The Relation between Income and Mortality in U.S. Blacks and Whites

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Differential mortality exists in the United States both between racial/ethnic groups and along gradients of socioeconomic status. The specification of statistical models for processes underlying these observed disparities has been hindered by the fact that social and economic quantities are distributed in a highly nonrandom manner throughout the population. We sought to provide a substantive foundation for model development by representing the shape of the income-mortality relation by racial/ethnic group.

We used data on black and white men and women from the longitudinal component of the National Health Interview Survey (NHIS), 1986–1990, which provided 1,191,824 person-years of follow-up and 12,165 mortal events. To account for family size when considering income, we used the ratio of annual family income to the federal poverty line for a family of similar composition.

To avoid unnecessary categorizations and prior assumptions about model form, we employed kernel smoothing techniques and calculated the continuous mortality surface across dimensions of adjusted income and age for each of the gender and racial/ethnic groups. Representing regions of equal mortality density with contour plots, we observed interactions that need to be accommodated by any subsequent statistical models. We propose two general theories that provide a foundation for more elaborate and testable hypotheses in the future. (Epidemiology 1998;9:147–155)

Keywords: race, socioeconomic factors, mortality, poverty, income, methods, kernel smoothing.

Associations between socioeconomic status (SES) and mortality were among the first epidemiologic observations and remain robust and widely replicated findings in public health research.[1–4] Racial/ethnic variation in mortality has also been a topic of great interest in epidemiology,[2] particularly in the United States, where mortality rates for blacks have been at least 60% greater than for whites for the entire 20th century,[5] growing even more disparate in recent years.[6] Because of their greater representation in national datasets, racial/ethnic comparisons in the United States have traditionally included only blacks and whites, although mortality data on other groups are increasingly available for analysis.[7–9]

The interrelation between race/ethnicity and SES has been the subject of much editorial comment,[3,10,11] but most published studies have simply included SES variables and an indicator term for black race in a model and tested for a group difference. Furthermore, studies that have adopted this strategy have reached a range of conclusions. Several publications report that adjustment for income and related measures "closes the gap" and thus "explains" the higher mortality rate of blacks relative to whites.[12,13] Other studies, however, report that discernible group differences remain even within income strata,[14] or that group indicators remain "significant" in models that are adjusted for income variables.[15]

A fundamental problem with these previous statistical analyses is that the model form and the inclusion of confounders were determined on the basis of significance testing. The problems associated with this strategy for model specification are well described.[16] For data involving social and economic quantities, however, the absence of randomization compounds the difficulty of interpreting these results.[17] The epidemiologic method for nonrandomized studies rests on the assumption that by adjusting for some finite set of measurable confounders, one can use the risk in the unexposed as an estimate of the risk that would have obtained in the exposed, had they not been exposed.[18] When considering socioeconomic exposures and making comparisons between racial/ethnic groups, however, this assumption is clearly untenable; the material, behavioral, and psychological circumstances of diverse socioeconomic and racial/ethnic groups are distinct on so many dimensions that no realistic adjustment can plausibly simulate randomization.[19]

To develop more realistic and useful models of the mechanisms that have produced the observed mortality patterns, the first task is to clarify the shape of the

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SES-mortality pattern across the age trajectory in strata of race/ethnicity and gender. This information provides a substantive basis for deciding what model forms are sensible. Models can be used to generate inference concerning etiology by allowing one to compare the observed patterns of mortality in populations with the patterns that would be expected under a variety of plausible causal hypotheses, and to use this comparison to identify theories of disease causation that could generate data that approximate those that are observed.[20]

Although the relation between socioeconomic status and mortality has been observed for several indicators of SES, including education[21–23] and occupation,[24,25] these variables entail several disadvantages compared with the use of income-based measures. Education has inherent discontinuities at points of program completion, and occupations must be categorized and ordered according to schema that may be somewhat arbitrary or idiosyncratic and that adhere to no natural scaling.[26] Occupational categories also exclude those who are not employed in the formal sector of the economy.[27] Moreover, both education and occupation are individual measures that may misclassify the social positions of spouses or dependents who share family resources but are not the primary "breadwinners."[28] In contrast, income may be assessed at either the individual or the family level and it may be represented continuously or with respect to some specific reference (for example, the poverty line).

Whereas the impact of income on mortality has been repeatedly demonstrated, the use of broad categorizations has often left the shape of this relation obscured. Dichotomizations of income are most frequently used, and studies using more than three or four categories of income are rare. Although a handful of studies have provided evidence about the shape of the income-mortality curve, each neglects at least one important dimension. Behrman *et al*,[29] for example, examined blacks and whites but considered only a relatively small sample of 58- to 73 year-old men. Pappas *et al*[30] included only whites in models of the income effect on mortality and applied age adjustment that assumed a constant effect of income across age categories.

Perhaps the most sophisticated and informative analyses are those of the National Longitudinal Mortality Study (NLMS) by Backlund *et al*[31] and Sorlie *et al*.[14] Backlund *et al*, however, opted not to stratify by racial/ethnic group, and they adjusted for this dimension with indicator variables, which therefore assumed a similar functional form and proportional responses. Sorlie *et al* also used continuous age adjustment and used family income with no adjustment for family size. Although the NLMS categorizes income into seven broad categories, both reports indicate that income has a roughly log-linear effect on mortality in most groups, and that the effect of income is more modest at higher ages and among women.[14,31]

We sought to explore the relation between income and mortality in blacks and whites. We used the longitudinal component of the National Health Interview Survey (1986–1990), a cohort of almost 400,000 adult men and women. The dataset includes over 12,000 mortal events (10,670 for whites and 1,495 for blacks), as well as self-reported family income and family size. Our research goal was to depict the shape of the income to mortality relation across the age dimension, within strata of race/ethnicity and gender.

