POLICY FORUM

DEMOGRAPHY AND INEQUALITY

The case for monitoring life-span inequality

Focus on variation in age at death, not just average age

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Inequality in length of life is the most fundamental of all inequalities; every other type of inequality is conditional upon being alive. As has long been recognized in studies of economic inequality, we can compare populations based on per capita gross national income, but there is a pressing need to further examine how income varies within populations via Gini coefficients and percentile-based metrics. Mortality inequalities should be approached in the same way. Human population health is generally monitored by average mortality levels, typically in terms of life expectancies, which belie substantial variation in length of life. Variation in ages at death, captured by a metric of life-span variation, should be used to supplement measures of average longevity when comparing or monitoring societies and population subgroups (*1*). Although life-span variation has historically been strongly inversely correlated with life expectancy (*2*, *3*), we are beginning to see this relationship reversed, resulting in positive correlation in some countries or subnational populations. Often these changes reflect midlife mortality crises with roots in stratified education and wealth. We discuss these measures and trends and how they can have profound implications for how individuals might plan and live their lives, and for how societies might organize and manage health care, insurance, pensions, and other social policies and programs.

Life expectancy at birth (or simply life expectancy, as we refer to it in the rest of the text) is the most common metric of survival. It is the hypothetical average age at death given age-specific death rates in a given year. Life-span variation, the variability in ages at death around that average, can be measured by using an index of variation or inequality—for instance, the standard deviation, Gini coefficient, or interquartile range. To illustrate, consider age-at-death distributions of non-Hispanic black and non-Hispanic white men in the United States based on 2012–2016 death rates. The life expectancy from this distribution is 72 years for blacks and 77 years for whites [see supplementary materials (SM)]. But the timing of death was variable, skewed below the average in both groups, meaning that deaths were more spread out below the life expectancy than above it. Among blacks, the spread in survival was noticeably wider. Men in the 25th to 75th percentile (the interquartile range) died between 63 and 85 years in the black distribution, whereas those in the white distribution died between 69 and 88 years. Although life expectancy for blacks was only 6% lower than for whites, the age window over which these deaths occurred was 17% larger for blacks.

Some early efforts by the Organization for Economic Co-operation and Development (OECD) to monitor within-group variability included a one-off report that measured life-span variation conditional upon survival to age 10 (*4*). However, although we currently monitor life expectancy at birth in all countries of the world, which captures between-country differences in average mortality, no international organization regularly monitors and compares the within-country variation in age at death. Likewise, many countries evaluate health and social policies by their success in eliminating gaps in life expectancy between race, ethnic, or socioeconomic groups. But few countries monitor the variation in age at death within and across such groups, which ignores an important and substantial part of the inequalities in mortality.

TRENDS IN LIFE-SPAN VARIATION

In high-income countries, life expectancy has doubled over the past century and a half. Life expectancy at birth in 2014 was around 81 years for people living in a country belonging to the OECD (SM). Averting deaths at any age increases life expectancy. But for life-span variation to decrease when life expectancy is increasing, more deaths need to be averted at younger than older ages. This compresses the age-at-death distribution, making ages at death more similar. Whether a death is considered younger or older depends on a threshold age that varies in time and between groups. This age generally sits below the life expectancy, and is specific to the age pattern of mortality (*2*).

In the past, death rates declined faster at younger ages compared to older ages as populations transitioned through different epidemiologic environments (*5*). Gains to life expectancy and concomitant declines in life-span variation resulted from strong reductions in infectious disease, maternal and child mortality, injuries, and more recently, cancers (*6*). Reduced circulatory disease mortality, by contrast, accounted for the bulk of life expectancy gains in the final decades of the 20th century, but its impact on life-span variation trends was moderate. The averted deaths from declining circulatory disease rates occurred at ages above and below the threshold age, which led to either minor increases or decreases in life-span variation depending on the sex, period, and population examined.

As a result of these historical changes, the inverse correlation between life-span variation and life expectancy was so strong that it was reasonable to question how much more information could be gained by looking at life-span variation in addition to life expectancy. Yet, it is becoming increasingly apparent that there are considerable differences between populations with respect to life-span variation at the same levels of life expectancy. For example, a U.S. man retiring at age 67 can expect to live another 16.8 years—almost as long as his British counterpart (17.0 years) (SM). But the American is facing substantially greater variability about that mean with a standard deviation that is 13.8% higher.

Two emerging phenomena, related to age-specific mortality changes below and above the threshold age, may weaken the historical association between life expectancy and life-span variation. One is that some subpopulations are experiencing stalls in reducing mortality at younger ages or even experiencing midlife mortality increase (*7*). The other is that mortality decline is occurring at ever higher ages in many countries (*8*). Further gains in life expectancy in low-mortality countries may increasingly come from disproportionate reductions in old-age mortality. These phenomena acting alone or in concert could result in increases in life-span variation alongside increases in life expectancy; i.e., changing the historically observed correlation from negative to positive.

