Socioeconomic Differentials in Mortality Risk among Men Screened for the Multiple Risk Factor Intervention Trial: I. White Men

ABSTRACT

Objectives. This study examined socioeconomic differentials in risk of death from a number of specific causes in a large cohort of White men in the United States.

Methods. For 300 685 White men screened for the Multiple Risk Factor Intervention Trial between 1973 and 1975, data were collected on median income of White households in the zip code of residence, age, cigarette smoking, blood pressure, serum cholesterol, previous myocardial infarction, and drug treatment for diabetes. The 31 737 deaths that occurred over the 16-year follow-up period were grouped into specific causes and related to median White family income.

Results. There was an inverse association between age-adjusted all-cause mortality and median family income. There was no attenuation of this association over the follow-up period, and the association was similar for the 22 clinical centers carrying out the screening. The gradient was seen for many—but not all—of the specific causes of death. Other risk factors accounted for some of the association between income and coronary heart disease and smoking-related cancers.

Conclusions. Socioeconomic position, as measured by median family income of area of residence, is an important determinant of mortality risk in White men. (*Am J Public Health.* 1996;86:486–496)

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Introduction

In 1865, in Providence, RI, less than one quarter of the population were taxpayers. These individuals constituted the affluent section of Providence society, and, for most age groups, their mortality rates were less than half of those of the less affluent nontaxpayers.[1] Data reported over the following 125 years indicate that socioeconomic position has remained an important predictor of mortality risk in the United States[2–13] in a period in which the relative importance of different causes of death has changed dramatically.[14]

The magnitude of socioeconomic mortality differentials has changed over time in the United States, the disparities having increased over the last 3 decades.[10,11,15,16] While mortality differentials are seen in essentially all of the industrialized countries in which they have been sought,[17,18] their magnitude differs between countries.[19,20] In formal comparisons of the size of mortality differences associated with education level,[20] it appears that larger differentials exist in the United States than in several European countries. The geographical and temporal variations in socioeconomic differentials in mortality indicate that their reduction could be achievable, with important gains for the overall health profile of the United States.

Previous studies of socioeconomic position and mortality have often originated from government data, in which case no information was generally available regarding characteristics other than age, sex, race/ethnicity, and, occasionally, socioeconomic position.[2,4,6,9,12,13] Studies with additional information have tended to deal with relatively small groups of individuals,[8] in which case there were limitations in the ability to examine socioeconomic differentials in risk of mortality from particular causes and/or the shape of the relationship between socioeconomic position and mortality risk. Data on men screened in the early 1970s for the Multiple Risk Factor Intervention Trial, which involved a 16-year mortality follow-up, allow for detailed examination of the socioeconomic gradient in mortality risk. Mortality differentials from a wide range of causes can be studied, providing evidence as to the possible etiologic roles of socioeconomic differences in susceptibility to disease in general and distributions of socially determined adverse exposures.[21] The contribution of key specific mortality risk factors, including smoking, blood pressure, and serum cholesterol, to the mortality differentials can also be investigated. Since income levels varied significantly for the White and Black men screened,[22] the relationship of income with mortality was investigated separately among Black and White men. This report gives the results for White men; a companion report gives findings for Black men.[22]

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Editor's Note. See related editorial by Link and Phelan (p 471) in this issue.

Methods

Methods used to recruit participants and collect baseline data on the men screened have been reported.[23,24] In brief, from November 1973 to November 1975, 361 662 men 35 to 57 years of age were screened at 20 Multiple Risk Factor Intervention Trial centers in 18 cities. Centers used a variety of recruitment methods, including house-to-house canvassing and screening of government or industrial employee populations, civic groups, unions, and churches.

Name, address, date of birth, self-reported race, Social Security number, and number of cigarettes smoked per day were recorded. Serum cholesterol levels were determined at one of 14 local laboratories with an Auto Analyzer II and with standardization by the Lipid Standardization Program of the Centers for Disease Control in Atlanta.[25] Three blood pressure measurements were taken with a standard mercury sphygmomanometer. Averages of the second and third readings are used in this report. Participants also reported whether they had been hospitalized for heart attack or were taking medication for diabetes. Vital status was determined through December 1990, an average of 16 years of follow-up (range = 15 to 17 years), by matching identifying information obtained from participants at the time of screening with the National Death Index (1979 to 1990) and data files obtained from the Social Security Administration (1973 to 1979). Vital status ascertainment was estimated to be 95% complete.[26] For decedents, death certificates were obtained and coded by a trained nosologist using the ninth revision of the *International Classification of Diseases.*[27]

The socioeconomic status of each participant, although not recorded at screening, was indexed by matching the participant's postal zip code with data from the 1980 US census,[28] this information coming from a period around 5 to 7 years after the screening examinations had been carried out. Median income for families headed by a White householder in the zip code area of residence was used as an ecologic marker of socioeconomic status. Income data could be computed for 300 685 of the 325 384 men who indicated at the time of screening that they were White. These 300 685 men came from 4644 zip code areas. Baseline characteristics and mortality rates for men with known and unknown income data Table 1) show that the latter had a less favorable risk factor profile and a slightly higher mortality rate than the former. The age-adjusted relative risk of mortality for the group without income data was 1.06 (95% confidence interval [CI] = 1.02, 1.11). Adjustment for smoking, diastolic blood pressure, serum cholesterol, prior heart attack, and medication for diabetes reversed this association, producing a relative risk of 0.90 (95% CI = 0.86, 0.93).

Mortality rates were age standardized by the direct method, based on the age distribution for the entire study population, and are presented as rates per 10 000 person-years of follow-up. Proportional hazards regression analyses,[29] stratified by the 22 clinical centers (one Multiple Risk Factor Intervention Trial center had three separate clinics), were performed to compute relative risks. These models included either age alone or age, diastolic blood pressure, serum total cholesterol, number of cigarettes smoked per day, history of hospitalization for heart attack, and medication for diabetes as covariates in examinations of the relationship between income and mortality. In the latter case, essentially all of the available explanatory variables were included. Separate regression models were fit for each clinical center to examine the consistency of the relationship of income with mortality after adjustment for age among the 22 clinical centers.

