65 years, the estimated percentage of lives saved increased from 15% to 64% (CR, 59%-66%). In recent years, the proportion of lives saved among women (69% [CR, 64%-72%]) appear to be even greater than among men (63% [CR, 57%-64%]).

Table 2 shows estimated YLL and estimated lives saved under the counterfactual scenarios by calendar year and sex for all ages and ages younger than 65 years. Overall, a gain of

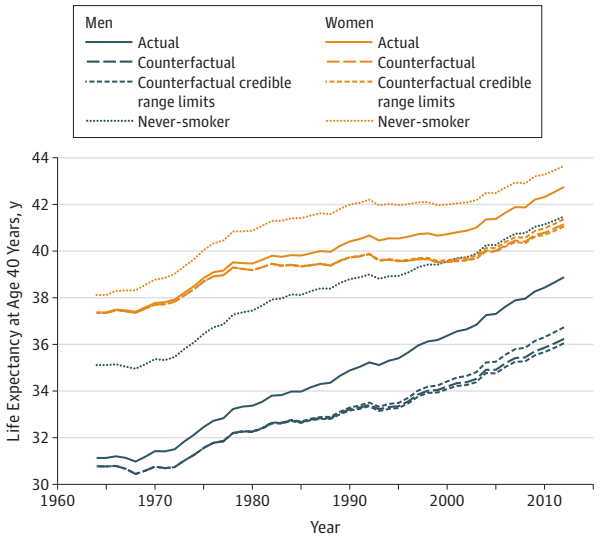
Table 2. Years of Life Lost (×1000) by Tobacco Control and Sex (All Ages and Ages <65 Years)

	Actual, No.	Primary Counterfactual		Lower Limit		Upper Limit	
		No.	Saved (%)	No.	Saved (%)	No.	Saved (%)
All Ages							
Men							
1964-1973	40 585	47 579	6994 (15)	47 579	6994 (15)	47 579	6994 (15)
1974-1983	40 625	52 565	11 939 (23)	52 466	11 841 (23)	52 661	12 035 (23)
1984-1993	40 640	59 639	18 999 (32)	58 535	17 895 (31)	60 375	19 735 (33)
1994-2003	37 446	69 866	32 419 (46)	65 676	28 230 (43)	71 838	34 392 (48)
2004-2012	32 287	73 132	40 845 (56)	65 013	32 725 (50)	76 085	43 797 (58)
Total	191 584	302 781	111 197 (37)	289 269	97 685 (34)	308 537	116 953 (38)
Women							
1964-1973	8970	9609	640 (7)	9609	640 (7)	9609	640 (7)
1974-1983	13 591	16 305	2715 (17)	16 293	2702 (17)	16 305	2715 (17)
1984-1993	16 852	24 166	7314 (30)	23 964	7112 (30)	24 191	7339 (30)
1994-2003	15 266	30 193	14 927 (49)	29 133	13 867 (48)	30 496	15 230 (50)
2004-2012	11 717	32 103	20 386 (64)	29 166	17 449 (60)	33 585	21 868 (65)
Total	66 396	112 377	45 981 (41)	108 164	41 769 (39)	114 187	47 791 (42)
Both							
1964-1973	49 555	57 188	7633 (13)	57 188	7633 (13)	57 188	7633 (13)
1974-1983	54 216	68 870	14 654 (21)	68 759	14 543 (21)	68 966	14 750 (21)
1984-1993	57 493	83 805	26 313 (31)	82 499	25 007 (30)	84 566	27 073 (32)
1994-2003	52 712	100 059	47 347 (47)	94 809	42 096 (44)	102 334	49 622 (48)
2004-2012	44 004	105 235	61 231 (58)	94 178	50 174 (53)	109 670	65 666 (60)
Total	257 980	415 157	157 178 (38)	397 433	139 454 (35)	422 724	164 744 (39)
Ages <65 Years							
Men							
1964-1973	12 095	14 589	2494 (17)	14 589	2494 (17)	14 589	2494 (17)
1974-1983	9876	13 391	3515 (26)	13 333	3457 (26)	13 447	3572 (27)
1984-1993	8343	13 733	5390 (39)	13 146	4802 (37)	14 115	5772 (41)
1994-2003	7007	17 282	10 275 (59)	15 386	8379 (54)	18 089	11 082 (61)
2004-2012	5792	18 232	12 440 (68)	15 272	9480 (62)	19 124	13 332 (70)
Total	43 113	77 227	34 114 (44)	71 726	28 613 (40)	79 364	36 251 (46)
Women							
1964-1973	2751	2973	222 (7)	2973	222 (7)	2973	222 (7)
1974-1983	2827	3427	600 (17)	3420	593 (17)	3427	600 (17)
1984-1993	2270	3429	1159 (34)	3332	1062 (32)	3442	1172 (34)
1994-2003	1359	3694	2336 (63)	3319	1961 (59)	3819	2460 (64)
2004-2012	1115	4314	3199 (74)	3627	2512 (69)	4783	3668 (77)
Total	10 323	17 838	7515 (42)	16 672	6349 (38)	18 444	8121 (44)
Both							
1964-1973	14 847	17 563	2716 (15)	17 563	2716 (15)	17 563	2716 (15)
1974-1983	12 703	16 818	4114 (24)	16 753	4050 (24)	16 874	4171 (25)
1984-1993	10 613	17 162	6549 (38)	16 478	5864 (36)	17 557	6943 (40)
1994-2003	8366	20 976	12 611 (60)	18 705	10 339 (55)	21 908	13 542 (62)
2004-2012	6907	22 546	15 639 (69)	18 900	11 993 (63)	23 907	17 000 (71)
Total	53 436	95 065	41 629 (44)	88 398	34 962 (40)	97 808	44 372 (45)

