# The External Costs of a Sedentary Life-style

EMMETT B. KEELER, PHD, WILLARD G. MANNING, PHD, JOSEPH P. NEWHOUSE, PHD, ELIZABETH M. SLOSS, PHD, AND JEFFREY WASSERMAN, MA

**Abstract:** Using data from the National Health Interview Survey and the RAND Health Insurance Experiment, we estimated the external costs (costs borne by others) of a sedentary life-style. External costs stem from additional payments received by sedentary individuals from collectively financed programs such as health insurance, sick-leave coverage, disability insurance, and group life insurance. Those with sedentary life-styles incur higher medical costs, but their life expectancy at age 20 is 10 months less so they collect less public and private pensions. The pension costs come late in life, as do some of the medical costs, and so the estimate of the external cost is sensitive to the discount rate used. At a 5 percent rate of discount, the lifetime subsidy from others to those with a sedentary life style is $1,900. Our estimate of the subsidy is also sensitive to the assumed effect of exercise on mortality. The subsidy is a rationale for public support of recreational facilities such as parks and swimming pools and employer support of programs to increase exercise. (*Am J Public Health* 1989; 79:975–981.)

## *Introduction*

A growing body of literature indicates that regular exercise may prove beneficial in ameliorating the consequences or preventing the onset of a wide range of diseases and chronic conditions.[1–9] The consequent improvements in health may translate into decreased use of health services and increased job productivity, resulting in economic benefits to society at large. Conversely, those who choose to lead more sedentary lives may actually impose costs on others.

We term such costs—costs that others pay as a result of an individual's decision to lead a relatively inactive life rather than exercise—external costs. By contrast, internal costs are those borne by the individual and are presumably taken into account in decisions about how much to exercise. External costs stem from additional payments received by sedentary individuals from collectively financed programs such as health insurance, sick-leave coverage, disability insurance, and group life insurance. The premiums and payroll taxes that finance these programs are the same for sedentary and active individuals. As a result, these social welfare programs may have the unfortunate side effect of subsidizing unhealthy behavior.

The external costs of smoking and drinking can in principle be converted to internal costs by appropriate excise taxes, but it is difficult to imagine how to tax a sedentary life-style. If, however, a sedentary life-style does impose external costs, subsidies to facilities and programs that promote exercise could well save money in the long run. Such subsidies might take the form of public parks or other recreational facilities that charge no fee or have fees below cost. The greater the external costs of inactivity, the greater the possible value of exercise promotion. In order to shed further light on this issue, we have calculated the external costs of a sedentary life-style.

Our focus on external costs can be contrasted with a recent analysis of the total (internal and external) costs and benefits of exercise.[10] Under assumptions similar to ours, exercise was shown to improve health efficiently, especially for those who enjoyed exercising. That analysis should encourage people to exercise because it is good for them. In this paper, we study a different question, which is more relevant to government action—if someone exercises, is that good for other members of society?

## *Methods*

We will briefly describe our methods and data; more details can be found in the Appendix and in a forthcoming report, available from the authors.*

### Cost Analysis

We focused our cost analysis on the lifetime (as opposed to current) costs incurred by individuals who exercise to varying degrees because some of the effects of exercise persist for many years. In judging any policy with long-term effects, it is important to discount costs that are incurred in the future. Most analysts of health policies consider a 5 percent discount rate as standard, but because the proper rate of discount is controversial, we have computed results for several discount rates that span the range commonly used.[11]

In order to assess the costs associated with reduced physical activity, we made use of a hypothetical person: the "active inactive" individual. Because we were only interested in estimating the effects of exercise on external lifetime costs, we needed to hold constant the effects of other differences between those who do and do not exercise regularly; this we did by changing only the value of the exercise variable in our estimated regression equation. Thus, we use the "active inactive" individual to determine what the lifetime costs would be if the group of inactive people in our sample had instead been active throughout their lives but retained all of their other characteristics.

Our modeling approach involved tracking, from age 20 to death, hypothetical cohorts of sedentary men and women who, for the purposes of comparison, were counterfactually made physically active. To accomplish this, we developed a life table, based on exercise status, that showed the probability of surviving to each age (see Appendix).

We used the life tables to compute the difference in costs that are due to a lack of exercise. These expected net external lifetime costs, X, are given by the formula:

From the RAND Corporation, Santa Monica. Address reprint requests to Emmett B. Keeler, PhD, Department of Economics, RAND Corporation, 1700 Main Street, Santa Monica, CA 90406. This paper, submitted to the Journal March 7, 1988, was revised and accepted for publication December 29, 1988.