The strategy in previous studies has generally been to select models and estimate adjusted parameters, with particular attention to the effect of adjustment on racial/ethnic differences. The elimination of these differences in the adjusted parameters has been offered as an "explanation" for the gap in the crude values, a strategy that is potentially misleading.[16–18] Although we wished to identify similarity or dissimilarity in the form of the relation across strata, we avoided statistical testing and interval estimation. Instead, we focused on the pattern of mortality that is evident when minimal assumptions about model form are imposed. As a basis for judging the precision of estimates, we suggest an alternative method for representing the relative degree of belief one might invest at any point. Finally, we describe two general theories for the mortality patterns observed.

Methods

The National Health Interview Survey

The NHIS is a continuing nationwide survey of the U.S. civilian noninstitutionalized population and is conducted through households. Each week, a probability sample of households is interviewed by personnel from the U.S. Bureau of the Census to obtain information about the health and other characteristics for each member of the sample household. The average annual sample consists of 45,000 households, including 120,000 persons. The annual response rate was 96–98% over the years analyzed here. Since one of the goals in designing the survey was to improve the precision of estimates involving the black population, sampling rates for selection of segments are increased in areas known to have the highest concentrations of blacks.

Mortality Follow-Up in the NHIS (1986–1991)

Beginning with survey year 1986, linkage information has been collected on NHIS respondents age 18 years and over to allow for matching with other data systems, including the National Death Index (NDI). Linkage of NHIS respondents with NDI provides a longitudinal component to NHIS, which allows for the ascertainment of vital status. At this time, mortality data are available for NHIS survey years 1986–1990, with follow-up to December 31, 1991. The National Center for Health Statistics (NCHS) uses a modification of a probabilistic approach to classify the NHIS-NDI potential matches.[32,33] They match an NDI record to an NHIS record if there is correspondence on any of 12 criteria, including Social Security Number, first name, middle initial, last name, father's surname, birth month, day, and year. Five categories of matches are formed, and each match is assigned a score in accordance with the number and pattern of items matched successfully. The first category classifies persons as deceased, and the fifth as still living. The remaining three classes designate matches with high degrees of probability, and in our analyses we use all matches from the first four categories that meet a minimum score which is recommended by the National Center of Health Statistics, as previously described.[34]

Definition of Race/Ethnicity

Since 1979, race has been obtained in the NHIS by asking the respondent to choose from among five categories: Aleut, Eskimo, or American Indian; Asian or Pacific Islander; black; white; and other. Respondents are then asked whether their national origin or ancestry is Puerto Rican, Cuban, Mexican/Mexicano, Mexican-American, Chicano, other Latin American, or Spanish. Those designating any of the above national origins are classified as Hispanic. Because of the smaller numbers of Hispanic participants (N = 27,239) and those in racial/ethnic groups other than white, black, and Hispanic (N = 13,787), only non-Hispanic blacks and whites were considered for analyses presented in this report. The classifications "white" and "black" used here therefore exclude those who identified their ethnicity as Hispanic.

Income Measurement

Family income is obtained in the NHIS interview by asking respondents to identify which category on a flash card represents the total combined family income during the last 12 months from wages, salaries, Social Security, retirement income, unemployment payments, interest, dividends, net income from business, farm, or rent, and any other money income received. The 27 income categories ranged from less than $1,000 (including loss) to $50,000 and above, with $1,000 increments up to $20,000 and $5,000 increments thereafter up to $49,999. To enable income to be used as a continuous measure, each respondent was assigned the midpoint of their interval. For the ≥$50,000 category, the value of $62,500 was used because it approximated the median of the group according to U.S. Census data.[35] All dollar amounts were then adjusted to 1990 dollars with the Consumer Price Index (CPI-U-X1).

Income/Poverty Ratio

To judge the resources available to families as a function of their total income, it is necessary to take into account the number of people dependent on that income. Previous researchers have approached this problem in several ways, including dividing the income by the number of people in the household or using multivariate adjustment for family size. We attempted to improve on this adjustment by expressing all family incomes relative to the 1990 federal poverty threshold for a family with the same number of members. Poverty thresholds were designed to account for the relatively larger fixed expenses of smaller units and the economy of scale achieved in larger units.[36]

Because the poverty thresholds represent the cost of satisfying basic needs for a given family size, the income to poverty ratio (I/P) is a measure of the resources available to the family after these needs are met. An I/P value of 1.0 indicates that a family is at the poverty level, whereas an I/P value of 2.25 indicates that the family income is at 225% of the relevant poverty threshold. With 27 possible income responses and 9 possible poverty levels, the total number of possible I/P values was 243, making a nearly continuous scale.

Finally, we took a log transformation of I/P for these analyses because the I/P variable is highly skewed to the right, and this transformation makes the quantity roughly symmetric. Furthermore, previous researchers have found the effect of income on mortality to be roughly log-linear.[14,31] In the log scale, therefore, the income needed to meet basic needs, given a specific family size, is subtracted, leaving log of disposable family income [that is, $\log(I/P) = \log(I) - \log(P)$].

