The Contribution of Smoking to Sex Differences in Mortality

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Synopsis

The contribution of smoking to sex differences in mortality is estimated on the basis of data from 12 studies of the mortality of nonsmoking men and women, together with mortality data for comparable general population samples. Most of the data are for samples drawn from the U.S. population from the late 1950s to 1980. The findings from different studies are generally consistent, once methodological factors are taken into account.

The findings indicate that, for total mortality, the proportion of sex differences attributable to smoking decreases from about two-thirds at age 40 to about one-quarter at age 80. Over the adult age span, it appears that about half of the sex difference in total mortality is attributable to smoking. Findings for ischemic heart disease mortality show a similar pattern. For lung cancer, it appears that about 90 percent of the sex difference in mortality is attributable to smoking.

The estimated contributions of smoking include both the effects of sex differences in smoking habits and the effects of sex differences in the increase in mortality caused by smoking. The quantitative results should be interpreted with caution, since several lines of argument suggest that multivariate analyses controlling for other relevant factors would produce lower estimates of the contribution of smoking to sex differences in mortality. Despite this limitation, the findings analyzed in this review, together with additional evidence from related research, strongly support the conclusion that cigarette smoking makes a major contribution to men's higher mortality, but other factors also play an important role.

In all contemporary developed countries males have higher mortality and shorter life expectancies than females (*1*). Recently Miller and Gerstein have concluded that "differential rates of cigarette smoking are apparently the overwhelming cause for the male-female longevity difference" (*2*). They based this conclusion on their finding that among nonsmokers there was little or no sex difference in life expectancy (if deaths due to violence were excluded). This study has aroused considerable controversy (*3–5*), in part because Miller and Gerstein's findings are in disagreement with the results of other researchers who have found that, even among nonsmokers, men have higher mortality than women (*4,6–15*). Based on these findings and a variety of additional evidence, several authors have argued that, although smoking makes a major contribution to sex differences in mortality, other factors also play an important role (*1,4,16–18*).

In order to evaluate these competing claims, I critically review the findings from studies of the mortality of nonsmoking men and women. Sex differences in mortality for nonsmokers are compared with sex differences in mortality for total population samples in order to estimate the proportion of sex differences in mortality that can be attributed to the effects of smoking. Evidence is presented concerning total mortality and two major causes of smoking-related mortality—lung cancer and ischemic heart disease (ischemic heart disease is the current World Health Organization designation for coronary heart disease.) The methodology of the studies is critically evaluated, and the findings are interpreted in the context of other research concerning the causes of sex difference in mortality.

Methods

Studies were included in this review if they met the following criteria. First, the study must provide death rates for nonsmoking men and women for total mortality, ischemic heart disease, and/or lung cancer. Second, the study must provide either age-specific death rates by 5- or 10-year age groups or age-adjusted death rates that have been adjusted to the same age distribution for men and women.

Table 1. Sample characteristics and methods for studies of mortality in nonsmokers and general population samples