157 million years (CR, 139-165 million) of life was associated with tobacco control, 111 million (CR, 98-117 million) for men and 46 million (CR, 42-48 million) for women. This suggests that individuals who avoided a premature smoking-related death gained 19.6 years of life on average (157 million years divided by 8.0 million lives saved). Before age 65 years, 42 million years (CR, 35-44 million) of life were saved, 34 million (CR, 29-36 million) for men and 8 million (CR, 6-8 million) for women. Similar to the pattern for premature deaths, the trend in proportion of years of life saved has shown a steady increase over time, increasing to 69% (CR, 63%-71%) in 2004-2012 from 15% in 1964-1973. The proportion of years of life saved has been greater among women than men.

Changing from the perspective of individuals who avoided premature deaths to the population as a whole, the estimated trend in life expectancy at age 40 years is shown in **Figure 3**. For men, life expectancy at age 40 years increased 7.8 years (31.1 years in 1964 to 38.9 years in 2012). Without tobacco control, the estimated increase would have been 5.5 years (CR, 5.3-6.0). Hence, 2.3 years (CR, 1.8-2.5) or 30% (CR, 23%-32%) of improved life expectancy for men is projected to be associated with tobacco control. In women, life expectancy at age 40 years increased 5.4 years (from 37.4 to 42.7 years), but without tobacco control, it would have been projected to increase by only 3.8 years (from 37.3 to 41.2 years). Tobacco control appears to be associated with 1.6 years (CR, 1.4-1.7) of the improvement in life expectancy for women or 29% (CR, 25%-32%) of the gain. The estimates of life expectancy at ages 50 and 60 years are shown in eFigure 9 in the Supplement.

Figure 3. Life Expectancy at Age 40 Years by Sex



Discussion

Tobacco control has made a unique and substantial contribution to public health over the past half century. This study provides a quantitative perspective to the magnitude of that contribution. The collectivity of tobacco control efforts since the first surgeon general's report was associated with the avoidance of an estimated 8.0 million (CR, 7.4-8.3 million) premature smoking-attributable deaths. Furthermore, with an estimated 157 million life-years saved, the beneficiaries of these avoided early deaths have gained, on average, nearly 2 decades of life.

In an earlier analysis of the effect of antismoking efforts on premature deaths, Warner[19] concluded that 789 000 premature deaths had been avoided through 1985. He estimated that tobacco control–influenced decisions not to smoke through that year would have resulted in 2.1 million additional premature deaths avoided between 1986 and 2000. Estimates from this analysis are substantially higher than those reported by Warner because we evaluated a much longer period of time, and the gap between actual smoking and the counterfactual scenarios has changed substantially.

Of the 8.0 million premature smoking deaths avoided, 4.4 million (CR, 3.8-4.6 million) were estimated to occur before age 65 years. This implies the avoidance of a large productivity loss due to illness and death during those working ages, which is estimated to impose a cost of about $100 billion annually in the United States.[20]

The relationship between tobacco control and life expectancy was also estimated: an increase of 2.3 years (CR, 1.8-2.5 years) for men and 1.6 years (CR, 1.4-1.7) for women after age 40 years. That these figures represent 30% (CR, 23%-32%) for men and 29% (CR, 25%-31%) for women of the total life expectancy gain in 1964-2012 demonstrates the important influence of tobacco control on the life expectancy of US adults.

The specifics of the findings of this study depend on a number of assumptions, as well as the methods by which they were incorporated in the analysis. Most importantly, the findings depend on counterfactual estimates of what smoking prevalence would have been in the absence of tobacco control. A cohort analysis was used, which considered a range of estimates based on smoking histories prior to 1964. Use of smoking prevalence at age 30 years, when further initiation is unlikely, provided a group whose initiation of smoking would not have been influenced by the surgeon general's report in 1964.