For an analysis of risk of total mortality, median income of families headed by White householders was categorized into fifteen $2000-interval groups ranging from $10 000 to $36 000. For other analyses and analyses of particular causes, median family income was divided into six groups based on the bottom and top deciles of income, together with quartiles of the men from zip code areas with median family incomes lying between these levels. These cutoffs were chosen to allow examination of differentials in cause-specific mortality with manageable tables. For these analyses, the group of men from zip code areas with the highest median family income were assigned a relative risk of unity. Regression coefficients are also presented from proportional hazards models in which zip code area median census tract income was treated as a continuous variable. The negative values of these coefficients were exponentiated to estimate change in risk associated with a $10 000 lower income.

TABLE 1—Baseline Data on White Men Screened Between 1973 and 1975, by Availability of Income Data for Zip Code Area: The Multiple Risk Factor Intervention Trial

	Income Data Available	Income Data Not Available
No. men	300 685	24 699
Mean age, y	46.0	46.2
Cigarette smokers, %	35.2	45.2
Mean systolic blood pressure, mm Hg	129.8	131.2
Mean diastolic blood pressure, mm Hg	83.5	86.6
Mean serum cholesterol, mg/dl	214.5	220.0
Prior hospitalization for heart attack, %	1.5	1.7
Medication for diabetes, %	1.4	1.3
Age-adjusted death rate (per 10 000 person-years)	69.4	74.4

Results

Characteristics of the 300 685 White men for whom zip codes were available are presented in Table 2 according to income. For the six income groups considered, there were weak trends of lower age and blood pressure with greater income and a very weak trend of higher cholesterol concentration with higher income. Lower prevalence rates of current cigarette smoking, previous heart attack, and diabetes with higher income were more pronounced findings. There was a strong correlation between income and other socioeconomic measures available to characterize zip code areas. In lower income zip code areas, unemployment was higher, the education level and the percentage of individuals in managerial or professional occupations were lower, and more people were below the poverty line.

All-Cause Mortality

Over the 16 years of follow-up, 31 737 deaths were identified among the

TABLE 2—Characteristics of White Men Screened, by Level of Median Family Income for Zip Code of Residence and Characteristics of Zip Code Areas of Residence

	Income, $[a]					
	<18 571 (n = 29 701)	18 571–21 585 (n = 58 832)	21 586–24 057 (n = 60 932)	24 058–27 372 (n = 60 834)	27 373–31 952 (n = 59 993)	≥31 953 (n = 30 393)
Characteristics of men screened						
Mean age, y	46.8	46.3	46.0	45.9	45.6	45.9
Mean systolic blood pressure, mm Hg	131.1	131.2	130.2	129.1	128.8	127.9
Mean diastolic blood pressure, mm Hg	84.2	84.0	83.6	83.1	83.1	82.7
Mean serum cholesterol, mg/dl	214.0	213.9	214.8	214.2	214.9	215.4
Cigarette smokers, %	40.6	38.7	37.1	34.6	31.0	28.5
Cigarettes per day for smokers, mean	27.2	26.8	26.9	26.8	26.1	26.2
Prior hospitalization for heart attack, %	1.8	1.8	1.5	1.5	1.3	1.0
Medication for diabetes, %	1.9	1.7	1.4	1.3	1.2	1.0
Population characteristics of zip code areas[a]						
Unemployment, %	4.6	3.7	3.4	2.8	2.3	2.0
Average years of schooling	13.1	13.6	14.0	14.4	14.8	15.4
Managerial or professional occupations, %	6.4	8.9	11.3	14.1	17.4	22.7
Below the poverty line, %	12.2	6.3	4.4	3.1	2.2	1.9

[a]Based on data from the 1980 US census.

TABLE 3—All-Cause Mortality among White Men Screened, by Level of Median Family Income for Zip Code of Residence

Income, $	No. Men	No. Deaths	Age-Adjusted Rate[a]	Age-Adjusted Relative Risk (95% CI)	Age- and Risk Factor–Adjusted Relative Risk (95% CI)
<10 000	3 541	525	91.8	1.75 (1.56, 1.96)	1.55 (1.38, 1.74)
10 000–11 999	6 312	882	87.6	1.67 (1.51, 1.85)	1.47 (1.33, 1.62)
12 000–13 999	16 545	2 258	86.5	1.62 (1.49, 1.77)	1.44 (1.32, 1.56)
14 000–15 999	28 136	3 501	78.9	1.50 (1.39, 1.63)	1.35 (1.24, 1.47)
16 000–17 999	37 931	4 595	78.2	1.49 (1.37, 1.61)	1.36 (1.25, 1.47)
18 000–19 999	42 430	4 564	70.1	1.33 (1.23, 1.44)	1.23 (1.14, 1.33)
20 000–21 999	50 644	5 174	68.1	1.31 (1.21, 1.42)	1.22 (1.13, 1.32)
22 000–23 999	39 704	3 901	64.5	1.25 (1.15, 1.35)	1.18 (1.09, 1.28)
24 000–25 999	24 921	2 226	61.9	1.19 (1.09, 1.30)	1.13 (1.04, 1.23)
26 000–27 999	19 681	1 702	59.0	1.15 (1.06, 1.26)	1.13 (1.03, 1.23)
28 000–29 999	13 631	1 093	56.5	1.10 (1.00, 1.21)	1.07 (0.97, 1.17)
30 000–31 999	7 971	680	58.2	1.10 (0.99, 1.23)	1.08 (0.97, 1.20)
32 000–33 999	4 709	357	51.9	1.01 (0.89, 1.15)	1.00 (0.88, 1.13)
34 000+	8 943	709	51.4	1.00 (Reference)	1.00 (Reference)

Note. Family income levels were based on data from the 1980 US census. Risk factors were diastolic blood pressure, serum cholesterol level, cigarettes per day, prior hospitalization for heart attack, and medication for diabetes. CI = confidence interval.
[a]Per 10 000 person-years.

