Measuring Socioeconomic Differentials in Mortality

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Abbreviations:
SII: Slope index of inequality
RII: Relative index of inequality

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Running head:
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(exactly 50 characters including spaces)

Abstract

Research on socioeconomic inequalities in health often examines inequality in mortality rates or life expectancy. The choice of inequality measure is important because it should be consistent with the dominant temporal trend in the characteristic of interest. The author argues that proportional measures of inequality in mortality rates and additive measures of inequality in life expectancy are preferable to the alternatives because the dominant temporal pattern in mortality has been one of proportional decline in mortality rates concomitant with additive increase in life expectancy. Proportional differentials in mortality rates are mathematically consistent with additive differentials in life expectancy, and both are stable measures of inequality given the temporal trends.

Social inequalities in health are a perennial topic of much popular interest and scholarly research (1–3). Because health is multidimensional, the array of possible measures is extremely wide. Although subjective measures can be predictive of objective health outcomes like death (4, 5), and the incidence of specific diseases is often of independent interest, researchers studying broad trends among populations often select mortality as a good objective measure of poor health (1, 2).

There are almost as many indexes of inequality as there are measures of health, and numerous sources in the research community have sought to offer guidance regarding the differences across indexes and how to choose between them (6, 7). Two broad classes of inequality indexes are those based on additive ("absolute") differences between indicators, like the number of inches I may be shorter in height than my neighbor, and those based on proportional ("relative") differences, like the fact she may earn 25% more than I do. There are many other measures of inequality that are less functionally constrained, such as the Gini coefficient, the index of dissimilarity, and other entropy measures, but these measures do a poor job of capturing socioeconomic inequality in health (8). Each type of index arguably has intrinsic merit, but researchers should choose indexes that are not misleading in the context of the problem they seek to describe.

Inequality is very interesting in an intertemporal setting, and many studies have examined trends in socioeconomic inequalities in mortality over periods of time (1, 2, 9–15). Measured at a point in time, any inequality index can reveal how far we must go to achieve equality. From a public health perspective, absolute levels of risk may always be important (2). But to gauge trends in inequality, the index we use should be consistent with the general trend in the underlying variable of interest.

In this paper, I argue that the nature of temporal change in mortality implies there are optimal choices of inequality indexes when measuring either mortality rates or life expectancies across groups, and those two optimal choices are not the same. Proportional inequality in mortality rates is more meaningful than is additive inequality because mortality rates are trending downward exponentially. Additive inequality is more meaningful than proportional inequality in life expectancy for a similar reason. The research community already seems comfortable with interpreting additive differences in life expectancy as inequality (1, 14–16), but it also frequently explores additive differences in mortality rates when proportional differences are more appropriate. Because these two types of measures can easily disagree on the trends, this leads to unnecessary confusion.

As I show, my recommendations about the optimal index given the choice of mortality measure are supported by the data and by theory. In the space that follows, I review the literature on trends in socioeconomic differentials in mortality, illustrating the problems of interpretation that arise from the use of multiple and often conflicting indicators. I present the two most common measures of socioeconomic inequality in mortality rates and illustrate why they can easily indicate different trends. Then I discuss the empirical and theoretical evidence why measures of proportional inequality in mortality rates, like measures of additive inequality in life expectancy, should be preferred.

The literature on socioeconomic inequalities in mortality

In mortality studies, variation in the choice of inequality index typically arises when the socioeconomic variable of interest is not dichotomous, when it is not measured well in vital statistics, or when both are true. The sex gap is probably the most fundamental inequality in human mortality, and there is little disagreement in the literature that the additive gap between the sexes in life expectancy is the most appropriate measure of inequality (16–19). Similarly, the race gap in the U.S. is typically calculated as the additive difference in life expectancy between African Americans and whites (14, 20). In both cases, the covariate is dichotomous and well measured in vital statistics, so it is straightforward to calculate life tables and life expectancy with precision.