*Manning WG, Keeler EB, Newhouse JP, Sloss EM, Wasserman J: The external economic costs of poor health habits. Santa Monica, CA: The RAND Corporation, forthcoming.

$$X = \sum_{t=20}^{\infty} \delta^{t-20} \cdot P(A|S)_t \cdot C(S)_t - \sum_{t=20}^{\infty} \delta^{t-20} \cdot P(A|RE)_t \cdot C(RE)_t$$

where

$\delta$ = annual discount factor (= $1/(1 + r)$),
$P(A|S)_t$ = probability of surviving from 20 to at least age t given a sedentary life style,
$C(S)_t$ = annual costs minus taxes and premiums at age t for those who are sedentary,
$P(A|RE)_t$ = probability of surviving from 20 to at least age t given regular exercise
$C(RE)_t$ = annual costs minus taxes and premiums at age t for those who exercise regularly.

The lifetime external costs of leading a sedentary life included in our analysis are: covered medical costs, covered work loss, group life insurance, the widow's bonus in Social Security, covered nursing home costs, pensions, and disability insurance. (Covered means paid through a collectively financed public or private policy.) Because inactive people lead shorter lives, they will pay less of the taxes and premiums that finance these programs. This differential adds to the lifetime costs borne by active people and so must be included (see Appendix).

Although the cost analyses follow hypothetical cohorts over time, the information for what happens at each age is based on recent (cross-sectional) experience for that age, and not on projections of what life will be like, e.g., in the year 2048 when those 20 years old in 1988 turn 80. Thus, we did not estimate the effects of secular and biomedical trends on the sequalae of a sedentary life-style. Instead, we used current estimates for such parameters as retirement, medical and nursing home costs, education, and life insurance arrangement. This simplifying assumption is commonly made (e.g., by the National Center for Health Statistics[12] in computing life expectancy) because the alternative is too difficult and too conjectural.

### Data

The primary data source for those under age 60 is the RAND Health Insurance Experiment (HIE), which has detailed information on health habits, diseases and chronic conditions, and the utilization of medical services. Because those aged 62 or over at the time of enrollment were excluded from the HIE sample and because we wanted to estimate lifetime costs, we used data on the elderly from a 1983 supplement to the National Health Interview Survey (NHIS) that includes information on health habits, use of medical services, and work loss. We supplemented these two sources with information from the Current Population Survey (CPS), the National Medical Care Utilization and Expenditure Survey (NMCUES), the Centers for Disease Control (CDC), and other sources.

The HIE sample is a random sample of individuals observed between November 1974 and January 1982 from six sites throughout the United States (Dayton, OH; Seattle, WA; Fitchburg, MA; Franklin, MA; Charleston, SC; and Georgetown, SC).[13,14] For this paper, we used data on 3,074 individuals enrolled in fee-for-service plans who were between the ages of 20 and 59. For those age 60 and over, we used unpublished data from the National Health Interview Survey (NHIS).[15] These data are from a supplemental questionnaire on health habits that was administered to 20 percent of the respondents to the 1983 NHIS who were at least 18 years of age; this yielded a sample of 22,418 persons.

### Measures of External Costs

The costs of medical services are external to the degree they are financed by health insurance. We know the fraction of inpatient and outpatient expense paid out of pocket on average for each age, so it suffices to compute the effects of exercise on total medical spending. In our analysis, we examined differences in medical expenditures between those who engaged in regular exercise and those who did not. In the case of the HIE, medical expenditure measures were based on insurance claims filed during the experiment for periods up to five years; and in the case of the NHIS, on reported outpatient visits and hospital admissions in the preceding year.

The work loss measure used in the analysis for those under age 60 is based on responses to a health diary that was filled out biweekly by HIE participants. Work missed by those surveyed in the NHIS was estimated using responses to a question concerning the amount of work missed over a two-week period. Data on wages and pensions come from the Current Population Survey.[16,17]

### Measures of Exercise Status

We classified each person in the HIE data set into one of the following three categories based on his or her reported level of exercise (ascertained by a single question) at the time of enrollment into the study: those with light or no exercise (mostly sitting or walking); moderate or strenuous exercise several times a week; or strenuous exercise most days. Individuals with role or physical limitations were separated from the rest of the population to avoid attributing the effects of their health problems to lack of exercise.