300 685 men in the cohort. Mortality rates and relative risk estimates, according to median zip code area family income (henceforth "income") categorized into 15 groups, are presented in Table 3. The relationship between income and mortality was similar among smokers and nonsmokers; the changes in risk associated with a $10 000 lower income were 1.22 (95% CI = 1.19, 1.26) for smokers and 1.18 (95% CI = 1.15, 1.22) for nonsmokers. The graded association between income and mortality was also similar by age; relative risks associated with a $10 000 lower income were 1.17 (95% CI = 1.12, 1.23) for men 35 to 44 years old at screening, 1.20 (95% CI = 1.16, 1.23) for men 45 to 54 years old at screening, and 1.16 (95% CI = 1.11, 1.21) for those 55 to 57 years old at screening.

Cumulative mortality over the follow-up period for six income groups, presented in Figure 1, demonstrates that the differentials persisted over time. Cumulative mortality rates at 15 years for men in the six income groups (lowest to highest) were 12.7%, 10.9%, 9.8%, 8.9%, 7.9%, and 7.4%.

There was a considerable range in income, both within and between clinical centers, among the White men screened. This permitted an estimate of the relationship between income and mortality to be obtained for each center. Figure 2 plots adjusted relative risk estimates and 95% confidence intervals for all-cause mortality corresponding to a $10 000 lower income. These estimates were also all greater than one (range = 1.12 to 1.55), and the association was significant in 21 of 22 centers.

Cause-Specific Mortality

Mortality data for specific causes of death are presented in Tables 4 through 6. For each cause, the tables show age-adjusted and risk factor–adjusted relative risks (age-adjusted mortality rates and numbers of deaths in each income category for these causes are available from the authors). While risks of most causes of death increased with decreasing income, there was considerable heterogeneity in the strength of these relationships. Table 7 summarizes this by presenting the relative risks of mortality, adjusted for age and for both age and risk factors, associated with a $10 000 lower income for both broad cause of death groups and individual causes. The degree to which adjustment for risk factors attenuated the income–mortality associations was greatest for cardiovascular causes of death and smoking-related cancers, reflecting that the limited set of risk factors measured was most applicable to the etiology of these conditions. For example, the relative risk associated with a $10 000 lower income was reduced from 1.25 to 1.16 for coronary heart disease after adjustment for other risk factors. For nonhemorraghic stroke, this relative risk declined from 1.43 to 1.31. For lung cancer, the relative risk declined from 1.40 to 1.27 as a consequence of the larger percentage of men who reported using cigarettes in the lower income as compared with higher income groups.

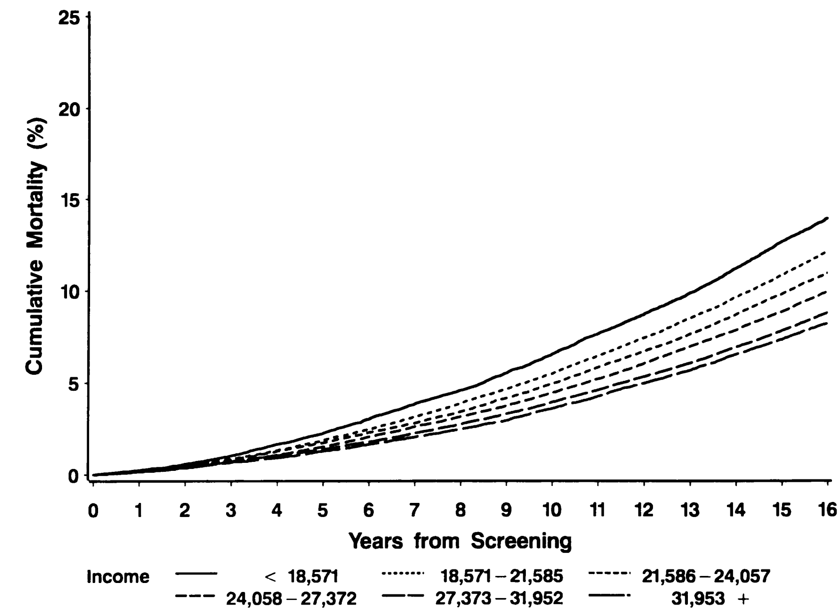

FIGURE 1—Cumulative mortality among White men screened, for six income categories.

Discussion

The cohort of men screened for the Multiple Risk Factor Intervention Trial provides a powerful database for study of the magnitude and causes of socioeconomic differentials in mortality. The differentials were of large magnitude and were seen for many—but not all—causes of death. There are, however, two major concerns regarding the data. The first relates to the degree to which the associations between socioeconomic status and mortality risk in the sample can be considered representative of the associations in the White population of the United States at large. While, for some centers, it is possible to calculate response rates from employment group surveys,[30] this cannot be done generally, nor can participants recruited through different mechanisms be analyzed separately. However, the consistency of the association of income with all-cause mortality for each of the 22 screening clinical centers provides evidence against the possibility that recruitment of men with both different average incomes and different mortality risks at the various screening centers underlies the observed relationships and indicates that the results may be widely generalizable among US White men.

An external check on the representativeness of the associations between income and mortality found in the Multiple Risk Factor Intervention Trial comes from a comparison with the equivalent associations seen in the National Longitudinal Mortality Study.[12] The latter provides 5-year follow-up data relating family income—applicable to the individuals themselves, not to their area of residence—to mortality for a representative sample of 155 346 White men 35 to 64 years of age at study entry. There were 6842 deaths among these men during follow-up, and standardized mortality ratios for that study are presented, together with Multiple Risk Factor Intervention Trial data, in Table 8. The trial cohort was divided into groups of equivalent size to those in the National Longitudinal Mortality Study for comparison. When analyzed by equivalent group size, the mortality differentials between income groups are somewhat wider in the National Longitudinal Mortality Study than in the Multiple Risk Factor Intervention Trial. However, when the mortality differentials presented in Table 3 are compared with those in the National Longitudinal Mortality Study, the two ranges are similar. This suggests that the Multiple Risk Factor Intervention Trial data provide a good model for socioeconomic differentials in mortality in the general population in relative terms but underestimate the absolute effect of these differentials because of underrepresentation of low-income men.