When the indicator variable is either continuous, as with education or income, or not well measured in vital statistics, cell size constraints typically prompt researchers to examine mortality rates rather than life expectancy. Ecological studies using county-level vital statistics matched to county-level characteristics like median income or % black often cannot examine life expectancy, which requires measurement of age-specific mortality rates (1, 2). Individual-level studies of trends have typically compared small, short panels that are separated across time, where small cell size motivates the choice of mortality rates (9–13). A recent study of educational differentials measures life expectancy after increasing cell sizes by treating education as dichotomous and measuring age in 10-year groupings (15). But when exploring the contributions to mortality by cause, the study switches to examining additive differences in mortality rates. As I will show, this is not the ideal juxtaposition.

Rather than making a choice, many researchers who examine socioeconomic inequality in mortality rates report indexes of both additive and relative inequality, probably in part because there is controversy over which type of measure is more meaningful (2, 7). Problems arise when the two measures indicate opposite trends in inequality. Often they have not, as in the case of two prominent studies that find that additive and proportional socioeconomic differentials in mortality rates widened among white men between the 1960s and the 1980s (9, 10). But the latter study reveals that trends in additive and proportional inequality in mortality rates among older women had moved in opposite directions.

Other studies of trends produce results with very clear inconsistencies across the two types of measure. Two related articles examine differentials in mortality rates across education and income between the 1960s and 1980s (12, 13). They find that proportional inequality had increased between for all race/sex groups, while additive inequality decreased for all but one group. A recent article reveals uniform narrowing in both additive and proportional indexes of income and racial inequality in mortality rates between 1966 and 1980, followed by a period of rising proportional inequality but stagnant additive inequality (2). An unpublished study of inequality in mortality rates among military retirees according to their final rank reveals widening proportional inequality in mortality rates since 1974 but stagnant or decreasing additive inequality (Edwards RD, Queens College, CUNY).

Reporting or at least exploring trends in all possible measures of inequality is certainly an option for researchers studying differential mortality rates. But when trends contradict one another, inference is clouded. I argue that evidence and theory suggest that proportional inequality in mortality rates should be the preferred indicator, just as additive differences in life expectancy seem to be universally well regarded. Both choices are motivated by similar evidence and theory. For exposition, I first explore how and why measures can disagree on trends in inequality.

Proportional versus additive inequality in mortality rates

It is very easy for trends in additive measures of additive socioeconomic inequality in mortality rates to diverge from trends in proportional measures. As discussed in a recent review of the literature (21), the key element is the nature of change in mortality rates. If all mortality rates are declining proportionally, then proportional inequality must remain the same while additive inequality will decrease, since additive gains are larger for groups with high mortality. If instead all mortality rates are declining additively, then additive inequality will naturally remain unchanged while proportional inequality will increase because gains are proportionally larger for groups with low mortality.

Table 1 depicts these patterns in two simple examples of inequality trends observed after a "top" group starts with half the mortality rate of a "bottom" group. I use two indexes of inequality that are standard in the literature. The slope index of inequality (SII) measures the average additive change in an indicator over the entire distribution of a characteristic at a point in time. In this dichotomous example, the SII is merely the difference of the two groups' mortality rates. The relative index of inequality (RII) is the proportional analogue of the SII. It is the average additive change over the distribution in the proportion of an indicator relative to the unconditional average of the indicator. Here, it is the SII divided by the average mortality rate over the two groups. These and other inequality measures are reviewed and discussed in greater detail elsewhere (8).

The SII and RII register very different trends in inequality depending on the underlying nature of mortality change. In panel A of Table 1, mortality rates of both groups decline at 1%, which leads to a larger additive change in the bottom group's mortality rate and an improvement in additive inequality as measured by the SII. But since both groups' mortality rates decline at the same proportional rate, the RII remains unchanged. Panel B considers inequality when mortality rates decline by a constant additive amount for both groups. The SII remains constant under this scenario, but the RII measures a worsening in proportional inequality because the bottom group experienced a less-rapid decline.

Which measure of inequality in mortality rates is better for examining trends in inequality depends on the nature of the overall trend in mortality. It is intuitive to expect that if groups are sharing equally in the typical gains against mortality, then inequality should remain fixed. Additive measures of inequality like the SII would be appropriate for indicators that tend to increase additively over time, while proportional measures like the RII would be appropriate when the trend is proportional change.