Analytic Techniques

Because we wished to explore the data with minimal assumptions about model form, we applied a kernel smoothing technique to estimate the continuous mortality surface across dimensions of age and $\log(I/P)$.[37] We divided the age by $\log(I/P)$ surface into a 40 by 20 grid and ran a gaussian kernel smoother across each of the 800 grid-points in succession. At each point x = [age, $\log(I/P)$], we computed probability of death by weighting every observation in the dataset x_i = [age$_i$, $\log(I/P)_i$] as a function of the distance from the kernel locus (x), according to the following function:

$$P(D_x) = \frac{\sum_{i=1}^{N} e^{-|x-x_i|^2} z_i}{\sum_{i=1}^{N} e^{-|x-x_i|^2}} \qquad (1)$$

where z_i is 0 if the participant remained alive at the end of the observation interval and 1 if the participant had died, and $P(D_x)$ is the probability of death at the kernel locus (x).

Because the kernel is symmetric in dimensions of age and $\log(I/P)$, it was necessary to impose a relative scale between the two axes. We therefore applied equal weight functions to distances of 2 years and 1 standard deviation of $\log(I/P)$, where the standard deviations of $\log(I/P)$ were calculated for each gender and racial/ethnic group separately. The kernel was run across 81 years of age (18–99 years) and 8 standard deviations of $\log(I/P)$ (−4 to 4), although the computed surfaces were trimmed along the age and $\log(I/P)$ dimensions to exclude estimates in regions where there were few observations. The region that remained after trimming ran from −2 to 2 standardized units of $\log(I/P)$ and up to age 85 years. This range enclosed over 95% of the observations in all groups.

TABLE 1. Total Number of Deaths,* Rate of Death, and Accumulated Person-Years, by Ethnicity, Age Group, and Sex (Weighted)

Ethnic Group and Age Group (Years)	Men			Women		
	Total Deaths	Rate/100 Person-Years	Total Years Follow-up	Total Deaths	Rate/100 Person-Years	Total Years Follow-up
White						
18–44	469	0.159	294,926	243	0.081	300,779
45–64	1,381	1.027	134,514	941	0.649	145,004
≥65	3,956	5.628	70,292	3,680	3.546	103,792
Black						
18–44	137	0.327	41,885	93	0.184	50,595
45–64	259	1.734	14,942	184	0.980	18,772
≥65	427	6.673	6,398	395	3.976	9,925
Total	6,629		562,957	5,536		628,867

* Deaths through December 31, 1991. Only deaths confirmed using the NCHS algorithm are included.

For presentation of absolute annual mortality rates, the three dimensions of the computed surface (age, income, mortality density) were collapsed into a two-dimensional representation by plotting strata-specific contour maps of mortality isoclines (that is, lines connecting points of equal absolute annual risk). Overlaid on these plots are additional contours to represent the relative quantity of evidence on which estimates were based. One may invest belief in the precision of the estimates in proportion to the quantity of data from which they are derived. A measure of uncertainty (lack of evidence) was defined as:

$$uncertainty = \sqrt{\frac{1-\hat{p}}{(\hat{p}n)}} \qquad (2)$$

where $\hat{p}$ is the estimated annual probability of death at each point on the surface, and n is the number of participants at risk at the nearest lattice point. Because the value of n is dependent on the size of the smoothing matrix chosen, however, the uncertainty value has no meaningful absolute scale and is employed here to give a subjective assessment about where one might invest greater or lesser degrees of belief in the estimates. Low values of uncertainty show regions in which rate estimates are based on greater quantities of data. Contour plots were also constructed comparing black and white rates by gender, using selected mortality isoclines (0.01, 0.025, and 0.05) to show representative mortality experiences across the age range. All processing was done using the XLISP-STAT programming language on a Sparc workstation, and plots were constructed from data matrices using S-PLUS software.

Results

Distribution of deaths, death rates, and total person-years of follow-up by gender, categorized age, and racial/ethnic group are shown in Table 1. Estimates are weighted to adjust for oversampling. The death totals shown include all events confirmed using the NCHS algorithm, including those with missing income data.

The distribution of *I/P* values by gender, categorized age, and racial/ethnic group are shown in Table 2, also weighted to adjust for oversampling. The percentages in each category with missing income data, which vary from 12% to 23%, are also shown. Medians and percentiles of *I/P* are shown rather than mean values, because the untransformed data are highly skewed to the right. Median *I/P* ratios are consistently higher for men and for whites, and they peak in middle age (45–64 years).

Mortality contour plots for the four racial/ethnic-by-gender groups across a range of about 40 years (ages 45–85 years) are shown in Figures 1-4. This age range

TABLE 2. Income/Poverty Ratio*: 25th Percentile, Median, and 75th Percentile, by Ethnicity, Age Group, and Sex (Weighted)

Ethnic Group and Age Group (Years)	Men				Women			
	25th Percentile	Median	75th Percentile	Percentage Missing	25th Percentile	Median	75th Percentile	Percentage Missing
White								
18–44	2.05	3.18	4.68	12.4	1.86	3.04	4.56	12.0
45–64	2.59	4.02	5.74	16.6	2.23	3.59	5.26	17.5
≥65	1.58	2.45	3.75	19.9	1.27	2.02	3.24	22.5
Black								
18–44	1.07	2.01	3.35	19.5	0.69	1.54	2.80	17.5
45–64	1.28	2.37	3.87	20.7	0.94	1.88	3.23	21.9
≥65	0.92	1.42	2.17	21.8	0.77	1.15	1.88	23.1

* Reported total annual family income divided by the federally established poverty line for a family of the same composition.