A second concern relates to the use of an ecologic index of socioeconomic status, median family income for zip code area of residence. The fact that the income data relate to 1980 rather than the time of the survey (5 to 7 years earlier) is probably a minor concern; while changes occur in the characteristics of neighborhoods, this is unlikely to seriously influence their ranking in terms of income of resident families in the period. If the actual family income of the participant is considered to be the underlying socioeconomic variable of interest, then the use of the ecological indicator could be seen as a source of misclassification. The relatively large populations of the zip code areas—as compared with the census tracts or blocks often used in US studies—may lead to some attenuation of the underlying mortality differentials as a result of the heterogeneity of socioeconomic level within individual zip code areas. However, the similarity of the income–mortality gradients in the Multiple Risk Factor Intervention Trial and studies in which income has been categorized at the level of the individual participant[12,31] suggests that personal family income and median family income of the zip code area of residence function in a similar manner as discriminators of mortality risk. Census-based data have been compared directly with individual socioeconomic indicators as predictors of health and health-related behaviors in US[32] and British[33] studies, the findings of which attest to the robustness of the area-based methodology.

The use of ecological indices of socioeconomic status has a long tradition in both the United States[3,7,34,35] and the

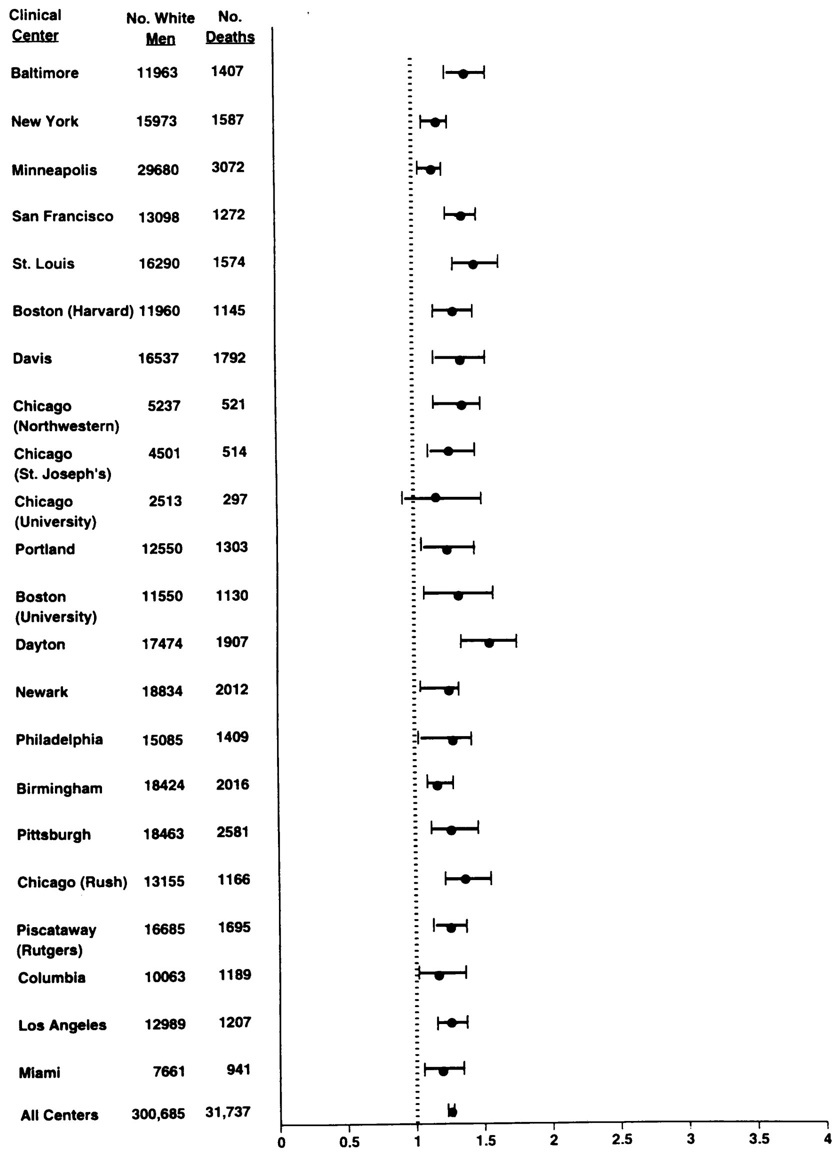

FIGURE 2—Relative risk of death associated with a $10 000 lower income among White men screened in each of 22 clinical centers.

United Kingdom.[36–38] As well as median income, these indicators have included factors such as level of education, tenure and quality of housing, car ownership, and area unemployment rates. Ecological measures may, in some circumstances, provide more stable information regarding socioeconomic status than individual-based socioeconomic data. First, consider the situation of temporary loss of earnings of a family member around the time individual-level data are collected. This would lead to reduced family income but not to a change of the ecological measure, the median family income of zip code area of residence. In this case, the ecological measure would be a better indicator of the usual socioeconomic circumstances of the study participant than individual-based data.

Second, family incomes in studies such as the National Longitudinal Mortality Study are not adjusted for size of the family; therefore, the same level of family income could have a different relationship to the actual economic circumstances of the individuals involved, depending on the size of the family and the number of dependents. For a given level of family income, large families will generally be in worse economic circumstances than small families. This will be reflected in the area of residence in which the family can afford to live. Again, in this respect, the ecological measure may be a better index of actual economic circumstances than the individual-based measure.