The exercise categories for the NHIS sample are also based on responses to a single question: "Are you less active, about as active, or more active than others your age?" Again, we placed individuals with physical or role limitations in a separate category. Thus, the NHIS categories differ from those of the HIE in that the NHIS measures each person's perceived amount of exercise relative to the average for his or her age group, rather than the more objective HIE measure of how often the person exercises.

### Other Covariates

Our estimates of the effect of exercise on the costs of medical care and sick leave controlled for age, sex, race, smoking, drinking, education, health status, family income, and family size by including them as explanatory variables in a multiple regression analysis. In the analysis of the HIE data, we also controlled for coinsurance rate and the use of seatbelts. Education and seatbelt use are proxies for differences between those who engage in regular exercise and those who do not that may affect work loss and the use of medical services but are not affected by the amount of exercise.

## *Results*

### Use of Medical Services and Work Loss

[illegible] moderate exercisers had 12 percent fewer o[illegible]isodes than the group with little or no exercise, st[illegible]ercisers had only 8 percent fewer outpatient e[illegible] those with little exercise (Table 1). The effect of strenuous exercise was substantially larger for inpatient use than for outpatient care (30 percent lower inpatient use

**TABLE 1—Differences in Medical Use and Work Loss in the Health Insurance Experiment (HIE) Sample**

| Level of Exercise | Outpatient Episodes (excluding well-care) Ratio | 95% CI | Inpatient Admissions (excluding maternity) Ratio | 95% CI | Male Work Loss[a] Ratio | 95% CI |
|---|---|---|---|---|---|---|
| Little | 100 | — | 100 | — | 100 | — |
| Moderate | 88 | (80, 96) | 90 | (71, 113) | 83 | (61, 112) |
| Strenuous | 92 | (81, 105) | 72 | (52, 100.2) | 68 | (47, 99) |

NOTE: Entry indicates percentage ratio of use to use by those with little exercise with similar non-exercise characteristics.
[a]HIE data did not permit an estimate of work loss for females.

rate compared to a 8 percent lower rate of use of outpatient care).

We were concerned that health status could affect exercise, as well as exercise affecting health status—the syndrome expressed by, "I exercise if I feel well." Even though we controlled for role or physical limitations, we felt that perhaps our dichotomous limitation measure was too crude a measure of ability to exercise. Hence, to check the sensitivity of our results to the possibility that health status may affect exercise, we added general health and mental health indices and a count of the number of chronic diseases to our list of covariates.[16] Strenuous exercisers had a 20 percent lower hospitalization rate and used 6 percent less outpatient care than light exercisers, after these adjustments (results not shown). Thus, the magnitude of the effect of exercise on inpatient use depends on how one treats the causal relationship between health status and exercise.

For adult males, moderate exercisers had 18 percent fewer work loss days than those with little exercise, while those with strenuous exercise missed 32 percent fewer days.

We also examined the effects of lack of exercise using the 1983 NHIS for all adults (Table 2). The NHIS sample exhibited a more pronounced effect of exercise than the HIE sample. As an example, for moderate exercisers, the HIE data exhibited a 12 percent lower outpatient use rate than for never or light exercisers, in comparison to the 29 percent lower outpatient use rate in the NHIS data for moderate exercisers.

### Cost Analysis

As a base case, we estimated the external costs of those who, although not physically limited, do not exercise even when young—about 12 percent of men and 20 percent of women in our population. The lifetime external costs in each category for those who classified themselves as not very active physically are given in Table 3. For those 20–59, we used data from the HIE and included all medical expenses (except maternity and well care) and all covered work loss; for the aged, we included all medical expenses based on data from the NHIS.

**TABLE 2—Differences in Medical Use and Work Loss in the National Health Interview Survey (NHIS), 1983**

| Level of Exercise | Outpatients Visits Ratio | 95% CI | Hospital Admissions Ratio | 95% CI | Work Loss Ratio | 95% CI |
|---|---|---|---|---|---|---|
| Below average | 100 | — | 100 | — | 100 | — |
| Average | 71 | (65, 78) | 66 | (58, 76) | 70 | (51, 95) |
| Above average | 72 | (65, 80) | 65 | (57, 75) | 77 | (56, 100) |

NOTE: Entry indicates percentage ratio of use to use by those with little exercise with similar non-exercise characteristics.