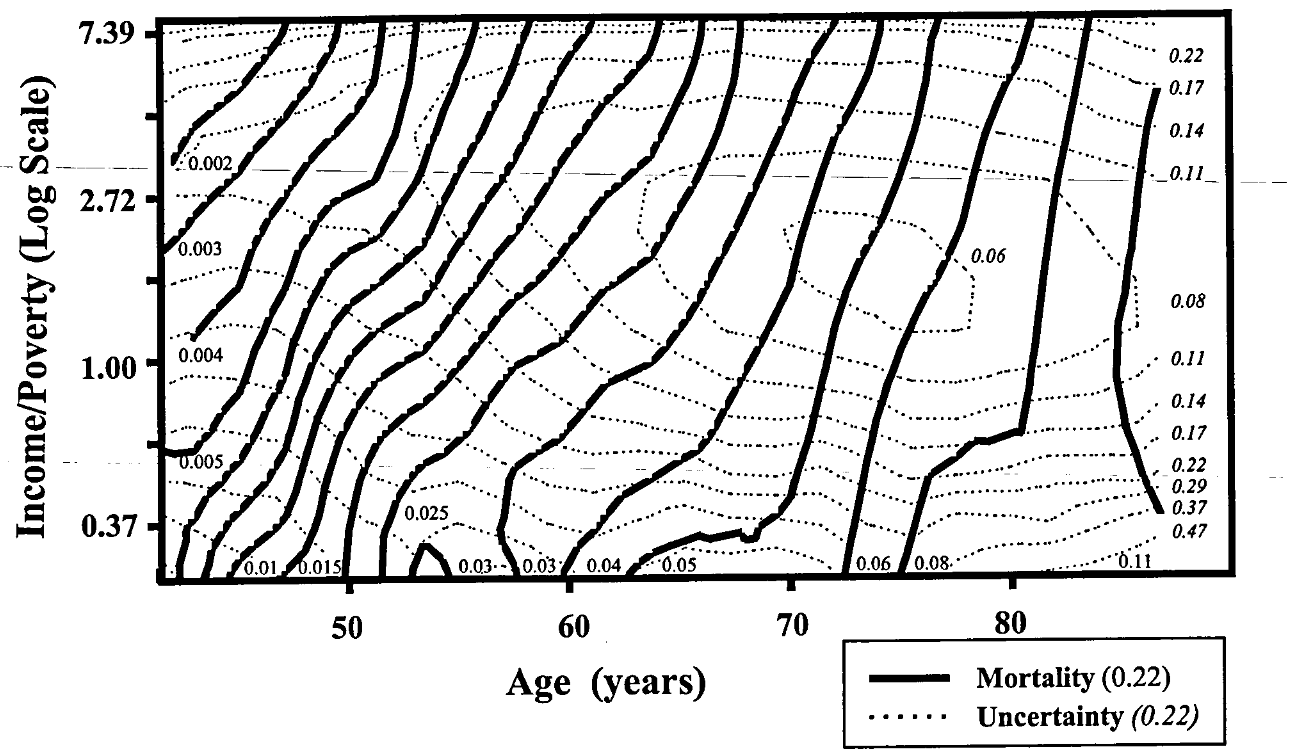

FIGURE 1. Isoclines of annual mortality for white men, by age and income/poverty ratio.

captures over 80% of the deaths, and the sparse representation of deaths across much of the I/P range outside of these ages led to unstable estimates elsewhere. Selection of contours for display was based on an exponential sequence (e^n, where n ranged from −6 to 0 by increments of 0.25). The mortality isocline lines on the plot connect regions with equal absolute mortality rates along dimensions of age and I/P, with labels for the

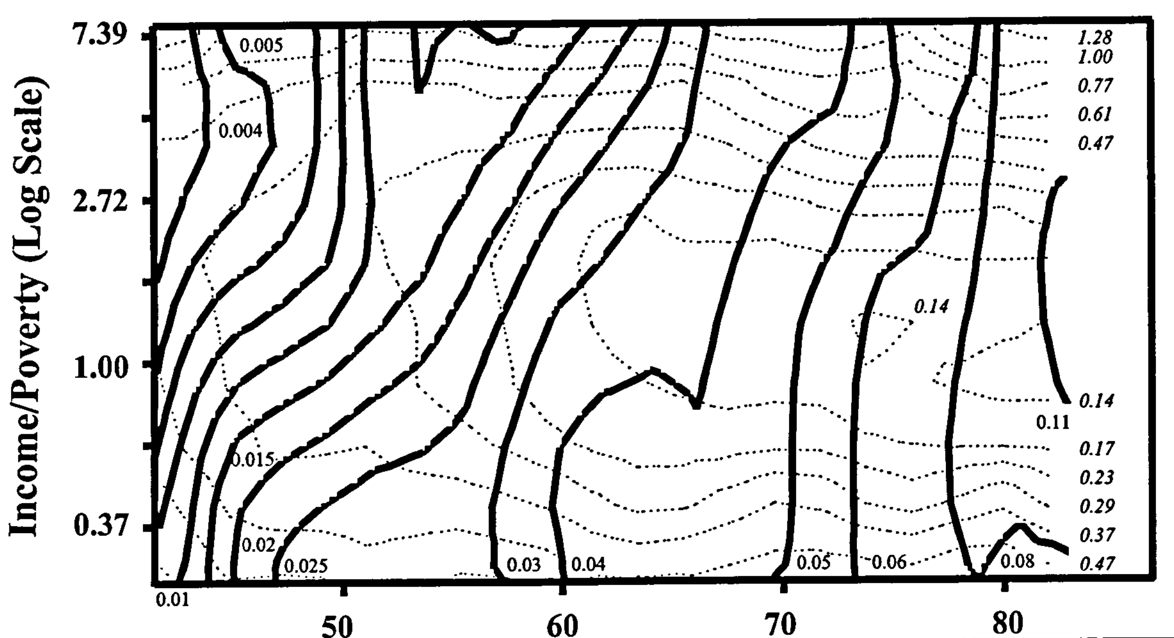

FIGURE 2. Isoclines of annual mortality for black men, by age and income/poverty ratio.

