10. Cost-effectiveness of ASSIST

Richard M. Peck and Mary Ellen Wewers

Contributors: Anne M. Hartman and Barry I. Graubard

Contents

Tables

10. Cost-effectiveness of ASSIST

The data on the cost-effectiveness of the American Stop Smoking Intervention Study (ASSIST) were analyzed in terms of cost per life-year gained and cost per quit. This chapter reports the findings of those analyses and examines the methodology used to estimate this cost-effectiveness, as well as factors and assumptions affecting the results.

The analyses yielded a cost-effectiveness best estimate of $1,255 per quit and $2,093.02 per life-year gained, based on a conservative assumption of a 0.63 decrease in tobacco prevalence rates attributable to ASSIST. These estimates compare favorably with alternatives such as intensive physician-based interventions and the implementation of formal smoking cessation guidelines, as well as other accepted public health-related interventions such as mammography. Moreover, effects not considered in the analysis, such as the long-term effects of policy interventions and the development of a tobacco control infrastructure, have the potential to reduce these costs further. Thus, the ASSIST intervention represents a cost-effective approach to the improvement of public health.

Introduction

This chapter documents the cost-effectiveness of ASSIST. The analysis demonstrated that the conservatively estimated cost of each life-year gained from ASSIST compares favorably with the cost per life-year gained from many other population-level public health interventions.

The decision to implement any publicly funded public health intervention must address two basic questions. First, does the intervention have beneficial effects? Second, are the effects large enough to justify the expense of the intervention—in other words, is the intervention cost-effective? Examining cost-effectiveness enables an assessment of the value per dollar spent on one program compared with amounts spent on other programs and, therefore, provides essential information for decisions about how to spend scarce resources.

In this chapter, two effects of ASSIST are examined in light of the total expenditures of the project: how many people quit smoking and how many life-years were gained. The analyses show that ASSIST was cost-effective and yielded an improvement in public health, per dollar spent, that is highly competitive with a broad range of public health interventions. The estimated cost per quit is $1,255, and the dollar amount spent per life-year gained is $2,093. In the context of other public health interventions, the cost per life-year gained attributable to ASSIST is less than the cost per life-year gained attributable to other types of preventive interventions.

The population reached by ASSIST was large—in 1999, about 73.3 million adults throughout 17 states. Of these 73.3 million adults, about 20 million were smokers. Thus, even a small reduction of smoking prevalence in this population would represent a large effect in terms of the number of people who either quit smoking or did not initiate smoking. For example, for a population of this size, a decrease of 0.1 percentage points in the average prevalence of smoking would translate into about 70,000 individuals. Therefore, on a per person basis, the cost of preventing tobacco use is likely to be low. A cost-effectiveness analysis is a method for determining that cost.[1]

The principal application of cost-effectiveness calculations is to compare competing interventions; therefore, an important consideration in selecting the outcome measure is its comparability with data from other relevant interventions. Several other types of calculations provide benchmarks by which the cost of a program can be measured. Numerous studies have estimated the dollar cost per life-year gained for a variety of interventions, thereby providing useful benchmarks.[2]

A Cost-effectiveness Analysis: The Basic Approach

The basic approach to a cost-effectiveness analysis is as follows.

- An intervention is undertaken: for example, a medical procedure, an educational program, the placement of a guardrail or additional lighting on a busy highway, and so forth.
- Corresponding to the particular intervention, an outcome (or a set of outcomes) is identified: typically a measure that can be quantified, such as a death rate, lives gained, life-years gained, or some other effect determined by the nature and purpose of the intervention.
- The measure is assessed prior to the intervention to establish its baseline level of occurrence in the absence of exposure to the intervention.
- The intervention is implemented.
- After the intervention has occurred, the outcome measure is re-assessed, and change in the measure is determined from the baseline level.

The total cost (fixed, variable, and marginal costs combined) of the intervention is then divided by the change in the outcome measure to compute the dollar cost per unit change in outcome. Expressed as an equation, the basic cost-effectiveness measure is a ratio:

$$\text{cost-effectiveness} = \text{total cost} / \text{change in outcome due to intervention.} \qquad (10.1)$$

The lower the resulting number, the more cost-effective, or economical, is the program.

Present Discounted Value

Rarely are the costs and outcomes so clearly defined and simultaneously related as in the guardrail example (see sidebar). More typically, expenditures and outcomes occur at different points in time, and the costs are not constant.

An Example of Cost-effectiveness

The following simple example illustrates the basic approach to analyzing cost-effectiveness.

Suppose there is a stretch of road where a large number of fatal auto accidents occur; the number of deaths per year is 10. A guardrail, which will last about 5 years and costs $2.5 million, is installed. It lasts only 5 years because it is struck by cars and quickly becomes ineffective and must be replaced. After the guardrail is installed, the total number of fatalities decreases to 8 per year. Hence, the annual cost per year is $500,000, and the number of lives gained is 2. Thus, the cost per life gained is $250,000. The policy issue is, of course, whether there is another intervention that would give a lower cost per life gained. If installation of additional traffic lights costs $1 million per year but gains 10 lives, the cost per life gained of this intervention would be $100,000. Traffic lights would be a more cost-effective policy option. If funds are limited, cost-effectiveness suggests that traffic lights should probably take precedence over the installation of a guardrail.