Study	Type of study and age range[1]	Number of Men	Number of Women	Definition of nonsmoker[2]	Percent nonsmokers[3] Men	Percent nonsmokers[3] Women	Comments[4]
American Cancer Society study, U.S., 25 States, 1959–63 (6).	Prospective, 35–84	440,558	562,671	Never smoked cigarettes, pipes, or cigars regularly	22	67	Nonrandom sample
Whites, 1967–71 (*19*).	Prospective, 35 and older	358,422	483,519	.......do.	22	65	.......do. ....
National mortality survey, U.S., 1966–68, whites (*7*).	Cross-sectional, 2-sample, 35–84	25,266 in population sample	29,308	Never smoked cigarettes (less than 5 packs or 100 cigarettes ever smoked)	28	63	11,318 men and 5,636 women in deaths sample
All races (*20*).	.......do.	28,267 in population sample	32,653	.......do.	28	61	12,931 men and 6,595 women in deaths sample
Framingham, MA 1948–69 (*8*)	Prospective, 30–59	2,336	2,873	Not current cigarette smoker (had not smoked cigarettes within the past year, as of the most recent biennial examination)	22	59	Sample composed of random sample (69 percent participation rate) plus volunteers (14 percent of total sample)
Erie County, PA 1972–74 (*2*)	Cross-sectional, 2-sample, 30 and older	3,916 in population sample		Less than 20 packs of cigarettes ever smoked	29	64	6,930 in deaths sample; smoking data available for 63 percent of decedents; smoking for general population estimated retrospectively in 1979; available data represent approximately 73 percent of a 1972–74 population sample
Tecumseh, MI 1959–80 (*9*)	Prospective, 35–74	1,360	1,394	Never smoked cigarettes, pipes, or cigars	17	63	Participation rate 88 percent
Rancho Bernardo, CA, 1972-80 (*10*)	Prospective, 30–69	1,535	1,981	Never smoked cigarettes	28	44	Participation rate 85 percent for men and 90 percent for women
Alameda County, CA, 1965–74 (*11*)	Prospecitive, 20 and older	3,158	3,770	Never smoked cigarettes	29	48	Participation rate 86 percent; ever-married 16–19-year-olds included
Current mortality survey, U.S., 46 States, whites, 1958–59 (*21*, *22*)	Cross-sectional, 2-sample, 35 and older	31,516 in population sample	34,339	Never smoked as many as 5–10 packs of cigarettes or (for men) 50–75 cigars or 3–5 packages of pipe tobacco	....	....	2,381 men and 749 women in deaths sample; men's deaths for 1958 only
Sweden, 1963–72 (*12*)	Prospective, 18–69	27,342	27,732	Never smoked cigarettes, pipes, or cigars as often as daily or almost daily and hasn't smoked even occasionally within past 10 years	27	68	....

Table 1. Sample characteristics and methods for studies of mortality in nonsmokers and general population samples—Cont.

Study	Type of study and age range[1]	Number of: Men	Number of: Women	Definition of nonsmoker[2]	Percent nonsmokers[3]: Men	Percent nonsmokers[3]: Women	Comments[4]
British-Norwegian migrant study, 1963–68 (*13*)	Prospective, 35–69			Not current regular cigarette smoker (usually less than 1 cigarette a day)	....	....	Norway and Britain samples include both random population samples and siblings of migrants; participation rate 86 percent for migrants in U.S. and "somewhat lower" for Norway and Britain
Norway		12,089	14,066				
Britain		8,089	9,607				
Norwegian migrants in 12 U.S. States		5,254	4,762				
British migrants in 12 U.S. States		10,038	9,979				
British physicians 1951–73 (*14*)	Prospective, 20 and older	34,440	6,194	Never smoked as much as 1 cigarette a day (or 1/4 ounce tobacco a week) for as long as 1 year	17	50	Sample of physicians not representative of general population; participation rate for men about 69 percent and for women about 60 percent; followup for men's mortality, 1951–71 only
Japan, 29 health districts, 1966–73 (*23*)	Prospective, 40 and older	122,261	142,857	Not stated	24	90	....

[1] Age range at intake.
[2] In the prospective studies, data concerning smoking were self-reported. In the cross-sectional 2-sample studies, data concerning smoking were self-reported or reported by a proxy (usually the spouse) for the population samples and reported by next-of-kin for the deaths samples.
[3] Percent nonsmokers at intake.
[4] Unless otherwise specified in the comments, samples were probability samples with participation rates of at least 90 percent. In the prospective studies, mortality followup was at least 90 percent complete.
NOTE: Numbers in parentheses apply to references section.

Third, each death rate to be reported must be based on at least 20 deaths. Table 1 lists the 12 studies (*2,6–14*, *9–23*) included in this review and provides information concerning the samples and methods of each study.

(For the Tecumseh study (*9*), additional information has been provided by Dr. Millicent Higgins, Associate Director for Epidemiology and Biometry, Division of Epidemiology and Clinical Applications, National Heart, Lung, and Blood Institute, in a personal communication dated February 7, 1985).