**TABLE 3—An Inactive Person's Lifetime External Costs**

| | Discount Rate 0% | 5% | 10% |
|---|---|---|---|
| Costs[a] | | | |
| Medical care[b] | 60 | 11 | 5 |
| Sick leave | 5 | 2 | 1 |
| Group life | 4 | 1 | 0.4 |
| Nursing home | 11 | 0.7 | 0.1 |
| Retirement pension | 129 | 16 | 4 |
| Taxes on earnings[a] | 183 | 27 | 9 |
| Total net costs[a,c] | 27 | 4 | 1 |
| Life expectancy at age 20 (years) | 56.9 | 21.2 | 13.0 |

[a]Measured in thousands of 1986 dollars.
[b]Excludes maternity and well care.
[c](Sum of costs) minus taxes on wages. For example, 27 = 60 + 5 + 4 + 11 + 129 − 183. Due to rounding, categories may not sum to total.

For undiscounted lifetime costs, medical costs and retirement pensions are the largest external costs, and after subtracting taxes on earnings, the total net undiscounted costs are $27,000 per person (Table 3).

Costs discounted at 5 percent show much lower nursing home and pension costs. The other costs fall less because a part of them occurs early in adulthood. The discounted lifetime external costs fall to $4,000 at a 5 percent discount rate, and $1,000 at a 10 percent rate.

Table 4 shows the change in these costs if relatively inactive individuals had exercised regularly but otherwise retained their characteristics and habits (i.e., if they became "active inactive" people). As discussed in the Appendix, we modify the CDC Health Risk Appraisal (HRA) estimates of the effects of exercise on men, and combine recent evidence[5,6,10] in assuming exercise adds 1.5 years of life for men. Then, additional exercise increases total life expectancy by 300 (undiscounted) days, and reduces medical costs. Because active individuals live longer, nursing home payments increase as do pensions. Overall, however, the effect of increased exercise is to decrease undiscounted external

**TABLE 4—Difference between External Costs of Relatively Inactive Persons and Those Same Individuals Had They Been Active**

| | Discount Rate 0% | 5% | 10% |
|---|---|---|---|
| Differences in Costs[a] | | | |
| Medical care[b] | 14.8 | 1.8 | 0.6 |
| Sick leave | 1.1 | 0.5 | 0.3 |
| Group life | 0.3 | 0.1 | * |
| Nursing home | −1.0 | −0.1 | * |
| Retirement pension | −7.0 | −0.5 | −0.1 |
| Taxes on earnings[a] | −1.1 | −0.1 | * |
| Differences in total net costs[a,c] | 9.3 | 1.9 | 0.8 |
| Life expectancy at age 20 (days) | −300 | −22 | −4 |

NOTE: * Indicates figure is less than 0.05. All costs are external.
[a]Measured in thousands of 1986 dollars.
[b]Excludes maternity and well care.
[c](Sum of costs) minus taxes on wages. Due to rounding, categories may not sum to total.

**TABLE 5—Sensitivity of Costs of Inactivity to Assumptions on Effects on Mortality (5 Per cent Discount Rate)**

| | Alternative Mortality Assumptions | | |
|---|---|---|---|
| | Effect of Exercise is 1.5 More Years for Men | No Effect of Exercise on Mortality | HRA Model |
| Costs[a] | | | |
| Medical care[b] | 1.8 | 2.0 | 1.2 |
| Sick leave | 0.5 | 0.5 | 0.5 |
| Group life | 0.1 | 0.0 | 0.4 |
| Nursing home | −0.1 | 0.0 | −0.3 |
| Retirement pension | −0.5 | 0.0 | −3.3 |
| Taxes on earnings[a] | −0.1 | 0.0 | −0.5 |
| Total net costs[a,c] | 1.9 | 2.5 | −1.1 |

[a]Measured in thousands of 1986 dollars.
[b]Excludes maternity and well care.
[c](Sum of costs) minus taxes on earnings. Due to rounding, categories may not sum to total.

costs.

The discounted external lifetime costs, which are more relevant to policy, tell a similar story. At a 5 percent discount rate, increasing exercise saves $1,900 in lifetime costs. This represents our best estimate of the external costs of a sedentary life-style. By way of comparison, at a discount rate of 5 percent lifetime external costs of relatively inactive persons are greater than those of smokers ($1,000), but less than those of heavy drinkers ($4,600).*

### Sensitivity Analysis

We analyzed the influence of alternate assumptions concerning the effects of exercise on mortality (Table 5). For convenience, the first column of Table 5 repeats the results from the second column of Table 4. The second column gives the costs assuming exercise has no effect on mortality; that is, the standard United States life table is used for both groups. Only medical costs and sick leave differ, and these are both higher for sedentary people than they would be if these same people were active.