This is precisely what is being seen at the national level in the United States. From 1980 to 2014, life expectancy increased by about 10% for men and 5% for women

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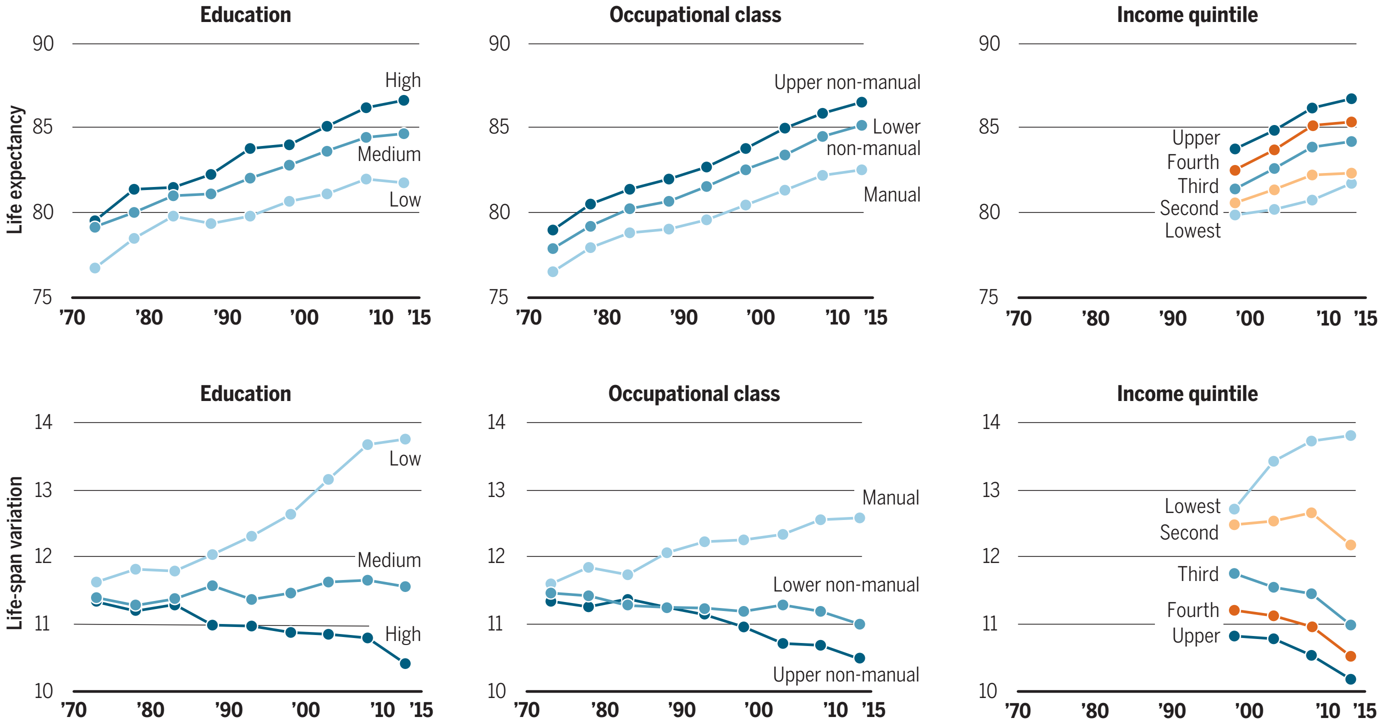
Trends in life expectancy and life-span variation for Finnish females, 1971–1975 to 2011–2014

Life expectancy is the average age at death, and life-span variation is the standard deviation, conditional upon survival to age 30, with age-specific death rates frozen at those observed in the given year. See supplementary materials for data and methods, including trends for males (which are qualitatively similar), and robustness checks using alternative measures of life-span variation.



[although both sexes experienced declines from 2014 to 2016 (fig. S1)]. Life-span variation, however, fluctuated sharply over the period, with sustained increases observed in the late 1980s, early 2000s, and the 2010–2016 period (fig. S2). Not coincidentally, these years were marked by mortality episodes that primarily affected young adults—the HIV/AIDS and crack-cocaine epidemics of the 1980s, and more recently, the increase in accidental poisonings, particularly from opioids (SM). Had we been monitoring life-span variation as closely as life expectancy, the U.S. midlife mortality crisis would possibly have been uncovered earlier in an attempt to understand why life-span variation was increasing at the dawn of the 21st century.