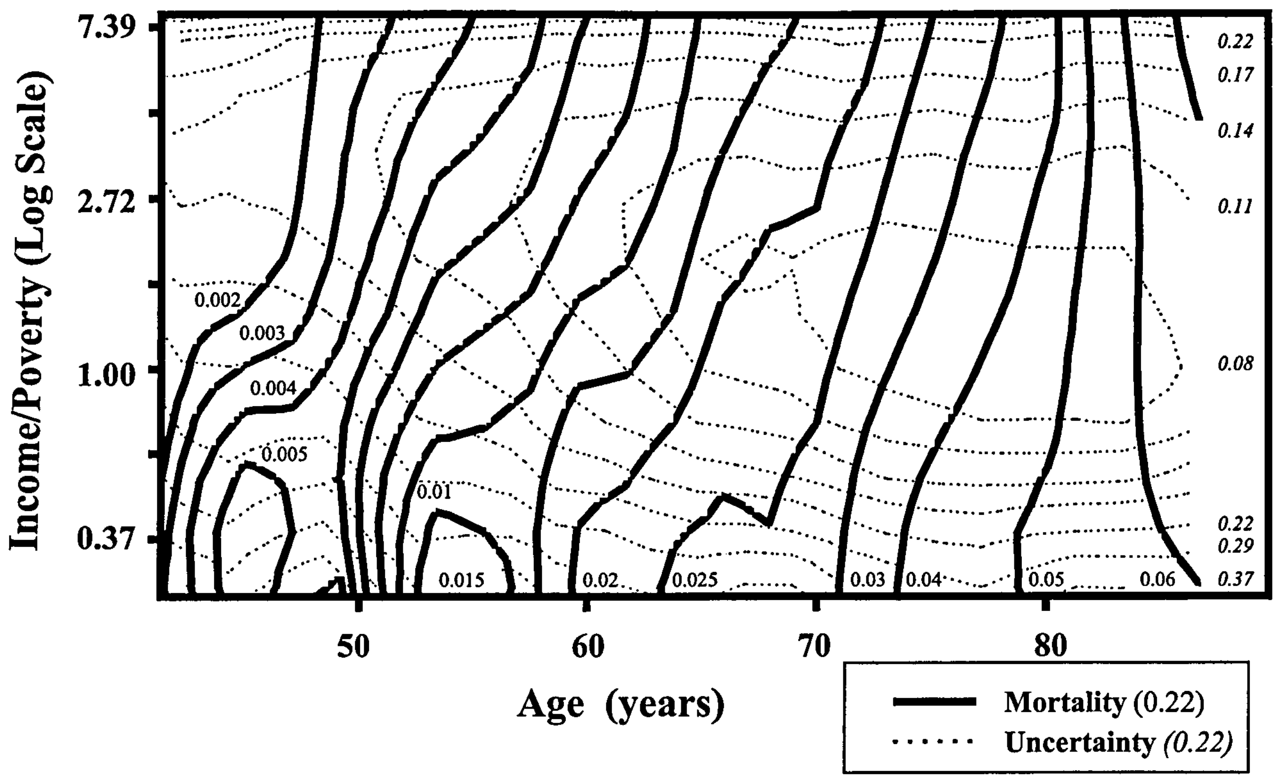

FIGURE 3. Isoclines of annual mortality for white women, by age and income/poverty ratio.

estimated probability of mortality running near the bottom of the plots. The uncertainty isocline lines connect regions of equivalent evidence along dimensions of age and *I/P*, with labels for the uncertainty value in italics near the right-hand side of the plots. The most striking difference between the contour plots for men and women is that women reach comparable mortality rates about a decade after men of similar age and *I/P*. All four plots conform to the previously reported general pattern of steepest income slope in the middle ages, a weaker income effect in the older ages (≥65 years), and income isoclines that are roughly linear in the log scale. Figures 5 and 6 show selected contours (0.01, 0.025, and 0.05) for blacks and whites, by gender.

Discussion

These analyses provide basic insights into the relation between age, income, and racial/ethnic group. Excess mortality exists for blacks for most of the income range, although the estimated disparity narrows below the poverty line, and there is even an estimated crossover at lower incomes for older men and women (Figures 5 and 6). In general, the angular displacement of the contour lines from the vertical, which represents the deleterious impact of poverty and the protective effect of higher income, appears smaller in magnitude for blacks than whites. Blacks therefore not only encounter a given mortality level sooner in age than whites, but also appear to derive less protection from higher income. For the 0.01/year mortality isocline in Figure 5, for example, the poorest white men experience this level of mortality at about age 45 years, although it is not reached by their wealthier counterparts until almost age 60 years. For black men, on the other hand, the difference in this mortality level between poorest and richest is about a decade. The 0.05/year isoclines are nearly vertical, indicating little effect of income on the probability of mortality once participants reach advanced age. The black to white disparity also narrows at older ages.