The last column is based on the unaltered HRA results which show enormous beneficial effects of exercise on mortality (see Appendix). The mortality changes strongly affect pensions and use of nursing home care. If lack of exercise has a large effect on mortality, sedentary individuals pay much more in Social Security taxes than they live to collect. Even when discounted at 5 percent, these late-life effects mean that those who do not exercise subsidize those who exercise: the external costs of inactivity decrease as the assumed beneficial effect of exercise on mortality increases.

Next, we investigated the sensitivity of our results to other assumptions and data sets, while holding the effect on life expectancy at its middle value of 1.5 years for men. For comparison, the first column in Table 6 repeats the first column of Table 5. First, to test the sensitivity to data source, we used parameters based entirely on NHIS data (for the young as well as the old) (column 2). The major change was that the estimated effects of exercise on medical costs were much larger, which caused the external costs of a sedentary life-style to double. However, the sick leave and nursing home estimates are consistent with the HIE results.

Second, to test the sensitivity to how we estimated the health effects of exercise, we contrasted sedentary individuals with current exercisers, rather than with the sedentary people made hypothetically active (third column of Table 6). Because inactive people have other characteristics which are associated with lower medical use (for example they have less education, on average), they spend less on medical services than active people, despite their inactivity. The negative signs in the third column show that currently inactive people are not subsidized by exercisers; the first column however shows that inactivity is subsidized. In other words, if the people who are inactive started to exercise, they would pay current exercisers $1,900 more than the $700 they currently pay. The main reason inactive people do not impose higher external costs is that they die earlier.

The base case included all medical use, but some of the difference in medical use between inactive persons and "active inactive" persons may be unrelated to exercise. As a sensitivity test, we therefore narrowed the definition of medical services to those thought to be related to exercise and other habits. The fourth column gives the resulting medical costs when this restriction is imposed. (Here, we returned to the inactive group made hypothetically active.) Medical and total external costs fall by roughly a factor of two.

Fourth, many people become less active later in life. We therefore tried to estimate the costs that such a switch to inactivity impose on others. In doing so, we assumed that these people were similar to moderate or heavy exercisers up to age 50 and then became sedentary. Because the differences

**TABLE 6—Sensitivity of Costs to Assumptions at 5 Per Cent Discount Rate**

| | Alternative Assumptions | | | | | |
|---|---|---|---|---|---|---|
| | Inactive Individuals if Active | All NHIS Data | Active Individuals | Narrow Definition of Medical Costs[b] | Switch at age 50 | Total Costs |
| Costs[b] | | | | | | |
| Medical costs[c] | 1.8 | 4.4 | −0.4 | 0.9 | 1.1 | 2.6 |
| Sick leave | 0.5 | 0.3 | 0.4 | 0.4 | 0.1 | 1.3 |
| Group life | 0.1 | 0.1 | 0.1 | 0.1 | * | 0.1 |
| Nursing home | −0.1 | −0.1 | −0.1 | −0.1 | −0.1 | −0.1 |
| Retirement pension | −0.5 | −0.5 | −0.6 | −0.5 | −0.4 | −0.5 |
| Taxes on earnings[a] | −0.1 | −0.1 | 0.1 | −0.1 | * | −0.7[d] |
| Total net costs[a,c] | 1.9 | 4.3 | −0.7 | 0.8 | 0.8 | ? |

NOTE: * Indicates figure is less than 0.05. All costs are external, except last column.
[a]Measured in thousands of dollars.
[b]Only costs in diagnoses that are "probably related" to exercise.
[c](Sum of costs) minus taxes on earnings. Due to rounding, categories may not sum to total.
[d]Earnings, not taxes on earnings.

due to a sedentary life-style start late in life, sick leave and medical costs effects are diluted by discounting (column 5). At a 5 percent discount rate, external costs are $800 larger than if this group exercised throughout their lifetime.

Finally, the last column in Table 6 gives data on total costs rather than external costs; that is, it includes the portion borne by the person. Total costs are by definition higher than external costs in areas in which people pay part of the costs themselves. The costs shown in the last column amount to $4,000 but that figure does not count the cost to the sedentary person and his or her family of premature death and disability. Although this latter cost is probably larger than any of the costs shown, it is hard to quantify, so we have left the total cost figure in the lower right hand corner as a question.