Indeed, often the full effect of an intervention is not manifest until many years after the intervention actually takes place. In the case of ASSIST, expenditures were incurred beginning in 1991 (through 1999), but the principal outcome, the decrease in smoking prevalence, was not measured until 1999. Moreover, the reason the decrease in smoking prevalence is important is that it is linked to a subsequent decrease in morbidity and mortality, but these effects are not realized for many years.

The procedure for taking into account the scattered timing of outcomes and expenditures is called *discounting*. The basic premise underlying discounting is time preference: a dollar now is worth more than receiving a dollar a year from now. Accordingly, saving a life now is viewed as being more valuable than saving a life in the distant future. Similarly, society prefers to have resources available now as opposed to later, because those resources yield benefits in the interim. Accordingly, an expenditure E that takes place S years prior to the outcome has a value in the year for which the analysis is being conducted. This value is called a *present discounted value* (PDV) and is expressed by the equation

$$PDV \text{ of } E = E(1+r)^S. \qquad (10.2)$$

In equation 10.2, r is called the *discount rate*. For example, if r is 3%,* then $100 spent 10 years ago has a present value of about $134. A past expenditure has a present discounted value that is typically larger than the original amount of the expenditure. An expenditure T years in the future, on the other hand, has a present discounted value given by the formula

$$PDV \text{ of } E = E(1 + r)^{-T} = E/(1 + r)^T. \qquad (10.3)$$

The present discounted value of a future expenditure E is typically smaller than the actual amount E that will accrue in the future. Thus, for r equals 3% (r = 0.03), $100 that will be spent 10 years from now has a present discounted value of $74.71.

Briefly, discounting enters into the ASSIST expenditure calculations as follows. Some ASSIST expenditures

*A standard assumption in cost-effectiveness estimates is that $r = 3\%$.

occurred years before the outcomes were measured. The present value of these expenditures, as measured in 1999, is higher than the actual amount spent in earlier years. While the actual amount spent over the years 1991–98 was $124.3 million, after adjusting for inflation and making present discounted value adjustments, the amount comes to $150.2 million. In addition, the outcome of life-years gained from smoking cessation induced by ASSIST will be realized many years in the future. Here, discounting yields a smaller value for the life-years gained due to ASSIST. The full effects of discounting are presented in tables 10.1 and 10. 2 (for expenditures) and table 10.3 (for discounted life-years saved).

The Role of Sensitivity Analysis in Cost-effectiveness

A standard procedure in a cost-effectiveness analysis is to examine how sensitive results and conclusions are to various key assumptions in the analysis. One needs to undertake this exercise because virtually all cost-effectiveness studies involve some uncertainty about assumptions. This analysis is done by changing assumptions and parameters of the study and then examining how conclusions and results are altered. A sensitivity analysis was performed as part of evaluating the cost-effectiveness of the ASSIST interventions, and details of this analysis are presented in tables 10.4, 10.5, and 10.6.

It is standard in a well-constructed cost-effectiveness study to include a discussion of alternative assumptions; essentially, one wants to test how sensitive the ranking of various alternatives is to "tweaking" or modifying these assumptions. Further discussions of the role of sensitivity analyses in cost-effectiveness studies can be found in *Methods for the Economic Evaluation of Health Care Programs.*[1]

Cost-effectiveness: ASSIST

Data Sources

Population Data

The Tobacco Use Supplement of the Current Population Survey (TUS-CPS),[3] developed by National Cancer Institute staff, was used to ascertain smoking prevalences for each state and the District of Columbia. Prevalence estimates from September 1998, January 1999, and May 1999 were combined and served as the outcome measure of smoking prevalence for each ASSIST state. The methodology is described in chapters 4 and 9 and has been published elsewhere.[4,5]

Expenditure Data

Staff from the National Cancer Institute's Contracts Office calculated total annual expenditures for each of the 17 ASSIST states. These expenditures were derived from quarterly financial reports submitted to the Contracts Office by each designated state ASSIST budget officer during the years 1991–98. Direct expenditure categories included (1) total labor, including fringe benefits; (2) nonexpendable equipment; (3) materials/supplies; (4) local travel; (5) national travel; (6) advertising; (7) intervention; (8) mobilization; (9) other costs (e.g., printing, conference expenditures); and

Table 10.1. ASSIST Total State Expenditures

	Total raw expenditures		
State	**1991–98 dollars**	**Constant 1999 dollars**	**Discounted 1999 dollars**
Colorado	8,260,979	8,984,179	10,055,436
Indiana	5,763,030	6,186,421	6,818,329
Maine	5,210,617	5,647,276	6,295,698
Massachusetts	7,486,699	8,028,884	8,837,345
Michigan	9,900,100	10,751,896	12,011,014
Minnesota	7,577,788	8,205,738	9,138,988
Missouri	6,882,817	7,484,172	8,378,485
New Jersey	7,597,419	8,226,867	9,163,094
New Mexico	5,330,994	5,805,699	6,512,573
New York	12,422,191	13,438,427	14,951,936
North Carolina	9,518,407	10,347,318	11,582,019
Rhode Island	5,120,477	5,547,537	6,185,110
South Carolina	5,846,040	6,302,111	6,985,959
Virginia	7,195,520	7,802,116	8,704,722
Washington	8,265,514	8,983,315	10,053,423
West Virginia	4,714,941	5,107,610	5,693,737
Wisconsin	7,241,516	7,885,140	8,841,855
Total	124,335,049	134,734,705	150,209,722
All ASSIST states			
Mean	7,313,826	7,925,571	8,835,866
SD	2,004,863	2,176,815	2,432,420
Coefficient of variation	0.27411962	0.27465721	0.27528936
Maximum/minimum			
Maximum (New York)	12,422,191	13,438,427	14,951,936
Minimum (West Virginia)	4,714,941	5,107,610	5,693,737