All data presented for age groups broader than a 10-year age span are based on age-adjusted death rates to ensure comparability of male and female death rates. In two cases, the available age-specific death rates were based on fewer than 20 deaths, so data for several age groups were used to calculate age-adjusted death rates which were based on an adequate number of deaths, for ischemic heart disease in the Framingham study (*8*) and lung cancer in the American Cancer Society study (*6*). In the Erie County and Swedish studies, data for 5-year age groups have been used to calculate

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age-adjusted death rates for 10-year age groups (*2,12*). In the British-Norwegian migrant study (*13*), death rates for cardiovascular and noncardiovascular mortality were added to obtain death rates for total mortality.

The sex mortality ratios given are death rates for males divided by death rates for females. For each study that provided information concerning mortality in a total population sample comparable to the nonsmoker sample, the percent of the sex differences in mortality attributable to smoking was calculated as

$$100\left(1 - \frac{\Delta_n}{\Delta_t}\right)$$

where

Δ_n = male minus female death rates for nonsmokers and Δ_t = male minus female death rates for the total population sample.

The death rates in the Miller and Gerstein Erie County study excluded deaths due to violence or traumatic causes (accidents, suicide, and homicide), so death rates for total mortality have been estimated by adding to the death rates given in the Erie County study the national death rates for whites for violent deaths in 1973 (*24*). Estimates of total mortality excluding violence have been derived from the American Cancer Society study data and the National Mortality Survey data by subtracting from the total death rates given in these studies the national death rates for violence for whites for 1961 for the cancer study and 1967 for the mortality study (*24*). (Although both the Erie County study and the American Cancer Society study included nonwhites, the percent of nonwhites was so low that in both cases the death rates for violence for whites were used in the calculations. Calculations using the death rates for violence for all races yielded similar results.)

Findings on the Contribution of Smoking

The findings for total mortality are presented in table 2. The sex mortality ratios for nonsmokers are greater than 1.0 in every case except the two oldest age groups in the Erie County study. Thus, in almost every case men had higher mortality than women even among nonsmokers. The sex mortality ratios for the nonsmokers are lower than the sex mortality ratios for the corresponding total population samples. This indicates that, as expected, sex differences in mortality are smaller in the absence of the effects of smoking. The proportion of sex differences in total mortality attributable to smoking appears to decrease with age, from approximately two-thirds at about age 40 to approximately one-quarter at about age 80. Over the adult age span, the proportion of sex differences in total mortality attributable to smoking is estimated to be about 40 to 60 percent.

The findings for ischemic or coronary heart disease mortality are presented in table 3. For ischemic heart disease, as for total mortality, the sex mortality ratios for nonsmokers are greater than 1.0 and less than the sex mortality ratios for the total population samples. The proportion of sex differences in ischemic heart disease mortality attributable to smoking appears to decrease with age, with estimates ranging from a high of 60 percent for 45–54-year-olds to a low of 18 percent for 75–84-year-olds in the American Cancer Society study.

Findings for lung cancer mortality also indicate that the sex mortality ratios for nonsmokers are greater than 1.0 and less than the sex mortality ratios for total population samples (table 4). The one study with age-specific data suggests a decreasing proportion of sex differences attributable to smoking at older ages. The proportion of sex differences in lung cancer mortality attributable to smoking appears to be very high, approximately 90 percent for these U.S. samples.

Confidence in these findings is enhanced by the general agreement of results from different studies and the generally sound methodology and large sample sizes of many of these studies. The results that most clearly deviate from the general patterns of the findings are the low sex mortality ratios for nonsmokers in the 65–84 age category in the Erie County study.

Methodological Problems

There are several differences in methods and sample characteristics that could contribute to the deviant findings for the older age groups in the Erie County study and to the smaller differences among the findings of the other studies.

The definition of nonsmoker varies in different studies, but two lines of evidence suggest that these differences did not have a substantial impact on the findings. First, there appears to be no association between the definition of nonsmoker in a given study and the findings of that study (compare table 1 with tables 2–4). Second, for the total mortality data in the American Cancer Society study, parallel results have been calculated using the two most common definitions of nonsmoker, "never smoked cigarettes regularly" and "never smoked cigarettes, pipes, or cigars regularly." Data from appendix table 2a in Hammond's monograph (6) shows that generally similar results were obtained using these two different definitions of nonsmoker.