Third, even at a given level of personal family income, there are many factors related to the physical and sociocultural environment of the area of residence, and thus to the median family income of the zip code area, that could influence health.[39] In the Alameda County study, for example, it was shown that residents of "poverty areas" experienced elevated mortality rates even after statistical adjustment for income, education, race, health status at study entry, availability of health care, and a host of behavioral factors considered detrimental to health.[8]

In broad terms, the income differentials in mortality due to specific causes are similar in the Multiple Risk Factor Intervention Trial cohort and in the representative sample in the National Longitudinal Mortality Study.[12] However, the smaller number of deaths in the National Longitudinal Mortality Study in the equivalent age bands to the Multiple Risk Factor Intervention Trial cohort results in lower power for detailed examination of these associations. Furthermore, data on behavioral and physiological risk factors for mortality, available in the Multiple Risk Factor Intervention Trial, are unavailable in the National Longitudinal Mortality Study.

A striking finding from both this investigation and the National Longitudinal Mortality Study[12] is the graded and continuous nature of the association between income and mortality, with the differentials persisting into relatively privileged groups. This fine stratification of mortality risk has also been demonstrated in studies carried out in the United Kingdom and Canada.[18,31,40–43] The fact that socioeconomic differentials in mortality are not confined to groups that are, in any straightforward sense, materially deprived presents a serious challenge to any simple interpretations couched in terms of absolute poverty.

The degree to which socioeconomic differentials in health are in some ways artifactual (i.e., produced by the ways in which data are collected and analyzed) has been debated.[44–47] In particular, the manner in which causes of death are coded could be related to the socioeconomic position of the deceased. This is likely to occur with respect to the category of symptoms, signs, and ill-defined conditions (*International Classification of Dis-*

eases codes 780 through 799), which displays a marked gradient with income in the present study. Similarly, the same category is used more frequently for deaths occurring among minority populations than among Whites in the United States.[48] However, such an excess of poorly categorized deaths among lower income men is unlikely to greatly dilute the income–mortality associations for other causes, since a very small proportion of deaths end up with unspecified attribution.

In the United Kingdom, an empirical study of cause of death coding in relation to social class demonstrated that, with regard to broad cause groups, social class differentials in mortality are not greatly affected by bias in cause of death coding.[49,50] In a large study of the accuracy of death certificate data for cancer mortality, carried out in the United States,[51] the degree of misclassification between cancer sites is such that it is unlikely to completely account for differences in associations between income and particular cancers reported here. It could be, however, that in certain cases—such as with the acquired immunodeficiency syndrome (AIDS)—differences in access to health services according to income level influence the manner in which cause of death is classified.

Socioeconomic differentials in mortality could be produced by health-related social mobility if ill health leads to a worsening of socioeconomic position. The role of such health-related social selection in producing socioeconomic health differentials has been widely discussed,[45,46,52–54] but current evidence suggests that, at least acting in a direct manner, social selection has a relatively small influence on the magnitude of the differentials.[55]

Two aspects of the present study have a bearing on this. First, as discussed earlier, the area-based measure of socioeconomic position, median family income of place of residence, is less affected by loss of earnings due to poor health than an individually based measure. Therefore, the socioeconomic indicator used in this study is protected, to an extent, from the influence of health-related social selection. Second, mortality differentials generated by health-related social selection would be expected to be greatest early in the follow-up period. This is because sick men who suffer downward social mobility have an elevated mortality risk. Their high rate of death removes them from the study population, so at each successive follow-up period they have less influence on mortality differentials.[56] In a mortality follow-up of a 1% sample from the 1971 census in England and Wales, it was shown that socioeconomic differentials in mortality did not decrease with follow-up time, a finding that was interpreted as demonstrating that the role of health-related social mobility in producing socioeconomic differentials in mortality was small.[56] In this investigation, mortality differentials by income group also showed no tendency to decrease as the time from screening increased (Figure 1).

The present study could not examine the influence on mortality risk of socioeconomic position in early life or changes in social status from early childhood to adulthood. In the National Longitudinal Survey of Labor Market Experience of Mature Men, data are available on socioeconomic position at various stages of the life cycle.[57] Within the constraints of this small study (around 1500 deaths occurring in a cohort of 5000 men), the extent of family assets during middle age was inversely associated with mortality risk, in line with the findings of the present study. However, level of education and first occupation on entry into the labor market have an influence on mortality that is apparently distinct from that of family assets. This highlights the need to consider socioeconomic careers, rather than socioeconomic position at one point in time, in future studies.

The degree to which known risk factors account for income differentials in mortality was examined through stratification and through statistical adjustment. Smoking is an important behavioral risk factor for mortality from a variety of causes, and men in lower income groups were more likely to report smoking cigarettes. The stratification into smokers and

TABLE 4—Relative Risk Estimates, Adjusted for Age and All Risk Factors, of All-Cause and Cardiovascular Disease Mortality among White Men Screened, by Level of Median Family Income for Zip Code of Residence

	Income, $					
Cause of Death (No. Deaths)	<18 571	18 571– 21 585	21 586– 24 057	24 058– 27 372	27 373– 31 952	≥31 953
All causes (31 737)						
Age	1.59**	1.41**	1.32**	1.22**	1.10**	1.00
Risk factors	1.41**	1.28**	1.22**	1.15**	1.07**	1.00
Coronary heart disease (10 579)						
Age	1.62**	1.47**	1.37**	1.25**	1.16**	1.00
Risk factors	1.39**	1.30**	1.24**	1.16**	1.11*	1.00
Stroke (986)						
Age	1.63**	1.26	1.08	1.01	0.85	1.00
Risk factors	1.39**	1.11	0.98	0.94	0.82	1.00
Intracranial hemorrhage (265)						
Age	1.04	1.24	0.69	0.83	0.70	1.00
Risk factors	0.91	1.11	0.63	0.78	0.68	1.00
Nonhemorrhagic stroke (560)						
Age	2.39**	1.54*	1.47*	1.31	0.98	1.00
Risk factors	2.01**	1.35	1.33	1.22	0.94	1.00
Other cardiovascular disease (2537)						
Age	1.65**	1.35**	1.25*	1.24*	1.09	1.00
Risk factors	1.45**	1.22*	1.15	1.17	1.06	1.00
All cardiovascular disease (14 102)						
Age	1.63**	1.43**	1.33**	1.23**	1.12**	1.00
Risk factors	1.40**	1.27**	1.21**	1.15**	1.08*	1.00

Note. Family income levels were based on data from the 1980 US census. Risk factors were diastolic blood pressure, serum cholesterol level, cigarettes per day, prior hospitalization for heart attack, and medication for diabetes, as well as age; these were included in the regression model as covariates.
*$P < .05$; **$P < .01$.