(10) cost-sharing. Indirect expenditures, as estimated by each ASSIST state, were added to the direct expenditures to yield total expenditures.

The raw expenditures are listed in the second column of table 10.1. The total actual (or nominal) expenditure by the 17 ASSIST states from 1991 to 1998 was about $124.3 million. The amounts spent by each state varied, from about $4.7 million (West Virginia) to $12.4 million (New York). The average spent per state was $7.3 million. Although the more-populated states, such as New York and Michigan, had the highest total expenditures, their per capita amounts were less than in the less-populated states. The average per capita expenditure for the entire ASSIST project for the period 1991 to 1998 was $2.45. (See

Table 10.2. ASSIST per Capita Expenditures (Adult Population, 18 Years Old and Older)

	Per capita expenditures		
State	**1991–98 dollars**	**Constant 1999 dollars**	**Discounted 1999 dollars**
Colorado	2.76	3.00	3.36
Indiana	1.31	1.40	1.54
Maine	5.41	5.87	6.54
Massachusetts	1.59	1.71	1.88
Michigan	1.36	1.47	1.64
Minnesota	2.16	2.34	2.61
Missouri	1.69	1.84	2.06
New Jersey	1.24	1.34	1.49
New Mexico	4.28	4.67	5.23
New York	0.90	0.98	1.09
North Carolina	1.67	1.81	2.03
Rhode Island	6.83	7.40	8.25
South Carolina	2.00	2.15	2.38
Virginia	1.38	1.50	1.67
Washington	1.94	2.10	2.35
West Virginia	3.36	3.64	4.06
Wisconsin	1.86	2.02	2.27
All ASSIST states			
Mean	2.45	2.66	2.97
SD	1.63	1.77	1.98
Coefficient of variation	0.66	0.67	0.67
Maximum/minimum			
Maximum (Rhode Island)	6.83	7.40	8.25
Minimum (New York)	0.90	0.98	1.09

table 10.2.) At the state level, per capita expenditures ranged from about $0.90 (New York) to $6.83 (Rhode Island).

Discounted Expenditure Data

The raw expenditure data were adjusted in the following ways: The first year of ASSIST expenditures is 1991, and the last year assessed in this analysis is 1998. (Although the project was funded through October 1, 1999, the prevalence data do not extend that far.) Though annual inflation rates were low during that time, over 8 years the consumer price index rose 22.3%; thus, it is necessary to adjust for inflation in the computations. Accordingly, total ASSIST expenditure, measured in inflation-adjusted constant 1999 dollars, was $134.7 million (table 10.1). Per capita inflation-adjusted expenditures (i.e., constant dollars measured in terms of 1999 prices and not

Table 10.3. Life-years Gained Attributable to ASSIST: Women

Age of quitting in 1999	Expected life-years gained	Expected life of smoker	Years to expected death	Discounted life-years gained (1999)	Total number of quits	Total life-years gained (population)	Discounted life-years gained (population)[a]
18.5	4.30	75.7	57.20	0.725	6,559	28,202	4,757
22	4.30	75.7	53.70	0.806	15,503	66,661	12,489
27	3.93	76.3	49.27	0.846	16,343	64,281	13,830
32	3.57	76.7	44.73	0.884	18,264	65,141	16,144
37	3.20	77.4	40.40	0.908	20,812	66,597	18,898
42	2.83	78.0	35.97	0.923	20,555	58,240	18,980
47	2.47	78.7	31.73	0.918	18,074	44,583	16,586
52	2.10	79.6	27.60	0.889	15,548	32,651	13,826
57	1.73	80.7	23.67	0.830	12,234	21,206	10,159
62	1.37	82.0	20.03	0.734	9,913	13,548	7,277
67	1.00	83.6	16.60	0.599	9,096	9,096	5,446
72	0.63	85.4	13.37	0.420	8,721	5,523	3,664
77	0.27	87.5	10.53	0.194	7,635	2,036	1,478
Total life-years gained						477,765	143,534

Note: The assumed recidivism rate is 0.50, and all quitters are assumed to be lifetime smokers.

[a]Discounted life-years gained (population) = Discounted life-years gained (per capita) × total number of quits.