*Discussion*

Because there has been no direct trial of the lifetime costs of not exercising, we have had to use several observational studies to estimate the components of costs. The main uncertainty in our overall estimate of lifetime costs comes from the validity of the assumptions, rather than statistical noise. Therefore, we have included extensive sensitivity analyses that show how our computed costs vary with the assumptions.

If sedentary individuals were more active they would live longer and reduce the costs they impose on others. The reduced costs come from lower covered medical and work loss costs associated with an active life-style. The higher taxes paid by active individuals over their longer lifetimes more than offset the additional pension payments received by active people as a result of their increased life expectancy. The effect of exercise is appreciable; for example, the external costs of a sedentary life-style are almost double the external costs of smoking.

In contrast to drunken drivers, the costs that sedentary people impose on others are indirect; sedentary people do not drive their armchairs into innocent bystanders. Most of these external costs are captured in the model, but we assumed there were no effects of inactivity on early retirement. In a study of those obtaining permanent disability Social Security benefits in 1975, 38 percent of retiring workers ages 55–64 had cardiovascular disease as their primary diagnosis.[19] Assuming the year 1975 was typical, we can estimate that three per cent of those ages 55–64 retire early because of cardiovascular disease, to which lack of exercise can contribute. Early retirement has large external costs associated with it, both because it decreases taxes paid and increases pension and disability insurance payments. If a sedentary life-style increased the probability of early retirement, our estimates of the external costs of a sedentary life-style are too low.

One of the largest uncertainties in our calculations concerns the degree of causality in the link between exercise and health status. Although we controlled for physical limitation and several other differences between exercisers and non-exercisers, we cannot be certain that the association we have found between inactivity and health-related costs is completely causal. In principle, this issue could be settled by a randomized experiment of the effects of exercise promotion, but size, cost, ethics, and long-term adherence problems make such an experiment impractical. The issue of causality remains to plague any observational attempt to estimate external costs of inactivity.

The association between exercise and mortality raises the same chicken-and-egg issue. Many epidemiological studies have shown dramatic differences in future heart disease between those who are sedentary and those who exercise.[5,6,20] These studies have controlled for age and other health habits. Still, it is hard to rule out the possibility that heavy exercisers are inherently more healthy than sedentary people in unmeasured ways, so that inactive persons who take up exercise will not enjoy the gains in life expectancy that models based on those studies would predict. If exercising has no effect on mortality and morbidity, then there are no benefits to making sedentary people more active. Because of this uncertainty, the revised HRA model 3.0 says only that exercise is probably good for you, and does not attempt to quantify its life-extending benefits.

Nevertheless, individuals contemplating a switch to a more active life-style will probably benefit from doing so.[5] According to Paffenbarger and Hyde,[4] the time spent walking is just returned in later life (undiscounted), and joggers who burn calories twice as fast as walkers can get double their exercise time back in increased life expectancy. However, the time given up to exercise is now, while the life extending benefits of exercise accrue in the future. Hence, if people care more about time now than time later,[11] they should engage in exercise that they either enjoy or has other benefits for them (e.g., increasing their feeling of well-being, physical appearance, etc.).

From a policy perspective, our results provide an economic rationale both for government spending on recreational facilities that encourage a more active life style, as well as for employer spending on worksite wellness programs that encourage exercise. About one-sixth of the population is sedentary but not physically limited. Whether subsidies to encourage exercise would induce enough additional exercise among that group to justify their costs is an issue we must leave to others; if our estimate of $1,900 in benefits per active person is approximately correct, a relatively small additional percentage of exercising would be enough to justify a subsidy, especially because the majority who already exercise would also derive benefits from such facilities and programs.

**ACKNOWLEDGMENTS**

This work was financed by a Grant No. HS05278-02 from the National Center for Health Statistics Research (NCHSR), Rockville, Maryland. An early version of this paper was presented at the APHA meetings in New Orleans in the fall of 1987. Some of the results have been discussed in seminars at the University of California-Los Angeles and at NCHSR.