TABLE 5—Relative Risk Estimates, Adjusted for Age and All Risk Factors, of Cancer Mortality among White Men Screened, by Level of Median Family Income for Zip Code of Residence

Cause of Death (No. Deaths)	Income, $ < 18 571	18 571–21 585	21 586–24 057	24 058–27 372	27 373–31 952	≥ 31 953
Esophagus (309)						
Age	1.64	1.32	1.47	1.56	1.26	1.00
Risk factors	1.50	1.23	1.39	1.49	1.23	1.00
Stomach (437)						
Age	1.31	1.05	1.02	0.99	1.02	1.00
Risk factors	1.23	0.99	0.98	0.96	1.00	1.00
Colon (1192)						
Age	1.50**	1.27	1.21	1.25	1.01	1.00
Risk factors	1.50**	1.26	1.20	1.25	1.00	1.00
Rectum (204)						
Age	1.98*	1.30	1.63	1.37	0.94	1.00
Risk factors	1.98*	1.30	1.63	1.37	0.94	1.00
Pancreas (658)						
Age	1.14	1.19	1.12	1.13	0.96	1.00
Risk factors	1.06	1.13	1.07	1.09	0.95	1.00
Lung (3729)						
Age	1.76**	1.79**	1.66**	1.41**	1.12	1.00
Risk factors	1.49**	1.57**	1.48**	1.30**	1.12	1.00
Melanoma (293)						
Age	0.53*	0.81	0.79	1.00	0.89	1.00
Risk factors	0.52*	0.80	0.79	0.99	0.88	1.00
Prostate (658)						
Age	1.23	1.34	1.10	1.16	1.20	1.00
Risk factors	1.19	1.31	1.08	1.15	1.19	1.00
Brain (485)						
Age	1.03	0.87	1.06	0.82	0.82	1.00
Risk factors	1.03	0.87	1.06	0.82	0.82	1.00
Lymphatic (529)						
Age	0.91	0.91	0.87	0.76	0.97	1.00
Risk factors	0.89	0.89	0.86	0.75	0.97	1.00
Hematopoietic (583)						
Age	1.38	1.22	1.23	1.16	1.10	1.00
Risk factors	1.34	1.19	1.21	1.14	1.09	1.00
All cancer (11 111)						
Age	1.38**	1.32**	1.26**	1.17**	1.03	1.00
Risk factors	1.26**	1.23**	1.18**	1.12**	1.02	1.00

Note. Family income levels were based on data from the 1980 US census. Risk factors were diastolic blood pressure, serum cholesterol level, cigarettes per day, prior hospitalization for heart attack, and medication for diabetes, as well as age; these were included in the regression model as covariates.
*$P < .05$; **$P < .01$.

nonsmokers demonstrates that income–mortality risk gradients are similar for smokers and nonsmokers. Similarly, even after adjustment for smoking and other risk factors, a $10 000 lower income was associated with an 18% higher mortality. While lack of data on lifetime smoking patterns does not permit separation of nonsmokers into never-smoking and ex-smoking groups, other studies in which such data are available attest to the robustness of this finding.[40,47,58]

For some causes of death—notably coronary heart disease and lung cancer—adjustment for risk factors led to quite substantial attenuation of the excess mortality among lower income groups. This is not surprising since the risk factors measured at screening related to these diseases in particular. It is probable that the residual associations seen after risk factor adjustment are at least partially due to the inaccuracy inherent in using single measurements of the risk factors that were measured.[59–62] Thus, more detailed information on smoking behavior and blood pressure would allow for better statistical adjustment for these risk factors, with attribution of income differentials in mortality to these factors consequently becoming more evident. However, in the case of serum cholesterol, the lower cholesterol levels in the lower income groups should produce a gradient in coronary heart disease risk in the opposite direction to that actually seen. If the lower serum cholesterol in the lower income men were a lifelong phenomenon rather than just a property of middle age, better measurement of serum cholesterol and improved statistical adjustment would actually lead to magnification, rather than attenuation, of the inverse relationship between income and coronary heart disease risk.

It is also the case that the socioeconomic differentials in mortality could be more marked if better indicators of socioeconomic position than median family income of zip code areas of residence were available. In a study of public servants in London, it was shown that improved characterization of socioeconomic position, through the use of multiple indicators, led to the demonstration of mortality differentials that were considerably wider than those seen when less precise measures were used.[40] In this study, the large socioeconomic differentials in coronary heart disease mortality could only partly be accounted for by differences in smoking, blood pressure, cholesterol, glucose intolerance, physical activity, height, and prevalent disease.[40,63] More detailed information on both known risk factors (including alcohol consumption, obesity, physical inactivity, and diet) and socioeconomic position is required if the degree to which the former account for coronary heart disease and lung cancer mortality differentials is to be elucidated further.

The degree to which known risk factors "explain" socioeconomic differentials in mortality should not be taken as a measure of reduced intrinsic importance of the differentials. The fact that smoking accounts for some of the difference in mortality rates between the income groups does not mean that social causes are themselves less important. Smoking—like alcohol use, exercise, and diet—does not occur in a social vacuum. That smoking breaks the rule that households with low incomes cope by decreasing the personal expenditure of adults cannot be reduced to personal failure. In constrained economic circumstances, smoking can be one

TABLE 6—Relative Risk Estimates, Adjusted for Age and All Risk Factors, of Noncardiovascular, Noncancer Causes of Death among White Men Screened, by Level of Median Family Income for Zip Code of Residence