It is reasonable to ask which of these patterns are "real," in the sense that they represent stable and reproducible phenomena. Contours of uncertainty are provided in Figures 1–4 to show where estimates are based on the greatest quantity of data. Although this information does not give readers a cutpoint below which they ought not to trust the estimate at a given point, it provides a relative scale on which to extend credibility to the patterns shown. Readers can thus scale their own level of skepticism, rather than relying on fixed decision points based on convention, such as 95% confidence intervals or 0.05 *P*-values. Three general patterns are evident in the data: (1) excess mortality for blacks relative to whites at similar age and *I/P* values, (2) modification in the *I/P* effect over the age range, and (3) variation in the magnitude of *I/P* effect in blacks relative to whites. These three observations imply a displacement of the black rates to the left relative to the white rates. This displacement can be achieved either by shifting blacks down on the *I/P* scale or to the right on the age scale. Put another way, the data are consistent with

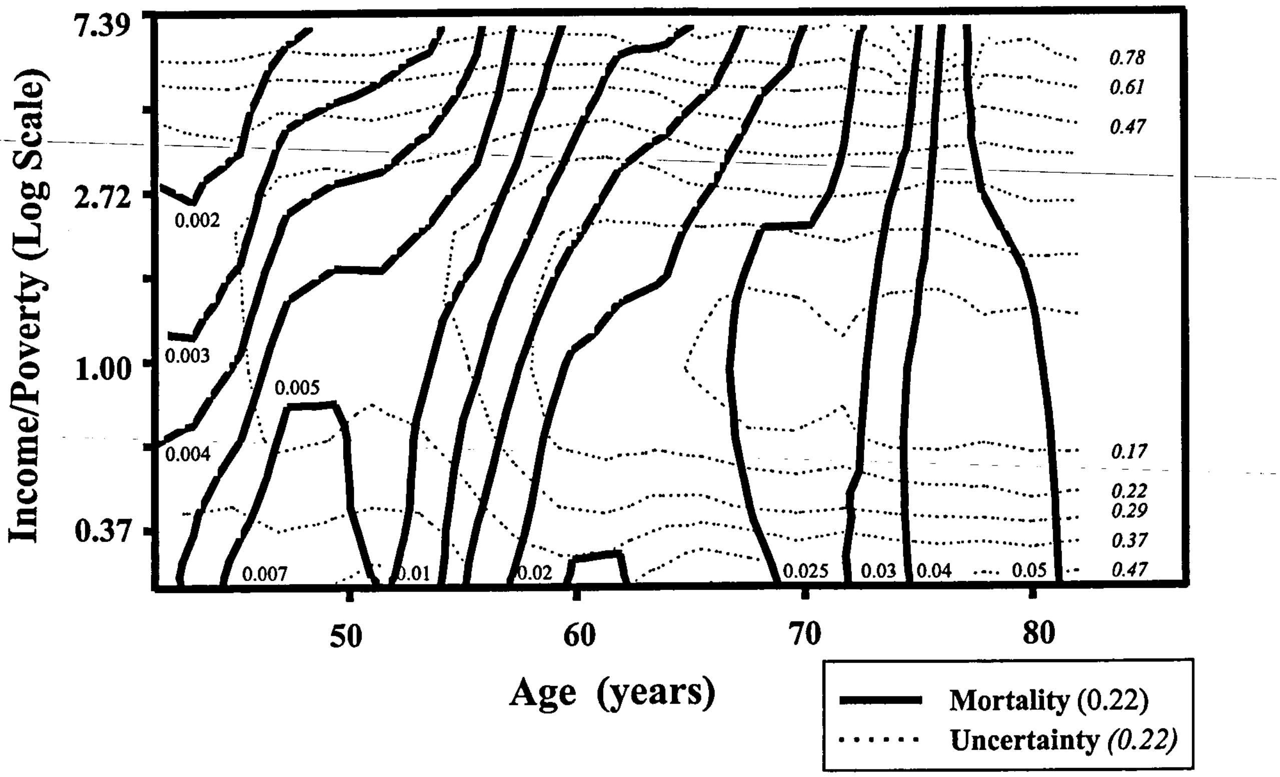

FIGURE 4. Isoclines of annual mortality for black women, by age and income/poverty ratio.

the general notion that, compared with whites, blacks are actually "older" or "poorer" than indicated by their values of age and *I/P*. We describe two broad theories that accommodate this shift in the black scale relative to whites: the Incommensurability Hypothesis and the Weathering Hypothesis. The former addresses the shift in the *I/P* scale, and the latter addresses the shift in the age scale. These are not mutually exclusive models, and in fact may be complementary. Neither has previously been applied specifically to the question of all-cause mortality gaps.

The Incommensurability Hypothesis suggests that when blacks and whites are compared at equal levels of one socioeconomic indicator, they remain unequal on other social indicators.[2,19,38] For example, when matched on educational level, blacks earn 80–90% the annual income of whites,[35,pp116–140] and when matched on income, blacks have roughly 20% of the accumulated assets enjoyed by whites.[39] The Incommensurability Hypothesis suggests, therefore, that the higher mortality of blacks at each level of income is, at least in part, a function of residual economic inequality between the groups.