Temporal trends in mortality

Our common perception of additive differences in life expectancy as best indicating socioeconomic inequality in mortality is already consistent with the notion that sharing equally in gains in life expectancy should be associated with static inequality. Throughout the last several hundred years of human history, "best practices" female life expectancy at birth, the highest recorded level in any country in a particular year, has increased remarkably linearly (22). The same is true of the life expectancy for both sexes in industrialized countries since 1955 (23), for which a straight line regression explains 90 percent or more of the temporal variation.

In any particular country, life expectancy is not strictly linear but may accelerate and decelerate somewhat over time, as shown for the U.S. since 1933 in Figure 1. Progress against mortality is a complicated function of the advent and implementation of new technologies, incomes, and behaviors, all of which fluctuate around trends. The figure also shows the waxing and waning of the female advantage, arguably the most fundamental human inequality in mortality that is universally measured as the additive gap in life expectancy (16–19).

As life expectancy has grown additively, and as additive inequality in life expectancy has ebbed and flowed, mortality rates have been declining proportionally. In fact, demographers have historically tended to characterize the dominant temporal trend in mortality in industrialized countries since the Second World War as one of steady proportional decline in mortality rates (24–26). There are signs this view may be changing somewhat given the linearity of life expectancy increases (27, 28), but proportional decline remains the basis for many official forecasts, including those of the U.S. Social Security Administration.

Figure 2 plots the logarithm of age-adjusted mortality rates in the U.S. since 1933 for males, females, and both sexes combined using data from the Human Mortality Database (29). As with life expectancy, rates of decline in mortality rates have clearly oscillated, but 92.7 percent of the temporal variation in U.S. log mortality rates can be explained by a straight-line projection (23, 24). Comparison of Figures 1 and 2 also reveals the tight empirical link between the proportional female advantage in mortality rates and the additive female advantage in life expectancy.

Perspectives from mathematical demography

Recent advances in mathematical demography have revealed that proportional change in mortality rates and additive change in life expectancy are conceptually as well as empirically related. By extension, these findings suggest that proportional differences in mortality rates across any covariate are roughly equivalent to additive differences in life expectancy. Since we measure additive inequality in life expectancy, we should measure proportional inequality in mortality rates; both measures are consistent with the concept of sharing equally in the gains against mortality as representing stable inequality.

The formal relationship between mortality rates and life expectancy is complicated (30, 31). But a recent contribution (32) reveals the following relationship between changes in remaining life expectancy at birth, $e^o(0,t)$, and changes in mortality rates over time, t:

$$\frac{\partial}{\partial t} e^o(0,t) = \bar{\rho}(t) e^\dagger(t) + \mathrm{Cov}_f[\rho(a,t), e^o(a,t)], \tag{1}$$

where $\rho(a,t)$ is the proportional rate of decline in mortality rates at age a; $\bar{\rho}(t)$ is the average across all ages; $e^\dagger(t)$ is the average years lost per death; and the last term is the covariance between $\rho(a,t)$ and $e^o(a,t)$, the expected years remaining at age a, weighted by the probability density of ages at death, $f(a,t)$. The covariance term in equation 1 tends to be small, and $e^\dagger$ changes slowly, so the equation reveals that additive change over time in life expectancy arises from proportional change over time in mortality rates.

Mortality rates and life expectancies change across other covariates as well as time, of course. In the traditional proportional hazards model (33), we assume that mortality rates vary proportionally with some covariate x. It is straightforward to reinterpret equation 1 to apply more generally to the gradient in life expectancy through a socioeconomic covariate x, where the proportional change in mortality rates through x, ρ_x, is now important:

$$\frac{\partial}{\partial x} e^o(0,t,x) = \bar{\rho}_x(t) e^\dagger(t,x) + \mathrm{Cov}_f[\rho_x(a,t), e^o(a,t,x)]. \tag{2}$$

The covariance term is likely to be small, as it was before, but the years of life lost per death, $e^\dagger(t,x)$, may vary more across the socioeconomic variable x than across time t, as was important in equation (1). But to a first approximation, equation 2 suggests that additive socioeconomic differences in life expectancy arise from proportional socioeconomic differences in mortality rates.