When nonsmokers were defined as those who never smoked cigarettes regularly, men who had smoked only pipes or cigars were included in the nonsmoker category. Consequently, the death rates for male nonsmokers were increased somewhat, as were the sex mortality ratios for nonsmokers. In addition, because men who had smoked only pipes or cigars were included in the nonsmoker category, the effects of this type of smoking were not included in the estimates of the proportion of sex differences in mortality attributable to smoking. Hence these estimates were decreased, but only by about 4 to 8 percent for different age groups. This latter result suggests that, at least in the United States around 1960, pipe and cigar smoking made a relatively small contribution to sex differences in mortality, and cigarette smoking was primarily responsible for the contribution of smoking to sex differences in mortality.

Another possible cause of differences in findings among studies could be differences in characteristics, such as the racial composition, region, or dates of the studies, or the extent of sex differences in smoking in the total population sample. However, no systematic relationship was found between these characteristics and the results of different studies. It is possible that other unmeasured sample characteristics, such as sex differences in smoking histories, may have contributed to differences in findings.

One major methodological difference between studies is that nine were prospective studies, while three were cross-sectional two-sample studies. In the cross-sectional two-sample studies, death rates for nonsmokers were calculated on the basis of estimates of the proportion of nonsmokers in a sample of deaths and in a representative general population sample. This study design appears to be more vulnerable to certain types of methodological problems, and these problems may have contributed to the deviant findings for the Erie County study.

For a cross-sectional two-sample study, there can be significant biases in the estimates of death rates by smoking status if the participation rates

Table 2. Ratio of total mortality to sex mortality and percent of sex differences attributable to smoking

Sample and age group	Sex mortality ratios: Nonsmokers	Sex mortality ratios: Total sample	Percent of sex difference attributable to smoking
American Cancer Society study 1959–63:			
35–44	1.29	1.92	71
45–54	1.33	2.16	74
55–64	1.72	2.45	53
65–74	1.65	2.00	37
75–84	1.35	1.47	25
National Mortality Survey, whites:			
35–44	1.42	1.75	58
45–54	1.71	2.02	50
55–64	2.19	2.32	32
65–74	1.52	1.83	44
75–84	1.35	1.41	21
35–84	1.59	1.81	38
Framingham, MA:			
45–54	1.44	1.81	61
55–64	1.97	2.23	27
65–74	1.54	1.80	34
Erie County, PA:[1]			
45–54	1.20	...	...
55–64	1.56	...	...
65–74	0.81	...	...
75–84	0.99	...	...
Tecumseh, MI:			
35–74	1.54	1.79	37
Rancho Bernardo, CA:			
30–69	1.38	1.69	62
Alameda County, CA:			
20 and older	1.30	1.48	49
Sweden:			
50–59	1.59	1.84	34
60–69	1.38	1.51	27
British-Norwegian Migrant Study:			
Norway:			
45–54	1.76	...	...
55–64	1.70	...	...
Britain:			
45–54	1.65	...	...
55–64	1.50	...	...
Norwegian migrants:			
55–64	1.74	...	...
British migrants:			
55-64	1.60	...	...
British physicians:			
20 and older	1.49	...	...

[1] For this study, sex mortality ratios are based on the death rates for total mortality excluding violence reported for Erie County nonsmokers plus death rates for violence from national vital statistics (see Methods).

differ by smoking status, particularly if the pattern of participation rates differs between the general population sample and the deaths sample. The potential for such bias is particularly troublesome when participation rates are as low as in the Erie County study (table 1).