It is much more difficult to isolate the effect on cessation probabilities of what transpired after 1964 from what began in the 1950s. The 1890 birth cohort provides the best estimate of cessation probabilities in the absence of tobacco control, a group in their 60s in 1950 when the first prominent research on smoking and lung cancer appeared.[8,9] The difference in men between actual smoking prevalence and the counterfactuals in 1964 (Figure 2) reflects small decreases in male smoking prevalence during the 1950s, which may have been in response to those studies, publicity about which itself constituted a form of tobacco control. Somewhat artificially, examination of premature deaths avoided began in 1964, thus ignoring initial stages of tobacco control from the 1950s, because the surgeon general's report is considered to have ushered in the tobacco control era. Although per capita cigarette consumption declined briefly after publication of the early research, the trend was not sustained, and it resumed its upward trajectory in 1955, continuing through 1963.[2] Premature death estimates included men who benefitted from cessation in the 1950s, but their contribution to mortality was small before the 1964 milestone. However, prolonged reduction in male smoking was considered in the lower bound counterfactual scenario, which declines continuously as seen in Figure 2.

Although it is conceivable that female smoking rates might have declined after 1964 in the absence of tobacco control, there is considerable evidence to suggest that these smoking rates would have continued upward.[2,10] In exploring how high smoking rates would have increased, alternatives of 50% ever-smoker prevalence at age 30 years as the primary counterfactual and a peak of 60% the upper bound, well below the rate

attained by men, were considered. Men reached their maximum smoking rate before 1964, but the level in 1964 was chosen as the primary counterfactual with bounds that decline to 60% or return to 80% ever-prevalence at age 30 years. In addition, there is uncertainty in the estimates of relative risk used in computing the mortality rates and in the actual smoking rates derived from NHIS, although these are large surveys with precise estimates.

Mortality relative risks associated with smoking are based on the Cancer Prevention Studies CPS-I and CPS-II, which cover the period of 1961-1999. Subsequent relative risks were assumed to have remained constant at the 1999 level. However, a recent study by Thun et al[21] indicated that mortality relative risk for current smokers compared with never-smokers may be continuing to increase, suggesting that lives saved may have been underestimated in this analysis. Another potential limitation of this analysis is that the cessation probability estimates did not control for smoking duration and years smoked. The increasing mean duration and years quit by age were indirectly accounted for in the actual tobacco control scenario by using age- and smoking status–specific mortality rates calibrated to US mortality. The expected longer mean duration for smokers and shorter years quit for former smokers under counterfactuals would not have been captured entirely, however, thereby underestimating death rates and hence health benefits from tobacco control. Further, the role of smoking intensity was not explicitly considered in this analysis, which has been declining steadily since the 1960s.[6] Because intensity is likely to have been higher in the absence of tobacco control, there may have been further gains not accounted for in the analysis.

Although all of these considerations could affect the findings, the estimates of life expectancy at age 40 years, for both 1964 and 2012 and for both sexes, are close to US federal government statistics.[22,23] Because the life expectancy estimates derive from the analysis, this provides strong validation of the methods and calculations.

For the future, a potential factor that may offset the gains estimated in this study is the recent increase in use, particularly among young adults, of noncigarette forms of tobacco, such as smokeless tobacco, cigars, hookahs, and e-cigarettes.[24-26] If these products are used instead of cigarettes, the adverse health effects are likely considerably less than that of cigarettes. However, if used in combination with cigarettes, these products may offset some of the potential benefits, especially as these young adults reach ages when smoking begins to claim its toll. The pattern of alternative tobacco product use that would have evolved had tobacco control never affected cigarette smoking is unknown.

Past successes of tobacco control have relied primarily on tax increases, media campaigns, smoke-free air laws, and advertising bans. Cessation treatment policies have also played a role but could play an increasing one. Physician interventions, such as the 5As (Ask, Advise, Assess, Assist, Arrange)[27] and the Ask, Advise, and Connect[28] method, which encourage quitting and the use of effective cessation treatments, can increase quit rates.[29] In addition, supply-side policies can play an important role with the Food and Drug Administration's recently granted authority to regulate cigarettes and smokeless tobacco products.

Conclusions

Despite the success of tobacco control efforts in reducing premature deaths in the United States, smoking remains a significant public health problem. During the time that tobacco control was associated with extending the lives of an estimated 8 million US individuals, smoking-attributable mortality occurred in approximately 17.7 million others. Today, a half century after the surgeon general's first pronouncement on the toll that smoking exacts from US society, nearly a fifth of US adults continue to smoke, and smoking continues to claim hundreds of thousands of lives annually. No other behavior comes close to contributing so heavily to the nation's mortality burden. Tobacco control has been a great public health success story but requires continued efforts to eliminate tobacco-related morbidity and mortality.

ARTICLE INFORMATION

Author Contributions: Dr Holford had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Holford, Meza, Warner, Moolgavkar, Levy.
Acquisition of data: Holford, Meza.
Analysis and interpretation of data: Holford, Meza, Meernik, Jeon, Moolgavkar, Levy.
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Critical revision of the manuscript for important intellectual content: Holford, Meza, Warner, Jeon, Moolgavkar, Levy.
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