	Income, $					
Cause of Death (No. Deaths)	<18 571	18 571–21 585	21 586–24 057	24 058–27 372	27 373–31 952	≥31 953
Infection (351)						
Age	1.73*	1.37	1.53*	0.79	0.77	1.00
Risk factors	1.65*	1.32	1.48*	0.77	0.76	1.00
AIDS (178)						
Age	2.13**	1.56	2.15**	0.67	0.49	1.00
Risk factors	2.02*	1.54	2.10**	0.68	0.50	1.00
Diabetes (402)						
Age	5.22**	3.72**	2.54**	2.16**	2.07*	1.00
Risk factors	3.66**	2.86**	2.00*	1.81*	1.86*	1.00
Respiratory (1270)						
Age	2.47**	1.94**	1.78**	1.36*	1.36	1.00
Risk factors	2.13**	1.73**	1.62**	1.27	1.35*	1.00
Chronic obstructive pulmonary disease (677)						
Age	2.70**	2.24**	1.95**	1.40	1.45	1.00
Risk factors	2.30**	1.98**	1.76**	1.30	1.46	1.00
Pneumonia and influenza (345)						
Age	2.46**	1.83*	1.35	1.25	1.14	1.00
Risk factors	2.15**	1.65*	1.23	1.17	1.11	1.00
Other respiratory (248)						
Age	2.06*	1.48	2.07*	1.52	1.55	...
Risk factors	1.89	1.38	1.96*	1.47	1.54	...
Digestive (1047)						
Age	2.21**	1.71**	1.83**	1.47**	1.37*	1.00
Risk factors	1.89**	1.51**	1.66**	1.37*	1.33*	1.00
Cirrhosis (603)						
Age	2.25**	1.84**	1.94**	1.61*	1.59*	1.00
Risk factors	1.91**	1.62*	1.76**	1.50*	1.55*	1.00
Other digestive (444)						
Age	2.16**	1.56*	1.70*	1.31	1.10	1.00
Risk factors	1.85**	1.38	1.54*	1.21	1.08	1.00
Symptoms, signs, and ill-defined conditions (227)						
Age	2.08*	1.82*	1.32	1.27	0.92	1.00
Risk factors	1.85*	1.65	1.22	1.19	0.90	1.00
Violent causes (1933)						
Age	1.73**	1.39**	1.22*	1.23*	1.14	1.00
Risk factors	1.61**	1.31**	1.16	1.18	1.13	1.00
Accidents (1073)						
Age	1.63**	1.29	1.15	1.13	1.04	1.00
Risk factors	1.53*	1.23	1.10	1.09	1.03	1.00
Suicide (705)						
Age	1.61**	1.40*	1.29	1.40*	1.35	1.00
Risk factors	1.47*	1.30	1.21	1.34	1.33	1.00
Homicide (153)						
Age	3.15**	2.22*	1.38	1.24	0.91	1.00
Risk factors	2.90**	2.09*	1.32	1.19	0.90	1.00
All noncancer, non–cardiovascular disease (6168)						
Age	1.96**	1.58**	1.47**	1.28**	1.20**	1.00
Risk factors	1.74**	1.44**	1.36**	1.21**	1.17**	1.00

Note. Family income levels were based on data from the 1980 US census. Risk factors were diastolic blood pressure, serum cholesterol level, cigarettes per day, prior hospitalization for heart attack, and medication for diabetes, as well as age; these were included in the regression model as covariates.
*$P < .05$; **$P < .01$.

TABLE 7—Relative Risks of Mortality Associated with a $10 000 Lower Median Income of Zip Code of Residence for White Men Screened

Cause (ICD-9 Code or Codes)	Age-Adjusted Relative Risk (95% CI)	Age- and Risk Factor–Adjusted Relative Risk (95% CI)
Broad cause groups		
All causes	1.26 (1.23, 1.28)	1.18 (1.16, 1.21)
Cancer	1.21 (1.16, 1.25)	1.15 (1.11, 1.19)
Cardiovascular disease	1.26 (1.22, 1.30)	1.17 (1.13, 1.21)
Noncancer, non–cardiovascular disease	1.36 (1.29, 1.43)	1.28 (1.22, 1.34)
Specific causes		
Infection (1–139)	1.35 (1.12, 1.62)	1.31 (1.09, 1.58)
AIDS (42–44)	1.57 (1.22, 2.01)	1.52 (1.19, 1.95)
Esophageal cancer (150)	1.20 (0.96, 1.48)	1.15 (0.93, 1.42)
Stomach cancer (151)	1.13 (0.94, 1.35)	1.09 (0.91, 1.31)
Colon cancer (153)	1.23 (1.10, 1.37)	1.22 (1.10, 1.37)
Rectal cancer (154)	1.25 (0.96, 1.64)	1.25 (0.96, 1.64)
Liver cancer (155)	1.35 (1.00, 1.83)	1.27 (0.94, 1.72)
Pancreatic cancer (157)	1.17 (1.01, 1.35)	1.13 (0.98, 1.30)
Lung cancer (162)	1.40 (1.31, 1.50)	1.27 (1.19, 1.36)
Bone cancer, connective tissue (170, 171)	0.95 (0.66, 1.37)	0.93 (0.65, 1.34)
Melanoma (172)	0.86 (0.71, 1.05)	0.86 (0.70, 1.04)
Prostate cancer (185)	1.11 (0.96, 1.27)	1.09 (0.95, 1.26)
Bladder cancer (188)	1.13 (0.85, 1.50)	1.08 (0.82, 1.43)
Kidney cancer (189)	1.01 (0.84, 1.22)	0.97 (0.80, 1.16)
Brain cancer (191)	1.04 (0.88, 1.23)	1.04 (0.88, 1.23)
Unspecified cancer (195–199)	1.13 (0.99, 1.29)	1.07 (0.94, 1.23)
Lymphatic cancer (200–202)	0.95 (0.81, 1.11)	0.94 (0.80, 1.10)
Hodgkin's disease (201)	0.91 (0.53, 1.57)	0.88 (0.51, 1.52)
Hematopoietic cancer (203–208)	1.16 (1.00, 1.26)	1.15 (0.98, 1.34)
Myeloma (203)	1.19 (0.89, 1.59)	1.17 (0.88, 1.55)
Leukemia (204–208)	1.15 (0.96, 1.38)	1.14 (0.95, 1.37)
Diabetes (250)	1.94 (1.57, 2.39)	1.62 (1.31, 1.99)
Diseases of the blood (280–289)	0.92 (0.66, 1.29)	0.89 (0.63, 1.24)
Diseases of the nervous system (320–389)	1.16 (0.95, 1.42)	1.14 (0.94, 1.39)
Motor neuron disease (335.2)	0.97 (0.68, 1.37)	0.95 (0.67, 1.34)
Rheumatic heart disease (390–398)	1.52 (0.98, 2.38)	1.52 (0.98, 2.37)
Coronary heart disease (410–414, 429.2)	1.25 (1.21, 1.30)	1.16 (1.12, 1.21)
Heart failure (428)	1.71 (1.24, 2.37)	1.57 (1.14, 2.18)
Stroke (430–438)	1.26 (1.12, 1.43)	1.17 (1.10, 1.23)
Intracranial hemorrhage (431–432)	1.14 (0.91, 1.42)	1.06 (0.85, 1.33)
Nonhemorrhagic stroke (433–438)	1.43 (1.21, 1.69)	1.31 (1.11, 1.55)
Aortic aneurysm (441)	1.10 (0.90, 1.34)	1.01 (0.83, 1.24)
Respiratory (460–519)	1.56 (1.39, 1.75)	1.44 (1.28, 1.61)
Chronic obstructive pulmonary disease (460–496)	1.62 (1.38, 1.91)	1.47 (1.25, 1.72)
Pneumonia and influenza (480–487)	1.70 (1.37, 2.11)	1.59 (1.28, 1.97)
Digestive (520–579)	1.40 (1.24, 1.57)	1.28 (1.14, 1.45)
Cirrhosis (571)	1.36 (1.16, 1.58)	1.25 (1.07, 1.46)
Genitourinary (580–629)	1.50 (1.11, 2.03)	1.39 (1.03, 1.88)
Symptoms, signs, etc. (780–799)	1.48 (1.14, 1.92)	1.40 (1.08, 1.81)
Violent causes (800–999)	1.27 (1.17, 1.39)	1.23 (1.12, 1.34)
Accidents (800–919)	1.28 (1.14, 1.43)	1.24 (1.10, 1.39)
Flying accidents (840–843)	0.50 (0.31, 0.79)	0.50 (0.31, 0.80)
Suicide (950–959, 980–989)	1.17 (1.01, 1.34)	1.11 (0.97, 1.28)
Homicide (960–969)	2.10 (1.51, 2.91)	2.00 (1.44, 2.78)