Table 3. Ischemic or coronary heart disease mortality—sex mortality ratios and percent of sex differences attributable to smoking

Sample and age group	Sex mortality rates: Nonsmokers	Sex mortality rates: Total sample	Percent of sex difference attributable to smoking
American Cancer Society study 1959–63:			
45–54	4.55	7.47	60
55–64	3.33	4.37	40
65–74	2.14	2.42	23
75–84	1.59	1.71	18
National Mortality Survey, all races:			
45–54	4.02	...	...
55–64	3.63	...	...
65–74	2.05	...	...
75–84	1.44	...	...
Framingham, MA:			
45–74	2.31	3.18	48
Sweden:			
50–59	3.09	3.76	37
60–69	1.76	2.08	30
British physicians:			
65 and older	2.87	...	...
Japan:			
50–59	2.05	...	...
60–69	1.33	...	...

Table 4. Lung cancer mortality—sex mortality ratios and percent of sex differences attributable to smoking

Sample and age group	Sex mortality rates: Nonsmokers	Sex mortality rates: Total sample	Percent of sex difference attributable to smoking
American Cancer Society study			
1959–63:			
40–84	1.50	...	...
1967–71:			
40–94	1.43	4.71	93
National Mortality Survey, whites:			
55–64	3.06	6.99	85
65–74	3.41	8.41	82
75–84	1.82	4.81	81
35–84	2.65	5.90	86
Current mortality sample:			
35 and older	1.33	6.26	95

Miller and Gerstein (*2*) have identified one source of bias of this type in their Erie County study. The estimates of the proportion of smokers in the population were based on a survey completed approximately 6 years after the period of the deaths sample. Deaths during the intervening time period would have eliminated more smokers than nonsmokers from the population sample. This would result in an overestimate of the proportion of nonsmokers in the population, and, as a consequence, the death rates for nonsmokers would be underestimated. This effect would be greater for men than for women, so the sex mortality ratios for nonsmokers would be underestimated. Estimates of the magnitude of this effect, based on the proportions of nonsmokers reported in the Erie County study and death rates for smokers and nonsmokers reported in the National Mortality Survey (*7*), suggest that corrections for this methodological problem would increase the sex mortality ratios for nonsmokers in the Erie County study by about 10 percent for the two older age groups shown in table 2 and a smaller amount for the younger age groups.

One additional methodological weakness of cross-sectional two-sample studies should be mentioned, although there is no specific evidence that this occurred in the studies under review. In a cross-sectional two-sample study, smoking histories are reported post mortem by a relative who may be uncertain about the deceased's smoking history. In this situation, unconscious processes could influence interview responses or coding of responses in a way that would bias results toward support of a researcher's hypothesis concerning the importance of smoking. Experimental studies have shown that unconscious processes of this type can have a substantial influence on the outcome of a variety of research processes (*25*). This type of bias would be less likely to occur in prospective studies, since smoking histories are self-reported before, rather than after, the deaths.

It should be mentioned that there are also methodological problems that may bias the results of prospective studies. For example, participation rates may vary by smoking status and subsequent mortality risk (*26*). Also, smoking appears to be underreported in self-report surveys (*27*), so it is possible that some of the self-reported nonsmokers actually do smoke. In the absence of quantitative data concerning the extent of these problems for men and women, it is impossible to estimate the impact they may have on the results presented in this review.

A final methodological point is that, for the cross-sectional two-sample studies, the age categories shown in the tables refer to age at death, while for most of the prospective studies the age categories refer to age at intake. In most cases, this methodological difference does not result in substantial problems of noncomparability, since the lag between age determination and death was small relative to the age span of the age groups used in the study. However, for the Swedish study, this lag varied between 0 and 9 3/4 years, so the stated age categories in the Swedish study are comparable to age categories about 5 years older in other studies. With this correction, there is good agreement between the Swedish and U.S. results.

Smoking and Violence Findings

One additional question, raised in the Miller and Gerstein paper (*2*), is the extent of sex differences in total mortality for nonsmokers if deaths due to accidents and other violence are excluded. Estimates from three studies in the United States are presented in table 5. These estimates are the least satisfactory of the data presented in this review, because in two out of three cases they are based on the assumption that national death rates for violence for whites apply to the population in the smoking study and because there are discrepancies between the results of these two studies and the Erie County study. Nevertheless, these data, together with data from table 2 and from national vital statistics (*24*), support the following conclusions concerning the U.S. population in the 1960s and early 1970s:

For 15-34-year-olds, about 90 percent of the male excess for total mortality was attributable to accidents and other violence. For 35-44-year olds, it appears that all of the male excess for total mortality was attributable to smoking and violence together. The proportionate contribution of violent deaths to the sex differences in total mortality decreases with age. At the oldest ages, the inclusion or exclusion of violence appears to have very little effect on the estimates of sex mortality ratios for nonsmokers or total population samples.