These perspectives all point to a single bottom line. The dominant temporal pattern in mortality can be viewed as either proportional decline in mortality rates or additive increase in life expectancy. Either way, measures of inequality that appropriately capture equal progress against mortality are proportional in the case of mortality rates or additive in the case of life expectancy. In the cross section, proportional differences in mortality rates are approximately equivalent to additive differences in life expectancy. Given that we measure socioeconomic differentials in life expectancy on an additive basis, we should measure socioeconomic differentials in mortality rates on a proportional basis.

Discussion

The choice and interpretation of inequality measures, like the underlying socioeconomic disparities in health they are designed to illuminate, is a topic of much recent interest in epidemiology and public health (3, 34, 35). In this paper I have tried to argue that when the indicator of health is mortality, we should measure either proportional inequality in mortality rates or additive inequality in life expectancies. These two measures are consistent with the temporal trends in either indicators, meaning that stable inequality implies equal sharing in the gains against mortality. They are also approximately equivalent to one another through formal demography.

While it is not incorrect to report both proportional and additive measures of socioeconomic inequality in mortality rates, the literature has shown that doing so can lead to confusion because the two indicators can easily diverge. Researchers should attempt to provide the clearest picture of trends to policymakers and the public.

Formally, I remain agnostic regarding the separate but related topic of the ideal measure of socioeconomic inequality in health conditions. Other work has dealt with this issue directly (3, 6, 34, 35). I speculate that since proportional indexes of inequality, like the RII, are better for measuring socioeconomic differentials in mortality rates, they may also be preferable to additive indexes of inequality in the prevalence of health conditions. We typically model the odds of death rising linearly with health conditions, and odds ratios are more similar to mortality rates than years of life expectancy. This view would be consistent with a recent strand in the literature (6).

When viewed with the perspectives I have outlined in this paper, the preponderance of empirical evidence suggests that socioeconomic health inequalities have been widening. Additive differentials in mortality rates may be stable or even falling, but the trends in proportional differences in mortality rates or in additive differences in life expectancy best inform us about the evolution of socioeconomic disparities in health. As one recent report pointed out (15), it is striking that the racial gap in mortality seems to have narrowed since the late 1980s (14), while inequality based on education or income appears to have widened during that period. Adopting a common framework of measurement and interpretation will streamline continued research into dynamics such as these.

Acknowledgements

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Table 1: Two Simple Examples of the SII and RII in Mortality Rates per 10,000

Panel A: Uniform proportional decline

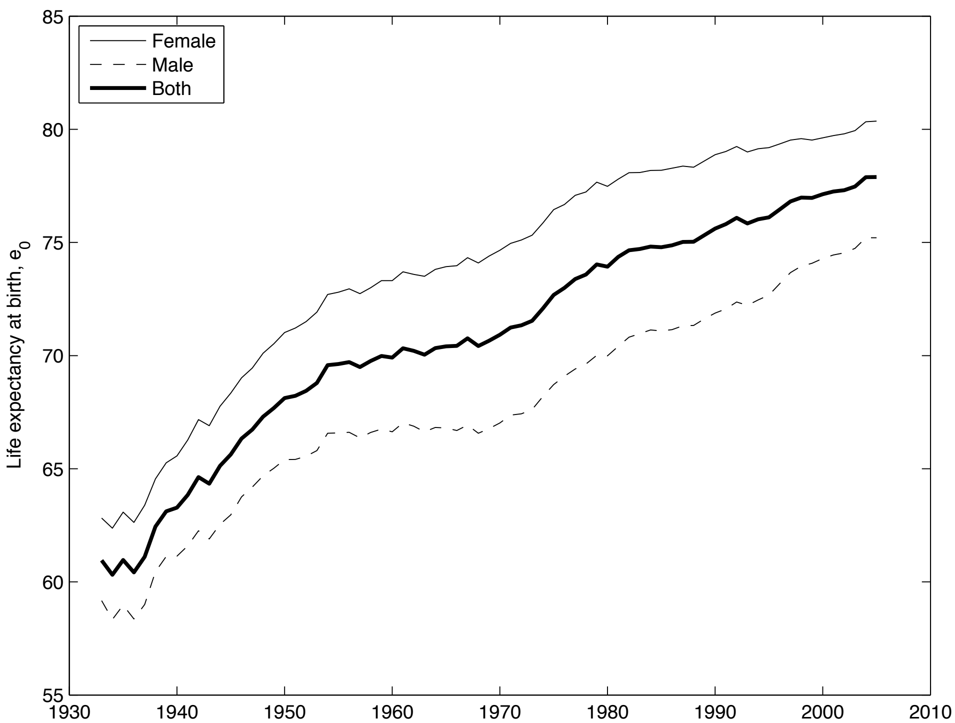
Mortality in:	Period 1	Period 2	Percent Change	Additive Change
Top group	100.0	99.0	−1.0%	−1.0
Bottom group	200.0	198.0	−1.0%	−2.0
Average	150.0	148.5	−1.0%	−1.5
SII	−100.0	−99.0	−1.0%	1.0
RII	−0.667	−0.667	0.0%	0.000