Table 10.4. Cost-effectiveness with Various Recidivism Rates

Recidivism rate	Life-years gained	Discounted life-years gained	Dollars per discounted life-year gained
0.0	449,563	143,534	1,046.51
0.1	404,607	129,181	1,162.79
0.2	359,651	114,827	1,308.14
0.3	314,694	100,474	1,495.01
0.4	269,738	86,120	1,744.18
0.5	224,782	71,767	2,093.02
0.6	179,825	57,414	2,616.28
0.7	134,869	43,060	3,488.37
0.8	89,913	28,707	5,232.55
0.9	44,956	14,353	10,465.10

Notes: Discount rate = 0.03. Decrease in prevalence ratio, women = 0.0096. Fraction of permanent quitters who are lifetime smokers = 0.50. Total ASSIST expenditure = $150,209,722 (discounted constant value expenditures).

Table 10.5. Cost-effectiveness with Various Changes in Women's Prevalence Rates

Change in women's prevalence	Expected life-years gained	Discounted expected life-years gained	Dollars per life gained
0.002	46,829	14,951	10,046.49
0.004	93,659	29,903	5,023.25
0.006	140,488	44,854	3,348.83
0.008	187,318	59,806	2,511.62
0.010	234,147	74,757	2,009.30
0.012	280,977	89,709	1,674.42
0.0096	224,782	71,767	2,093.02
0.0014	32,781	10,466	14,352.14

Notes: Recidivism rate = 0.5%. Permanent quit rate = 0.5%. Change in male prevalence rate = 0.000.

Table 10.6. Fraction of Lifetime Smoker Quits Attributable to ASSIST

Fraction of quitters attributable to ASSIST	Life-years gained	Discounted expected life-years gained	Dollars per life-year gained	Dollars per permanent quit
0.1	44,956	14,353	10,465.10	7,900.16
0.2	89,913	28,707	5,232.55	3,950.08
0.3	134,869	43,060	3,488.37	2,633.39
0.4	179,825	57,414	2,616.28	1,975.04
0.5	224,782	71,767	2,093.02	1,580.03
0.6	269,738	86,120	1,744.18	1,316.69
0.7	314,694	100,474	1,495.01	1,128.59
0.8	359,651	114,827	1,308.00	987.52
0.9	404,607	129,181	1,162.79	877.80
1.0	449,563	143,534	1,046.51	790.02

discounted) for individuals 18 years old and older across all 8 years averaged $2.66 (table 10.2).

The second adjustment converts raw expenditures into present values for the year of the analysis. The effect of ASSIST in terms of reduced smoking prevalence was measured for 1999 compared with 1991, and ASSIST expenditures began in 1991. The 1991 dollar value is different from its 1999 value, just as an expenditure to be made in the distant future has a different value in any earlier year. These present values are determined by adjusting for the opportunity cost of foregone interest, that is, by computing the present discounted value. Let *W* represent the year in which an expenditure was made. The expenditure made in year W is converted to its 1999 value as follows: One dollar spent in year W has a 1999 value of $(1 + r)$,$^{1999-W}$ so that Z dollars spent in W have a 1999 value of $Z(1 + r)$.$^{1999-W}$ For example, for $W = 1991$, 1999 minus 1991 equals 8 years, so that if r is 0.03 (i.e., a 3% rate of interest), then the value of that 1991 dollar is $1.27 in 1999. After adjusting for inflation and after expressing all expenditures in values for the year of analysis, the total amount spent by the ASSIST states, expressed as a 1999 discounted value, is $150.2 million. The per capita expenditure, expressed as a 1999 discounted value, is $2.97 per adult. Detailed values are given in tables 10.1 and 10.2.

Cost per Quit and Noninitiation of Smoking

An important effect of ASSIST is the decrease in smoking prevalence in the ASSIST states. As reported in chapter 9, the decrease in the prevalence rate attributable to ASSIST is 0.63 percentage points.[6] There are significant gender differences, however, in the effects of ASSIST: For men, the prevalence rate declined for the total sample by 0.09 percentage points; for women, the ASSIST-attributable decline was 0.96 percentage points. A complete discussion of the assumptions underlying these estimates is provided in chapter 9; sensitivity analysis is provided in tables 10.4, 10.5, and 10.6. These figures are used to determine the decrease in the number of smokers (those who quit and those who did not initiate smoking); the 1999 adult population (18 years old and older) of ASSIST states is multiplied by the ASSIST-induced decrease in smoking prevalence:

$$\textit{decrease in smokers} = \frac{(\textit{population})(\textit{decrease in prevalence})}{100} \quad (10.4)$$

or

$$\textit{ASSIST-attributable decrease in smokers} = \textit{population} \times 0.0063. \quad (10.5)$$

The total ASSIST-attributable decrease in smokers was about 478,860 for all 17 states combined. The total raw expenditure was $124,335,049. The total 1999 discounted value of the program, over all states and all years through 1998, was $150,209,722. The following ratio expresses the cost per quit:

$$\textit{cost per quit} = \frac{\textit{total discounted expenditure}}{\textit{decrease in the number of smokers}} \quad (10.6)$$

With no inflation or present value adjustments, the cost per quit is $259.65; the 1999 present discounted value is $313.68.

These initial estimates reflect relatively optimistic assumptions about the efficacy of ASSIST. They assume that there is no recidivism (or relapses) and that all smoking cessation (quits) generated by ASSIST occur among individuals who, but for ASSIST, would have remained lifelong smokers. If we assume that instead fully half of the quitters take up smoking again within 3 years, and that half of those who quit permanently would have done so on their own within 3 years (these assumptions follow from Gilpin et al.),[7] even in the absence of ASSIST, the net permanent reduction in smokers due to ASSIST is closer to

119,735, which in turn raises the cost per quit to $1,255.