Discussion

The evidence presented indicates that, for adults, approximately half of the sex difference in total mortality is attributable to smoking, with higher proportions of the sex difference attributable to smoking at younger ages and lower proportions at older ages. The same general pattern of results was observed for ischemic heart disease mortality. For lung cancer, about 90 percent of the sex difference in mortality appears to be attributable to smoking. These results are based primarily on data for the United States from the late 1950s to 1980. Similar results have also been found in analyzing Swedish data for the 1960s. Data from other countries are too incomplete for confident comparisons.

Results from different studies were generally similar, with the exception of the findings for the older age groups in the Erie County study. Several methodological factors that appear to have contributed to differences in findings have been discussed in a previous section. Variation in findings may also have been due to unidentified methodological factors and sample differences or to chance variation in results.

In interpreting these results, it is important to recall that, by the method of calculation I have used, the proportion of the sex difference in mortality attributable to smoking includes all of the sex difference in mortality above and beyond the amount of sex difference in mortality observed for nonsmokers. Thus, the proportion of the sex difference in mortality attributable to smoking includes not only the effects of sex differences in smoking habits, but also the effects of sex differ-

Table 5. Total mortality excluding violence—sex mortality ratios

Sample and age group	Sex mortality ratios: Nonsmokers	Total sample
American Cancer Society study 1959–63[1]:		
35–44	0.90	1.67
45–54	1.10	2.05
55–64	1.63	2.41
65–74	1.62	1.99
75–84	1.35	1.47
National Mortality Survey, whites[1]:		
35–44	0.98	1.51
45–54	1.56	1.95
55–64	2.14	2.29
65–74	1.50	1.81
75–84	1.35	1.41
Erie County, PA:		
45–54	0.92	...
55–64	1.47	...
65–74	0.75	...
75–84	0.97	...

[1] For these two studies, the sex mortality ratios are based on death rates for total mortality reported in the studies minus death rates for violence from national vital statistics (see Methods).

'The sex differences in the effects of smoking may be a result of interactions between smoking and risk factors that differ between males and females due to inherent physiological differences or differences in environmental exposures.'

ences in the increase in mortality caused by a given history of smoking habits. In addition, in the absence of controls for other factors that may co-vary with smoking (for example, alcohol consumption), the effects of these correlated factors are also included to some extent in the estimated proportion of the sex difference in mortality attributable to smoking. The relative importance of these three types of effects is at present unclear.

Concerning sex differences in smoking habits, not only has smoking been more common among men that among women, but also men smokers have generally had more dangerous smoking habits than women smokers (*6*, *12*, *18*, *23*). For example, among cigarette smokers, men smoke more cigarettes per day and more men inhale deeply.

Because of these sex differences in smoking habits, it has been difficult to find groups of men and women with similar smoking histories in order to evaluate possible sex differences in the effects of smoking. Available evidence suggests that the proportionate increase in death rates may be similar for men and women, but the absolute increase in death rates is greater for men than for women for total mortality, ischemic heart disease mortality, and lung cancer mortality (*6–8*, *11–14*, *17*, *23*, *28*, *29*).

This greater absolute increase in death rates for men contributes to the proportion of the sex differences in mortality attributable to smoking. The sex differences in the effects of smoking may be a result of interactions between smoking and risk factors that differ between males and females due to inherent physiological differences or differences in environmental exposures (*17*). For example, cigarette smoking and asbestos exposure interact to increase greatly the risk of lung cancer; many more men than women have been exposed to asbestos occupationally, and this is probably one reason why men who smoke have a greater increase in risk of lung cancer than women who smoke.