The Weathering Hypothesis was developed by Geronimus[40,41] to address the question of black-white

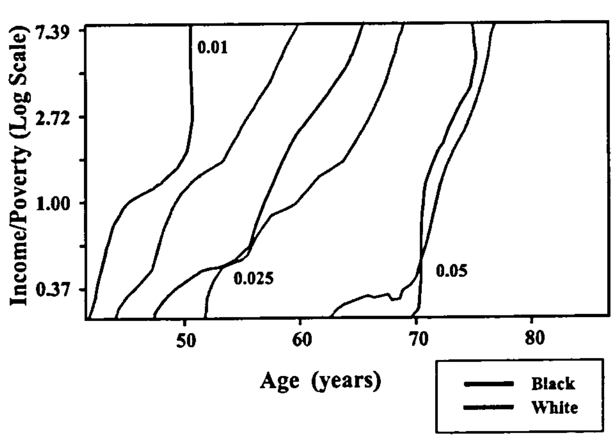

FIGURE 5. Selected average annual mortality isoclines for men, by age, income/poverty ratio, and racial/ethnic group.

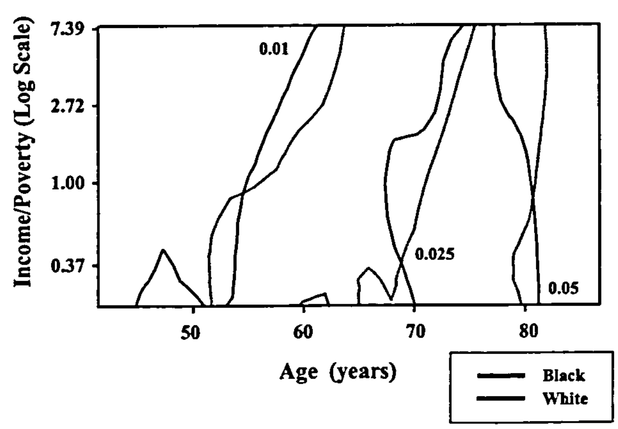

FIGURE 6. Selected average annual mortality isoclines for women, by age, income/poverty ratio, and racial/ethnic group.

differences in perinatal outcomes, specifically the higher rates of low birthweight and infant mortality for blacks relative to whites. The theory proposes that the accumulated effect of chronic social and environmental insults for blacks, as well as prolonged active coping with stressful circumstances, causes a progressive deterioration in health that leads to adverse outcomes. Because of the cumulative nature of this disadvantage, blacks face higher risk than whites of equal age, since blacks have been "aged" prematurely by the noxious social and environmental exposures that are part of the experience of being black in the United States. Applied to the question of all-cause adult mortality, the Weathering Hypothesis would entail a shift in the scaling of age for blacks relative to whites, such that at the same chronologic age, blacks are on average further along in pathogenic processes that result from injurious exposures and that contribute to higher probabilities of mortality.

Although we have attempted to impose minimal model form assumptions on the data, we have, by necessity, dictated several attributes of the smoothing procedure, including the kernel shape, the relation between age and income axes, and the dimensions of the smoothing matrix. Sensitivity analysis with a range of values for the first two of these, however, showed that deviations from our reported results were consistent with the uncertainty isoclines. That is, where the data were most dense, the sensitivity to our choices for smoothing parameters was least consequential.

Some caution in the interpretation of these data is required because of the potential for differential nonresponse to the NHIS income query (Table 2). We also note that income changes over time, and the *I/P* value at or near the time of death may not be the value that was reported some years earlier. Owing to the brief average length of follow-up (3.25 years), however, income volatility is not likely to be a major concern. Although "reverse causality" (poor health causing low income rather than low income causing poor health) has been suggested as a mechanism for differential volatility preceding death,[42] we are aware of little empirical evidence for this hypothesis.[43]

We have portrayed the shape of the income-mortality relation among blacks and whites by age and gender. In doing so, we avoided the imposition of strict model form, opting instead for a smoothing technique that entailed only minimal parameterization. We also avoided the common practice of basing explanatory inferences on the relation between crude and covariate-adjusted mortality probabilities. This inferential strategy has its basis in the assumption of randomization of exposures, which is very far from being met when racial/ethnic group and socioeconomic position are the factors of interest. Faced with unrandomized, observational data, therefore, covariate-adjusted parameters are not readily interpretable, and basic data description provides a more robust foundation for development of epidemiologic theory.[17]

The data description techniques applied here yielded a representation of mortality differentials between groups that provide a foundation for subsequent modeling toward the goal of identifying the underlying causal mechanisms. We have described two general theories that are consistent with the broad patterns that emerged in these analyses. We suggest the use of these theories to generate plausible models of the process, which can then be modified to accommodate elaborations in the theoretical framework as these hypotheses become more specific, testable, and refutable.