In summary, ASSIST, in the short run, reduced the number of adult smokers by about 478,860 in ASSIST states. Given that the 1999 discounted value of ASSIST is $150.2 million, the cost of this reduction per individual is $313. If the effects of ASSIST are assumed to persist, so that the total number of discounted quits increases over time and eventually approaches the discounted number of 877,730 in the ASSIST states, the cost per quit is as low as $171. Under more pessimistic assumptions about the long-run effect of ASSIST, the cost per quit is, of course, higher. Thus, the estimated cost per quit associated with ASSIST lies in a range between about $150 and $1,500. However, as previously noted, the conservative best estimate of the cost per quit is $1,255. By comparison, the cost per quit associated with brief, unsolicited advice from a physician (a 5-minute talk about the dangers of smoking and simple strategies for quitting) during a regular consultation is $500 for individuals who abstain from smoking for at least 1 year.[8] The cost per quit of the Agency for Health Care Policy and Research guidelines on smoking cessation is $4,119.[9]

Interpreting Changes in Prevalence

For any age cohort, the smoking prevalence is the number of smokers in

Examining ASSIST's Long-term Impact on Cost per Quit

To the extent that ASSIST activities resulted in permanent policy changes (youth access laws, clean indoor air acts, and higher excise taxes), an assumption may be warranted that the decrease in prevalence persists indefinitely into the future. Thus, the percentage of 18-year-olds who smoke is permanently reduced by 0.63%. An estimate of how such effects might alter the cost per quit was calculated as follows. The 1999 state population estimates for 18-year-olds were obtained for the 17 ASSIST states. It was assumed that 0.63% fewer of the individuals in this group would smoke. Thus, for the year 1999, approximately 8,496 fewer 18-year-olds smoked as a result of ASSIST. Assuming that the population of 18-year-olds would increase over time at the standard rate of 0.85% per year,[a] in each subsequent year there are 8,496 $(1 + 0.0085)^t$ fewer 18-year-old smokers. Since these noninitiations/quits occur in the future, these future nonsmokers attributable to ASSIST are discounted at the rate of 3%.

Discounting these growing cohorts of future nonsmokers (attributable to ASSIST) at 3% implies a net discount rate of 2.13% (i.e., [1.03/1.0085] – 1). Accordingly, the total discounted number of fewer 18-year-old smokers is 398,871. Here the standard formula for a perpetuity, $8496/i$, is applied, where i is the net discount rate. When this figure is added to the short-run effect of ASSIST (478,860 fewer smokers in 1999), the cost per additional nonsmoker generated decreases to $171. If, on one hand, a smaller population growth rate is assumed, say an annual rate of 0.425%, the cost per quit is somewhat higher, $185. On the other hand, if we assume that in the long run only 25% of the short-run decrease in smokers persists, the cost per permanent quit rises to $290 if the population growth rate is 0.85% and to $333 if the population growth rate is only 0.425%. One way to interpret these last calculations is as a measure of the cost per quit if the effects of ASSIST decay over time. Further sensitivity analysis on the cost per quit is reported in the next section.

[a]U.S. Directorate of Intelligence. 1999. *CIA world fact book.* Washington, DC: U.S. Central Intelligence Agency. http://www.photius.com/wfb1999/rankings/population_growth_0.html

that age cohort divided by the total number of people in that cohort; for example, adult smoking prevalence is calculated by dividing the number of adult smokers by the total number of adults in the population. The number of smokers can decrease in three ways: Individuals quit, move out of the state, or die. The number of smokers can increase in three ways: nonsmokers begin to smoke (initiation), ex-smokers begin to smoke again (reinitiation), or smokers move into the state. Leaving aside sampling and measurement differences, the prevalence can decrease if the number of nonsmokers increases while the number of smokers remains constant.

Between 1991 and 1998, smoking prevalence decreased from an average of 25.19% in ASSIST states to 22.17%. Statistical analyses (see chapter 9) indicate that about 0.63 of this 3.02 percentage point decrease, that is, about 21% of the decrease, can be attributed to ASSIST. Given the 1999 adult population of the ASSIST states, this decline means that about 478,860 people who would otherwise be smoking are not smoking because of ASSIST.

Most of the change in prevalence attributable to ASSIST is because of lower rates of initiation and smoking cessation. Most adult smokers began smoking when they were teenagers; more than 90% of adult smokers were smoking by the time they were 20. The average age of adult smokers in the ASSIST population was 41.48; the median age was 35.9. To calculate the most conservative cost-effectiveness estimate, one would assume that the entire decrease in prevalence is attributable to smoking cessation. Thus, to the extent that ASSIST reduces smoking prevalence by discouraging initiation, the gain in expected life-years is biased downward by this assumption, because increases in life expectancy are larger if an individual never initiates smoking. However, the differences in lifetime mortality and morbidity for individuals who quit in their early twenties do not differ much from those of lifelong nonsmokers. The degree of bias introduced for very young adults by the assumption that all of the reduction in prevalence arises from quits is probably small.