Findings concerning possible effects of factors that co-vary with smoking have been inconclusive. Findings from a study by Friedman and coworkers (*15*) suggest that confounding factors may be responsible for part of the effects attributed to smoking, but this conclusion is not supported by more limited data from the Swedish study (*12*). It appears that the proportion of sex differences in mortality attributable to smoking is due not only to sex differences in smoking habits, but also to sex differences in the effects of smoking, and the estimates of the contribution of smoking may also include effects of confounding factors.

One other very important caution should be noted in interpreting the estimates of the proportion of sex differences in mortality attributable to smoking. There are several reasons to believe that the method of analysis used, which focuses on the contribution of a single factor, such as smoking, may tend to overestimate the contribution of that factor. Indeed, if it were possible to identify each factor that contributes to higher male mortality and to make similar estimates of the percentages of sex differences in mortality attributable to each factor, then the sum of these estimates would be expected to exceed 100 percent.

One reason for this problem has been discussed. If two correlated factors both contribute to men's excess mortality, then single factor analyses that do not control for confounding factors will tend to attribute the effects of both factors to each individually. Similarly, if two factors have synergistic effects, for example, cigarette smoking and asbestos exposure, then single factor analyses will tend to attribute the synergistic effects to each of the factors individually. Thus, this type of single factor analysis can lead to "double-counting" of the effects of correlated risk factors and of synergistic effects.

There is another reason why the sum of the estimated contributions of individual factors to the sex difference in mortality may exceed 100 percent of the observed sex difference in mortality. This is related to the observation that, in addition to factors that contribute to higher mortality among males, there are factors that contribute to higher mortality among females (*10*, *17*, *18*). Consequently, if the contributions of all the factors that contribute to higher male mortality are summed, the total would be expected to exceed 100 percent of the observed sex difference in mortality by an amount equivalent to the contributions of all the factors that contribute to higher female mortality.

This is illustrated by the example of total cancer mortality for white adults in the United States. The estimated proportion of sex differences in total cancer mortality attributable to smoking is 89 to 98 percent, based on the very small sex differences in total cancer mortality observed for nonsmokers and the much larger male disadvantage observed for total population samples (*7*, *19*). However, the very small sex difference in total cancer mortality observed for nonsmokers reflects a balance between a female excess of breast cancer and a male excess for several other types of cancer, such as leukemia and bladder cancer (*6*, *12*, *19*). Thus, even among nonsmokers, men have higher mortality than women for certain types of cancer, and this implies that there must be other factors, in addition to smoking, that contribute to higher cancer mortality for men. The magnitude of the additional effects required to balance the female excess for breast cancer is indicated by the observation that, in this country, the female excess for breast cancer mortality has been equal to almost half of the sex difference in total cancer mortality (*24*).

Thus, the relative importance of the contribution of smoking to sex differences in mortality is probably overestimated by the type of single factor analysis I have discussed. Estimates of the contribution of smoking would be expected to be lower in a multivariate analysis that could take into account the contributions of confounding factors that co-vary with smoking, the contributions due to synergistic effects between smoking and other environmental exposures, and the contributions of factors that contribute to higher mortality risk for women as well as for men.

The data and methodological arguments presented thus far imply that, at least in the United States and Sweden in recent decades, smoking has been a major cause of excess mortality for men. Other factors, however, also have had an important influence on sex differences in mortality. This conclusion is supported by findings from studies of religious groups that proscribe smoking and by historical and international data.

Religion and Mortality Differences

Data for several religious groups that prohibit cigarette smoking indicate that, as expected, the male mortality disadvantage tends to be smaller in these groups than in general population samples. However, there is considerable variation in the sex differences in mortality in these groups because of differences in other characteristics.