Panel B: Uniform additive decline

Mortality in:	Period 1	Period 2	Percent Change	Additive Change
Top group	100.0	99.0	−1.0%	−1.0
Bottom group	200.0	199.0	−0.5%	−1.0
Average	150.0	149.0	−0.7%	−1.0
SII	−100.0	−100.0	0.0%	0.0
RII	−0.667	−0.671	0.7%	−0.004

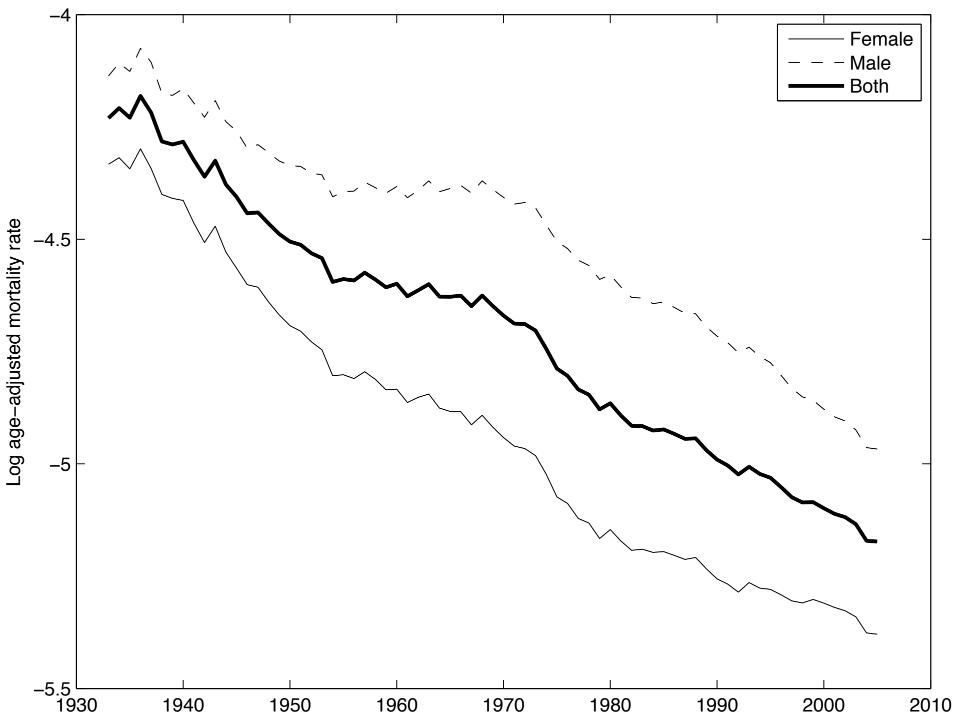
Notes: The top three rows in each panel depict mortality rates in two time periods and their associated percentage and additive changes for two fictional population groups of equal size, "top" and "bottom," and for the population average. The slope index of inequality (SII) in mortality rates is the additive difference between mortality at the top and bottom of the distribution, while the relative index of inequality (RII) is the SII divided by the average mortality level.

Figure 1: Period Life Expectancy at Birth in the U.S. Since 1933



Source: Human Mortality Database (29).

Figure 2: Log Age-Adjusted Mortality Rates in the U.S. Since 1933



Source: Human Mortality Database (29) and author's calculations. These data are weighted averages of an annual age and sex-specific mortality rates where the weights are the population age distribution for both sexes combined for 1970.