Life-years Gained by Smoking Cessation

Smoking is related to a number of diseases: heart disease, stroke, lung cancer, other cancers, and various pulmonary diseases (chronic obstructive pulmonary disease, emphysema, and pneumonia). The 1990 report of the surgeon general, *The Health Benefits of Smoking Cessation,*[10] provides an overview of the health benefits of smoking cessation; this section relies extensively on that report.

Suppose a person has been smoking for years but then quits.[*] What happens to that person's mortality and morbidity risks compared with a person who never smokes in his or her lifetime (a *never-smoker*) and an individual who continues to smoke? Such risks decrease but do not revert completely to the level

[*]It has become standard to measure effectiveness in terms of quality-adjusted life-years (QALY) gained. A limitation of this analysis is that it does not include measures of QALYs gained.

of a never-smoker. Risks do over time decline relative to an individual who continues to smoke. Whereas for some smoking-related diseases (heart attacks, congestive heart failure, and stroke) the risks decrease over time to that of a never-smoker, for other diseases (lung and other cancers) the risk decreases but stays above the level of a never-smoker. While the rate of decrease in lung capacity is halted, the damage to lung capacity is only slightly reversed with cessation. Decreases in lung capacity are linked to the incidence of various pulmonary diseases. Taken together, mortality and morbidity risks significantly decrease with cessation but never fall completely to the level of a person who has never smoked.

What is the gain in life expectancy? Only a few estimates are available. In the present analyses, the estimates were used from the Framingham study data that were used by D'Agostino and colleagues[11] based on the Framingham data as reported in the 1990 surgeon general's report (*The Health Benefits of Smoking Cessation*)[10] to compute the expected life-years gained by the decrease in prevalence attributable to ASSIST. A man who is a moderate smoker and who quits smoking between the ages of 35 and 39 gains 5.2 years of expected life. His life expectancy is 69, whereas the life expectancy of a never-smoker is 77. A long-term male smoker who ceases to smoke between the ages of 65 and 69 gains about 1.3 years in life expectancy. In the same Framingham study, women who quit between 35 and 39 years of age gained 3.2 years, and women who quit between 65 and 69 gained 1.0.[11] In general, the younger the smoker is when he or she quits smoking, the greater is the gain in expected life-years. While the absolute number of expected life-years is greater if an individual quits while young, the percentage gain in expected life-years from the point in time of quitting is about the same for both younger and older individuals.

For men, the ASSIST-attributable change in prevalence percentage is 0.09 ($p = .042$); for women, the ASSIST-attributable drop is –0.96 ($p = .023$; see chapter 9 for details). Since the drop attributable to ASSIST is statistically significant only for women, expected life-years gained were computed solely for women. In particular, the estimates reported by D'Agostino and colleagues[11] were used in order to linearly extrapolate and interpolate expected life-years gained for different age categories for women. Assuming that a woman who quits smoking at age 37 gains 3.2 years and one who stops at age 67 gains 1.0, the linear extrapolation-interpolation equation has the following form:

$$\text{expected life years gained for female smokers when quitting at } AGE = (2.2/30)(37 - AGE) + 3.2. \qquad (10.7)$$

This approach predicts that a woman who never smokes lives on average 4.3 years longer than a woman who is a lifetime smoker. (For equation 10.7, *never smoked* is equivalent to setting $AGE = 21$.) These estimates are roughly consistent with the findings of Peto and colleagues.[12]

Life-years gained are, for the most part, in the distant future. The standard procedure is to discount future life-years gained to generate a value for the year of analysis. For the ASSIST analysis, the assumption is that the 1999 death rates from smoking-related diseases persist into the future. However, such a projection is uncertain because there may be major breakthroughs in the prevention, early detection, and cures of some smoking-related diseases, which could lead to lower mortality and morbidity, or rates could increase if exacerbating circumstances occurred, such as increased air pollution. Because of such uncertainty, for the purposes of decision making about the allocation of resources, a life-year gained 40 years in the future is not treated as equivalent to a life-year in the year of the assessment.*

Discounting of future life-years gained is done in much the same way that a future monetary payment is discounted. The value of a life-year gained T years from the present (or a specified year) is $1/(1 + r)^T$. For example, if $r = 0.03$ and T equals 30, then a life-year gained 30 years from now has a discounted value of 0.41. For decision-making purposes, if there were two interventions, A and B, with the same cost, but A would yield benefits in the present whereas B would yield benefits 30 years from now, B would have to save at least 2.44 life-years for every single life gained by A in order to be more beneficial than A. Discounting reveals the tradeoffs between interventions in terms of time and benefits.

Life-years gained from smoking cessation differ significantly by gender; accordingly, gender differences in the effect of ASSIST have been analyzed. The estimated effect of ASSIST on the smoking prevalence of women is a statistically significant absolute decrease of 0.96 percentage points ($p = .023$). The estimated effect of ASSIST on male prevalence is a 0.09 increase in percentage prevalence and is not statistically significant ($p = .42$); the change in male prevalence attributable to ASSIST is assumed to be zero. These two estimates are used in calculating discounted life-years gained.