Note. Income levels were based on data from the 1980 US census. Risk factors were diastolic blood pressure, serum cholesterol level, cigarettes per day, prior hospitalization for heart attack, and medication for diabetes, as well as age. ICD-9 = *International Classification of Diseases*, 9th Revision; CI = confidence interval.

of the few activities undertaken for personal pleasure and one that provides some respite from the strain of coping with the consequences of material deprivation.[64] Similarly, in poorer areas, less healthy food is available than in affluent areas, and food is often more expensive.[65] The determination of socially patterned behaviors should be seen as part of the process generating socioeconomic differentials in health, not as a reason for considering social interventions unnecessary.[66,67]

In this investigation, for most causes of death, risk factor adjustment had little effect on the mortality differentials according to income group. This reflects lack of measurement of etiological factors—either because they were not included in the study or, more common, because they were not known—for most of these conditions. It has been argued that unfavorable socioeconomic environments increase the susceptibility to disease in general[68–72] and the potential biological mechanisms of stress-related immune suppression and neuroendocrine activation have been advanced to account for this phenomenon.[73,74] Within the general pattern of increased mortality risk with lower income, however, there was a marked heterogeneity of the strength—or even existence and direction—of the associations in the present study. This has been remarked on by other researchers[3] and examined in relation to site-specific cancer mortality in some detail.[21] It demonstrates the need to move beyond simple notions of increased general susceptibility to disease in less favored socioeconomic groups, presenting both a challenge and an opportunity to etiological investigations of particular diseases.

The extensive—and widening[10,15,16]—socioeconomic differentials in mortality indicate the depth of the social stratification that exists in the United States. Recent increases in inequalities in mortality also have been seen in the United Kingdom,[75,76] and, in both the United States and the United Kingdom, these trends parallel widening inequalities in income.[75,77] In the public health tradition, mortality differentials should be taken to be an indicator of what could be achieved, since reducing mortality rates of all socioeconomic groups to those of the highest income stratum would constitute an important health gain. There is, however, no sign that a reversal of the recent upward redistribution of income, which is required to achieve this goal, is likely to occur in the short term.[75,77]

The findings present a challenge of a different nature to epidemiologists. Socioeconomic mortality differentials are continuous across the social hierarchy and do not appear to be explicable in terms of absolute deprivation during adult life. Investigating the degree to which the socioeconomic careers of moderately afflu-

TABLE 8—Comparison of Income–Mortality Associations in the Multiple Risk Factor Intervention Trial (MRFIT) and the National Longitudinal Mortality Study (NLMS)

Income Group, $	% Population	SMRs[a] in NLMS	Age-Adjusted Relative Risk in MRFIT (95% CI)
≤ 18 950	12.2	167	1.56 (1.48, 1.65)
18 951–21 062	12.3	122	1.44 (1.37, 1.52)
21 063–22 612	13.9	97	1.33 (1.26, 1.40)
22 613–24 827	16.2	87	1.29 (1.23, 1.36)
24 828–32 804	36.9	80	1.14 (1.09, 1.20)
32 805+	8.4	66	1.00 ...

Note. In the MRFIT, participants were 35 to 57 years of age at baseline; in the NLMS, participants were 35 to 64 years of age at baseline. SMR = standardized mortality ratio; CI = confidence interval.
[a]SMR = 100 for total NLMS population.

ent people differ from those of people who are even better off, together with the ways in which this can lead to different patterns of accumulation of exposures detrimental to health over the entire life course, is necessary if further elucidation of the underlying factors is to occur.[38,57] □

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