## REFERENCES

1. Berkow R (ed): The Merck Manual of Diagnosis and Therapy, 14th Ed. Rahway, NJ: Merck, Sharp, and Dohme Research Laboratories, 1982.
2. Haskell WL: Exercise-induced changes in plasma lipids and lipoproteins. Prev Med 1984; 13:23–26.
3. Kottke TE, Caspersen CJ, Hill CS: Exercise in the management and rehabilitation of selected chronic diseases. Prev Med 1984; 13:47–65.
4. Paffenbarger RS, Hyde RT: (letter) N Engl J Med 1986; 315:400–401.
5. Paffenbarger RS, Hyde RT, Wing AL, Hsieh CC: Physical activity all-cause mortality and longevity of college alumni. N Engl J Med 1986; 314:605–613.
6. Powell KE, Thompson PD, Caspersen CJ, Kendrick JS: Physical activity and the incidence of coronary heart disease. Ann Rev Public Health 1987; 8:253–287.
7. Richter EA, Schneider SH: Diabetes and exercise. Am J Med 1981; 70: 201–209.
8. Simon HB: The immunology of exercise. JAMA 1984; 252:2735–2738.
9. Siscovick DS, LaPorte RE, Newman JM: The disease-specific benefits and risks of physical activity and exercise. Public Health Rep 1985; 100:180–188.
10. Hatziandreu EI, Koplan JP, Weinstein MC, Caspersen CJ, Warner KE: A cost-effective analysis of exercise as a health promotion activity. Am J Public Health 1988; 78:1417–1421.

11. Keeler EB, Cretin S: Discounting of life-saving and nonmonetary effects. Management Sci 1983; 29:300–306.
12. US Department of Health and Human Services, National Center for Health Statistics: Vital Statistics of the United States, 1980, Vol. II, Mortality, Part A, DHHS Pub. No. (PHS) 85-1101, Hyattsville, MD: NCHS, 1985.
13. Newhouse JP: A design for a health insurance experiment. Inquiry 1974; 11:5–27.
14. Brook RH, Ware JE, Davies-Avery A, *et al:* Overview of adult health status measures fielded in RAND's health insurance study. Med Care (Suppl) 1979; 17:1–131.
15. US Department of Health and Human Services, National Center for Health Statistics: Current estimates from the National Health Interview Survey, United States, 1983, Vital and Health Statistics, Series 10, No. 154. Washington, DC: Public Health Service, June 1986.
16. Current Population Survey, March 1985 (machine-readable data file) conducted by the Bureau of the Census for the Bureau of Labor Statistics. Washington, DC: Bureau of the Census, 1985.
17. US Department of Commerce, Bureau of the Census: Money income of households, families, and persons in the United States: 1984. Current Population Reports, Consumer Income, Series P. 60, No. 151. Washington, DC: The Bureau, 1986; 165–170.
18. Ware JE: Scales for measuring general health perceptions. Health Serv Res 1976; 11:596–619.
19. Burdette ME, Mohr M: Characteristics of Social Security disability. Social Security Administration Pub. No. 13-11947. Washington, DC: Department of Health, Education, and Welfare, December 1979.
20. Chave SPW, Morris JN, Moss S, Semmence AM: Vigorous exercise in leisure time and the death rate: A study of male civil servants. J Epidemiol Community Health 1978; 32:239–243.
21. Robbins LC, Hall JH: How to Practice Prospective Medicine. Indianapolis: Methodist Hospital of Indiana, 1970.
22. Pechman JA: Federal Tax Policy, 3d Ed. Washington, DC: Brookings Institution, 1970; 6.
23. US Department of Health and Human Services, National Center for Health Statistics: National Medical Care Expenditures Study, Data Preview Series, No. 15. Inpatient Hospital Services: Use, Expenditures, and Sources of Payment. Washington, DC: NCHS/DHHS, May 1983.
24. US Department of Health and Human Services, National Center for Health Statistics, National Medical Care Expenditures Study, Data Preview Series, No. 16. Contacts with Physicians in Ambulatory Settings: Rates of Use, Expenditures and Sources of Payment, Washington, DC: NCHS/DHHS, October 1983.
25. Price DN: Cash benefits for short-term sickness: Thirty-five years of data 1948–1983. Soc Sec Bull May 1986; 49:5–38.

## APPENDIX
## Further Details of Methods

### *1. Basis of Life Tables*

We constructed an abridged life table using 1980 data on national mortality and the 1984 Centers for Disease Control's version of the Health Risk Appraisal (HRA) program developed by Robbins and Hall.[21] The HRA was used to adjust survival rates to reflect differences in the relative risks of dying between people who exercise and those who lead more sedentary lives.