In contrast to gender, the effect of ASSIST does not seem to vary by age; that is, the effect of ASSIST is the same for all adult age cohorts, once gender is taken into account. Table 10.3 presents the calculations for life-years gained for women and by age of quit. The life-years gained by quits occur in the future and are discounted back (table 10.3, column 5) to the age of expected death in the absence of smoking cessation (table 10.3, column 4). Suppose, in the absence of cessation, a lifetime smoker can be expected to live T additional years. An individual who quits gains G expected life-years, so that his or her total expected life remaining is $T + G$. Hence, at the original expected time of death T, the discounted value of this gain of G years is

$$D = (1/r)[1 - e^{-rG}] = \int_0^G e^{-rt}\,dt. \qquad (10.8)$$

D is a value generated at time T in the future. To determine the value of discounted life-years (DLY), D in turn is discounted as follows:

$$DLY = D(e^{-rT}). \qquad (10.9)$$

*A more fundamental reason for discounting future lives saved, of course, is the underlying positive rate of time preference.

Equation 10.9 yields the discounted number of life-years gained for the age of cessation. For example, a 37-year-old man who quits smoking will gain on average 5.1 years of life. If he had not quit smoking, his life expectancy would have been 71 years, but with cessation his life expectancy is 76.1 years; hence, $G = 5.1$ and $T = 34.0$. Using equation 10.9, the discounted life-years that are gained for the age of cessation are 1.705 years. There are important gender differences in life-years gained. A 37-year-old woman who quits gains only 0.908 discounted life-years: The gain in expected life-years is smaller for women, and because women live longer, the future gain is discounted more for women than for men—that is, T is larger for women.

The total for life-years gained by ASSIST is calculated by taking the discounted number of life-years gained for each individual for each age cohort and multiplying this figure by the total number of individuals in the age cohort who have quit (attributable to ASSIST). For example, the total number of women between 35 and 39 in the ASSIST states is 4.3 million. The estimated decrease in the smoking prevalence rate of women attributable to ASSIST is 0.96 percentage points. Hence, the total number of quits attributable to ASSIST for the 35- to 39-year-old age cohort of women is 0.0096 times 4.3 million: about 41,000. If only 50% of these quits are permanent, then the total number of permanent quits is about 21,000. Multiplying this 21,000 by 0.9 years yields the total number of discounted life-years gained for the 35- to 39-year-old age cohort of women: about 19,000. These calculations are performed for each age cohort in the adult female population, and then the figures are summed to yield a total.

Applying this approach to the ASSIST population, assuming a 0.96 decrease in prevalence rate for women and assuming a permanent quit rate of 50%, the total gain in 1999 life-years is about 450,000. The total gain in discounted life-years is about 150,000. The average gain in discounted life-years for women is roughly 0.75.

ASSIST Cost per Life-year Gained

Cost per life-year gained depends on a variety of assumptions. The ASSIST analysis assumes that the long-run effect of ASSIST is a permanent decrease of about 95,068 smokers; this figure yields a total discounted number of life-years gained of about 71,767. In computing discounted life-years gained, the discount rate is assumed to be 3%, a standard assumption in cost-effectiveness estimates. (A smaller discount rate would yield a lower cost per life-year estimate.) Tables 10.4, 10.5, and 10.6 present the cost per life-year gained under a variety of different assumptions about the effectiveness of ASSIST and the reinitiation rate. One issue is the rate of relapse. Cromwell and colleagues assumed a short-run relapse rate of 45% and concluded from long-term follow-up data that over a 5-year period an additional 30% of quitters fail to abstain from tobacco use.[9] Gilpin and colleagues found similar estimates for recidivism.[7] Hence, a conservative approach is to assume that in the long run, only 50% of all ASSIST quitters are permanent quitters. Under this assumption, the cost per life-year is $790.

By assuming that each quit represents someone who otherwise would have been a lifetime smoker, the cost-effectiveness of ASSIST may be overstated. People who smoke differ in their propensity to quit; some are very close to quitting and will do so in the near future. A program such as ASSIST can hasten this decision. Others are likely to never quit, so that a program like ASSIST has no effect on their consumption of tobacco products. Although there is little guidance in the cessation literature about how individual differences in quitting might be incorporated into this analysis, such differences must be accounted for. Therefore, it is assumed that half of the permanent quits attributable to ASSIST represent individuals who would have quit anyway within the near future (assume 3 years). Under this assumption, the number of permanent quits that, in the long run, are attributable to ASSIST is 95,068. The corresponding number of discounted life years saved is 71,767, and the cost per life-year saved is $2,093. The cost per permanent quit is $1,580.03 if just the drop in female prevalence of 0.96 is used; the change in male prevalence attributed to ASSIST is zero. Costs per permanent quit are slightly lower, $1,255, if the overall population drop in prevalence attributable to ASSIST is 0.63.

Discussion

The actual cost-effectiveness of ASSIST may be lower than the best (and very conservative) estimate of $2.09 per life-year gained we have calculated. First, this estimate is based on the assumption that there is a one-time effect of ASSIST on smoking prevalence and that this effect does not persist beyond 1999. In fact, the programs, excise tax increases, and policies brought about by ASSIST are likely to have an enduring effect on lowering rates of smoking initiation by teenagers for a long time and will result in a continuing stream of individuals who would have become smokers but do not because of ASSIST. In addition, the programs, tax increases and policies instituted by ASSIST are likely to continue motivating and helping smokers to quit. Factoring in the life-years gained by dissuading people from smoking and from becoming smokers would further reduce the cost per life-year gained attributable to ASSIST.