Among the Hutterites, smoking is very rare, reflecting a strictly enforced prohibition against it (*30*). The Amish prohibit cigarette smoking, but many Amish men smoke pipes or cigars or chew tobacco (*31*). In contemporary data for the Hutterites and the Amish, men have higher mortality than women over most of the adult age span, although the excess of men's mortality over women's tends to be smaller for the Amish than for general population samples (*31*, *32*). Historical data for the Hutterites and the Amish suggest that for some age groups, women had higher mortality than men, but during the 20th century there was a shift from excess female mortality to excess male mortality (*31–33*). No evidence was found of changes in smoking habits that could account for the changing sex differences in mortality in these groups. Rather, it appears that the decrease and disappearance of the female mortality disadvantage was due to other factors, such as less childbearing (*18*, *32*).

Most Seventh Day Adventists also abstain from smoking, although many Adventists are converts and some smoked prior to their conversion (*34*, *37*). Data for Seventh Day Adventists in California indicate higher mortality for men than for women, but the male mortality disadvantage is generally smaller than among general population samples (*34*, *35*). Data for Adventists in the Netherlands suggest almost no mortality disadvantage for men (*36*), possibly reflecting not only the effects of abstention from smoking but also the effects of abstention from alcohol, greater education of the men, and other differences in the habits and characteristics of Seventh Day Adventists (*34–37*).

Analyses of international and historical data have shown a correlation between the magnitude of excess mortality for men and the amount of cigarette smoking (*16*,*38*,*39*). This provides additional evidence for the importance of the contribution of cigarette smoking to sex differences in mortality. At the same time, the international and historical data show a diversity of patterns that indicates the importance of a variety of other factors that also influence sex differences in mortality.

For example, historical data illustrate that men have had higher mortality than women even in some situations where cigarette smoking has been uncommon. For ages over 40, it appears that men had higher mortality than women in the United

States and most European countries in the second half of the 19th century when cigarette smoking was still rare (*18*, *40*, *42*). Previous analyses have shown that factors that may contribute to higher mortality for men in the absence of cigarette smoking include men's greater exposure to occupational hazards, heavier alcohol consumption, and possibly inherent sex differences in susceptibility to infectious diseases (*1*, *16–18*).

In contrast, Miller (*2*, *33*, *43*) has called attention to a study which showed that married men had a somewhat higher median age of death than married women in an Irish community where cigarette smoking was reported to be rare (*44*). However, the age distribution of men and women in this population was not given, and this raises questions concerning the interpretation of the median age of death data, particularly since the age distribution of men and women in this population may have been differently affected by emigration.

The other international data cited by Miller are also problematic. Miller lists five countries "where the men live as long or longer than the women" (*43*). However, for one of these countries, China, the United Nations source cited by Miller gives a longer life expectancy for females than for males (*45*). Miller does not provide evidence concerning sex differences in smoking habits in these countries, but I was able to find such evidence for China, Pakistan, and India.

In each of these countries, current evidence indicates that smoking is considerably more common among men than women (*46*, *47*). Also, a study in India has shown that smoking increases mortality for Indian men (*48*). Thus, smoking habits would tend to contribute to higher male mortality in India, Pakistan, and China, and other factors must account for the absence of a male disadvantage in life expectancy in India and Pakistan.

Data for India indicate that females have a shorter life expectancy than males because females have higher death rates in childhood and young adulthood (*1*, *17*, *18*). It appears that the major causes of these higher female death rates include less adequate nutrition and health care for females than for males and frequent childbearing by women who lack adequate health care and nutrition. This example illustrates that factors other than smoking can have an important influence on sex differences in longevity.

In conclusion, data for the United States and Sweden indicate that in recent decades about half of men's excess mortality has been due to smoking. Limited evidence suggests that this effect has been due primarily to cigarette smoking, with little contribution from pipe or cigar smoking. The contribution of smoking to sex differences in mortality appears to be due both to sex differences in smoking habits and to sex differences in the effects of smoking on mortality.

Several lines of argument indicate that estimates of the contribution of smoking based on the type of single-factor analysis I have discussed may be higher than estimates derived from a multivariate analysis that took into account the contributions of a broad range of causal factors. The evidence I have reviewed is in agreement with previous research which indicates that cigarette smoking is a major cause of men's higher mortality, but other factors also have an important influence on sex difference in mortality.

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