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References

1. Feinstein J. The relationship between socioeconomic status and health: a review of the literature. Milbank Q 1993;71:279–322.
2. Krieger N, Rowley DL, Herman AA, Avery B, Phillips MT. Racism, sexism, and social class: implications for studies of health, disease, and well-being. Am J Prev Med 1993;9(suppl):82–122.
3. Williams DR, Collins C. US socioeconomic and racial differences in health: patterns and explanations. Annu Rev Sociol 1995;21:349–386.
4. Williams DR. Socioeconomic differentials in health: a review and redirection. Soc Psychol Q 1990;53:81–99.
5. Cooper RS. Health and the social status of blacks in the United States. Ann Epidemiol 1993;3:137–144.
6. Kochanek KD, Maurer JD, Rosenberg HM. Why did black life expectancy decline from 1984 through 1989 in the United States? Am J Public Health 1994;84:938–944.
7. Hahn RA, Eberhardt S. Life expectancy in four U.S. racial/ethnic populations: Epidemiology 1990;1995;6:350–355.
8. Sorlie PD, Backlund E, Johnson NJ, Rogot E. Mortality by Hispanic status in the United States. JAMA 1993;270:2464–2468.
9. Wild SH, Laws A, Fortmann SP, Varady AN, Byrne CD. Mortality from coronary heart disease and stroke for six ethnic groups in California, 1985 to 1990. Ann Epidemiol 1995;5:432–439.
10. Williams DR. Race/ethnicity and socioeconomic status: measurement and methodological issues. Int J Health Serv 1996;26:483–505.
11. Navarro V. Race or class versus race and class: mortality differentials in the United States. Lancet 1990;336:1238–1240.
12. Rogers RG. Living and dying in the U.S.A.: sociodemographic determinants of death among blacks and whites. Demography 1992;29:287–303.
13. Sterling T, Rosenbaum W, Weinkam J. Income, race and mortality. J Natl Med Assoc 1993;85:906–911.
14. Sorlie P, Rogot E, Anderson R, Johnson NJ, Backlund E. Black-white mortality differences by family income. Lancet 1992;340:346–350.
15. Sorlie PD, Backlund E, Keller JB. US mortality by economic, demographic, and social characteristics: The National Longitudinal Mortality Study. Am J Public Health 1995;85:949–956.
16. Robins JM, Greenland S. The role of model selection in causal inference from nonexperimental data. Am J Epidemiol 1986;123:392–402.
17. Greenland S. Randomization, statistics and causal inference. Epidemiology 1990;1:421–429.
18. Greenland S, Robins JM. Identifiability, exchangeability and epidemiologic confounding. Int J Epidemiol 1986;15:413–419.
19. Kaufman JS, McGee DL, Cooper RS. Socioeconomic status and health in blacks and whites: the problem of residual confounding and the resiliency of race. Epidemiology 1997;8:621–628.
20. Koopman JS. Emerging objectives and methods in epidemiology. Am J Public Health 1996;86:630–632.
21. Elo IT, Preston SH. Educational differentials in mortality: United States, 1979–1985. Soc Sci Med 1996;42:47–58.
22. Feldman JJ, Makuc DM, Kleinman JC, Coroni-Huntley J. National trends in educational differentials in mortality. Am J Epidemiol 1989;129:919–933.
23. Kunst AE, Mackenback JP. The size of mortality differences associated with educational level in nine industrialized countries. Am J Public Health 1994;84:932–937.
24. Marmot MG, Shipley MJ, Rose G. Inequalities in death: specific explanations or a general pattern? Lancet 1984;1:1003–1006.
25. Duncan BB, Rumel D, Zelmanowicz, Mengue SS, dos Santos S, Dalmáz A. Social inequality in mortality in São Paulo State, Brazil. Int J Epidemiol 1995;24:359–365.
26. Jones IG, Cameron D. Social class analysis - an embarrassment to epidemiology. Community Med 1984;6:37–46.

27. Arber S. Integrating nonemployment into research on health inequalities. Int J Health Serv 1996;26:445–481.
28. Erikson R. Social class of men, women and families. Sociology 1984;18:500–514.
29. Behrman JR, Sickles R, Taubman P, Yazbeck A. Black-white mortality inequalities. J Econometrics 1991;50:183–203.
30. Pappas G, Queen S, Hadden W, Fisher G. The increasing disparity in mortality between socioeconomic groups in the United States, 1960 and 1986. N Engl J Med 1993;329:103–109.
31. Backlund E, Sorlie PD, Johnson NJ. The shape of the relationship between income and mortality in the United States: evidence from the National Longitudinal Mortality Study. Ann Epidemiol 1996;6:12–20.
32. Fellegi IP, Sunter AB. A theory of record linkage. J Am Stat Assoc 1969; 64:1183–1210.
33. Rogot E, Sorlie P, Johnson NJ. Probabilistic methods in matching census samples to the National Death Index. J Chron Dis 1986;39:719–734.
34. Liao Y, Cooper RS, Cao G, Durazo-Arvizu R, Kaufman JS, Luke A, McGee DL. Lower mortality patterns among adult Hispanics. Am J Public Health 1998;88 (in press).
35. U.S. Bureau of the Census. Current Population Reports. Money Income of Households, Families, and Persons in the United States: 1992. Series P60-184. Washington DC: U.S. Government Printing Office, 1993.
36. Fisher GM. The development and history of the poverty thresholds. Soc Sec Bull 1992;55:3–14.
37. Wand MP, Jones MC. Kernel Smoothing. London: Chapman and Hall, 1994.
38. Herman AA. Toward a conceptualization of race in epidemiologic research. Ethnicity Dis 1996;6:7–20.
39. Eller TJ. Household Wealth and Asset Ownership: 1991. U.S. Bureau of the Census. Current Population Reports. P70-34. Washington DC: U.S. Government Printing Office, 1994;xiii.
40. Geronimus AT. The weathering hypothesis and the health of African-American women and infants: evidence and speculations. Ethnicity Dis 1992;2:207–221.
41. Geronimus AT. Black/white differences in the relationship of maternal age to birthweight: a population-based test of the weathering hypothesis. Soc Sci Med 1996;42:589–597.
42. Vagero D. Inequality in health: some theoretical and empirical problems. Soc Sci Med 1991;32:367–371.
43. Fox AJ, Goldblatt PO, Jones DR. Social class mortality differentials: artefact, selection, or life circumstances? J Epidemiol Community Health 1985;39: 1–8.