The second reason for suspecting that both of the dollar estimates might be too high is that ASSIST helped establish tobacco control infrastructures in the states. Part of the ASSIST legacy is the experienced cadre of tobacco control practitioners who have been well trained in program design, advocacy, and media relations. Presumably these individuals will continue to train others, who will continue to conduct effective programs that in turn will lead to lower smoking prevalence, yielding additional life-years gained.

The estimates of cost per quit may be too low for at least two reasons. The first consideration is recidivism. To a large extent, decreases in prevalence are attributable to quits or prevented relapses. It is well documented that typically smokers do not permanently quit on the first try and that the overall recidivism rate is also quite high.[7] These factors were taken into account by assuming that only a certain fraction of the estimated quits will be permanent. In the baseline calculation, a recidivism rate of 50% is assumed, along with the assumption that half of all quitters would be, but for ASSIST, lifetime smokers. Table 10.4 presents cost-effectiveness ratios for various assumptions about recidivism. If the recidivism rate were 70%, for example, the cost per discounted life-year gained would be $3,488. In the most optimistic calculations, in which all quits are permanent, the cost per quit becomes $395, and the cost per life-year gained becomes $451.

Another consideration is timing. In the period prior to ASSIST (between 1968 and 1990), roughly 2.5% of all smokers quit permanently each year. At least some of the ASSIST-attributable decrease in prevalence occurred because ASSIST may have induced smokers who would have quit smoking anyway to have quit sooner. Therefore, some of the quits may not be fully attributable to ASSIST. If they could be accounted for, those quits would increase the cost per quit estimate.

Unfortunately, data are not available for a systematic investigation of these considerations. Little is known about the quit distribution age: For example, for a smoking cohort of age 40, the percentage who will permanently quit at age 40 + t, t = 1, 2, 3 . . . , and the fraction who will never quit is unknown. If these data were available, the next step would be to determine how ASSIST changed the shape of this distribution (i.e., induced people to quit earlier than they would have otherwise) and how ASSIST raised the cessation levels of smokers who would otherwise never have quit. Some rather mechanical steps can take this consideration into account. For example, if half the individuals who quit because of ASSIST would have quit within the next 5 years anyway, then the cost per quit of the ASSIST intervention doubles. This assumption was made in the best estimates of cost-effectiveness. Table 10.6 presents calculations in which the net effect of ASSIST is varied.

Summary

The purpose of computing the cost per life-year gained is to enable comparisons of the cost-effectiveness of ASSIST with other public health interventions for tobacco use and other public health issues. (The standard reference for a compendium of cost-effectiveness calculations is a 1995 article by Tengs and colleagues.[2] See also the "league tables" provided by the Harvard Center for Risk Analysis.[13]) While some interventions are more cost-effective than ASSIST, many are less cost-effective, including mammograms, exercise electrocardiograms, and other widely promoted interventions. Mammograms cost $2,700 per life-year gained, and electrocardiograms for 40-year-old men cost $108,000 per life-year gained. Among smoking interventions, a brief personal warning from a physician is very cost-effective (not so much because of a large effect, but because this advice is very cheap, about $10 per patient) as is smoking cessation advice for pregnant women. Smoking cessation advice for pregnant women reduces the number of low birth weight babies. Low birth weight babies often have medical problems that are expensive to treat, so cessation advice has a net negative cost, and the cost-effectiveness ratio is less than zero.

ASSIST was, however, more cost-effective than an intensive physician antismoking intervention in Maryland with a cost per life-year gained of $2,587. According to Cromwell and colleagues, nationwide implementation of the Agency for Health Care Policy and Research guidelines on smoking cessation has a cost per life-year gained of $2,820 (1999 discounted dollars).[9] At a cost per life-year gained of about $2,093, ASSIST appears to have been a relatively economical public health intervention.

Conclusions

1. The cost-effectiveness of ASSIST was analyzed relative to its cost per quit and cost per life-year gained. This analysis was based on population data from the Tobacco Use Supplement of the Current Population Survey and National Cancer Institute cost estimates for ASSIST, as well as quantitative assumptions regarding changes in smoking behavior over the term of the period studied.
2. The cost per quit of ASSIST interventions was estimated as $1,255 and cost per life-year gained was estimated as $2,093.02. These figures were based on best-estimate assumptions for factors such as the effectiveness of ASSIST interventions, long-term quit rates, and recidivism rates. Under the most optimistic assumptions, the cost per quit was been computed to be as low as $171, and cost per life-year gained as low as $395.
3. On a per capita basis, the overall cost of ASSIST interventions averaged $2.45 per person, with costs for individual states ranging from a low of $0.90 per person to a high of $6.83 per person.
4. From a cost standpoint, relative to improved health and lives saved, ASSIST compared favorably with other accepted public health interventions such as mammograms and electrocardiograms, as well as other less expensive tobacco control interventions such as physician counseling.

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