Unfortunately, some problems in the 1984 HRA model's treatment of exercise lead to implausibly large estimates of the effects of exercise. For example, according to computations that we performed using the HRA model, men who switch from a sedentary life style to exercise will live nine years longer, almost double the computed effects of not smoking! This estimate is implausibly large for two reasons: 1) the HRA fails to account for the fact that better health may lead one to exercise, rather than vice versa; and 2) the adjustment made to the HRA model's exercise risk multipliers for age is inadequate, which makes the computed effects of exercise for older males too large. These two problems were compounded by the fact that our measures of exercise do not match well with the HRA categories. For example, because we had no information on past exercise habits, we had to assume that current patterns represent lifelong patterns. Yet exercise habits are not particularly stable.

Given these problems, we decided to estimate the external costs of exercise in three ways. As an upper bound on mortality effects, we used the unaltered results of the HRA model. For a lower bound, we assumed that exercise had no effect on mortality whatsoever, so that external costs arose only from differences in medical and sick-leave costs for sedentary and active people. For our best estimate, we uniformly altered the age-specific relative mortality risks of not exercising in the HRA model, so that male exercisers lived one and a half years more than male nonexercisers. This value was derived from several recent studies.[5,6,10] We did not adjust the mortality values for women because very little is known quantitatively about the effects of exercise on women and because the effects of exercise in the HRA model were not nearly as large as for men.

### *2. Assumptions on Collective Financing*

To simplify the calculation of how much active and inactive people pay annually to finance these programs, we assume that each pays a given proportion of earnings, where the proportion is just enough to finance these programs (10.3 percent of earnings, at a 5 percent rate of discount). The assumption of proportionality is approximately correct for publicly financed goods and services,[22] and is also probably correct for privately financed pensions. Private premiums for health insurance are regressive, but this is somewhat offset by the benefits of Social Security payments and Medicaid financing for nursing home services being progressive.

### *3. Medical Care Services and Insurance Coverage*

We examined the use of medical care services (excluding dental care) by those who exercise varying amounts. In the case of the HIE (RAND Health Insurance Experiment), medical expenditure measures were based on claims filed during the experiment for periods up to five years, and the individual's pre-experimental insurance coverage was used to estimate external costs. In the case of the NHIS (National Health Interview Survey), medical measures were outpatient visits and hospital admissions in the preceding year. Visits and admissions were converted to expenditures using average prices from the National Medical Care Expenditure Survey (NMCES),[23,24] and data on insurance coverage of the non-elderly from NMCES were used to estimate the portion of medical costs that were external.

In our analysis, we examined differences in medical use between those who engaged in regular exercise and those who did not. Because some of the observed differences in medical care use may not be caused by the amount one exercises, we made three corrections:

- We excluded maternity services because it seemed implausible that exercise was causally related to the decision to have children. (We also excluded well care because it is generally not covered by insurance.)
- To increase the chances that the difference in use of medical services is caused by differences in the

amount one exercises, we limited one set of analyses to diagnoses thought to be directly related to bad habits.

- We controlled for a set of confounding variables, as described in the text.

*4. Work Loss*

In the HIE, work loss includes time lost from work due to one's own or someone else's illness, including time for visits to a physician. A half-day or more missed from work was counted as a work-loss day. Because we do not know the reason for the work loss, we cannot restrict our measure to sick days due to illnesses known to be related to exercise. Instead, we estimated the difference in total work loss among persons with different levels of exercise, controlling for health habits and other covariates.

Wage data from the CPS were used to convert work loss days into costs. To obtain a figure for external costs, we used an estimate that employers pay 38 percent of the cost of work loss.[25]

*5. Comparison of the HIE and NHIS Data Sets*

We compared the estimated effects of exercise on medical costs and work loss on the non-elderly in the NHIS and the HIE data. Although there were few statistically significant differences, in some cases there were appreciable differences in the estimated coefficients. The differences in the magnitude of the estimated responses to exercise between the HIE and NHIS prompted us to perform the cost analysis two ways: 1) we used data from the HIE for those under age 60 and the NHIS for those 60 and older; 2) we used data exclusively from the NHIS (i.e., for all age groups).

*6. Wages and Pensions*

Data on wages come from the Current Population Survey.[16] Data on pensions, public and private, by age, sex, and education class also come from the Current Population Survey; they have been adjusted for the estimated 21 percent underreporting factor in this survey.[17] (We include private pensions as collectively financed because most are defined benefit plans rather than defined contribution plans and because defined contribution plans generally convert to annuities whose payout is independent of exercise status.) We assume survivors in each age, sex, and education class get the average pension for that class, i.e., we assume amount of exercise has no effect on age at retirement.