Further evidence is observed among subpopulations in Finland, a country with an exceptionally long and good-quality time series of population register data, including socioeconomic status. Over the period 1971 to 2014, we see increasing life expectancy for women (see the figure, top) and men (fig. S3, top) aged 30 and above according to education, occupational class, and income quintile. The increases in life expectancy over time run mostly in parallel with one another, with some divergence because the lower socioeconomic groups experienced slower improvements. A policy implication is that the groups with a lower socioeconomic status are falling behind the upper classes, a lag that may be closed by investing in health and social policies to reduce mortality in the lower socioeconomic groups at all ages.

However, trends in life-span variation (see the figure, bottom; fig. S3, bottom) reveal a more worrisome pattern. The less-advantaged groups were not only dying earlier than advantaged groups, on average, but they faced greater variation in the eventual time of death—a double burden of inequality—which has increased over time. The diverging trends in life-span variation mainly resulted from differences in the pace of early and midlife mortality decline, in particular, slow improvements in early and midlife mortality in the lower socioeconomic groups. The pace of mortality decline at older ages was similar across occupational groups (*9*). A policy implication is that investing in efforts to drive down deaths in midlife—deaths that are typically considered premature and avoidable (e.g., deaths from accidents, violence, or substance abuse)—can reduce life-span variation.

This is not just a Finnish phenomenon. Life-span variation is diverging between social groups wherever it has been examined. In the United States, differentials in life-span variation between those who completed college and those who only completed high school doubled over the 1990–2010 period, mainly because of substantial increases in variability among the high school educated. At the same time, life expectancy differentials by the same two groups widened from 2.2 to 5.7 years (*10*). In Denmark, life-span variation increased among the lowest-income quartile and decreased among the other three quartiles over the 1986–2014 period, although all income groups experienced increases in life expectancy (*11*). It is important to note that in mostof these examples of increasing life-span variation, mortality declined over postretirement ages, even among the lowest socioeconomic groups. The increases in life-span variation among lower socioeconomic groups thus occurred because mortality reduction over preretirement ages was modest or absent.

INDIVIDUAL AND POPULATION IMPACTS

Like life expectancy, life-span variation constitutes a useful summary measure of mortality regimes (i.e., age-specific death rates). We argue that it has two important implications: one at the individual (micro) level and the other at the population (macro) level. Life-span variation reflects both individual uncertainty in the timing of death and heterogeneity in underlying population health.

At the micro level, life-span variation reflects individual discrepancies in the risk

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of death. In other words, it measures uncertainty in the timing of death. Economic models have shown that because individuals are inherently risk averse, they would forego additional years of expected life to reduce uncertainty in age at death (*12*). From this perspective, diverging life-span variation between socioeconomic groups means that an overlooked dimension of social inequality in health is increasing—those from more-advantaged groups can more effectively plan their life course, whereas less-advantaged groups face greater and increasing uncertainty about their survival.

For the individual, this can have profound consequences. One's subjective assessments of his or her survival are instrumental when making decisions about lifecycle investment and consumption, including education, training, and retirement (*12*). The Survey of Health, Ageing and Retirement in Europe, as well as its U.S. progenitor the Health and Retirement Study, routinely ask their respondents about their future expectations. These questions probe how long responders expect to live and when they expect to die. Answers to these questions underlie answers to others, such as: Will they work for pay after age 70? How much money will they spend this year? Will they leave an inheritance or help their children financially? Although often framed around financial decisions, these survey questions are attempts to examine responders' expectations about the family sphere (e.g., time spent with family members) and work (e.g., time to retirement), and how these expectations may be influenced by anticipation of one's own mortality.

Individuals are of course mostly unaware of life-span variability statistics, but experience of survival chances of friends and relatives will influence perceptions of survival expectations. For example, because of larger life-span variability, U.S. blacks are more likely than U.S. whites to experience an early death of close relatives (*13*). Studies have shown that these subjective survival expectations predict actual mortality and mirror known socioeconomic disparities in death rates (*1*, *14*). Furthermore, to the extent that mortality regimes (i.e., death rates) become inscribed in individuals' own mortality expectations—by which we mean that excess mortality experienced by certain social groups affects subjective survival assessment and future life course expectations for the members of that group—higher life-span variation also constitutes a form of disadvantage.

At the macro level, life-span variation is an indicator of heterogeneity in underlying population health. Understanding this heterogeneity is crucial for accurate forecasts in insurance and annuity markets, for public provision of medical care, and for creating equitable pension schemes when ages at death vary. Increasing life-span variation among disadvantaged groups implies that the individuals belonging to such groups are living increasingly diverse lives. This increasing heterogeneity mirrors diverging variability in other social realms, including increasing variation in participation in work and family life (*15*). Increasing life-span variation signals uneven age patterns of mortality decline, with faster declines at older rather than at younger ages, or even rising early and midlife mortality. Therefore, monitoring life-span variation may facilitate early detection of adverse mortality developments and warrant social interventions at younger ages.

TOWARD A COMPREHENSIVE MEASUREMENT OF MORTALITY

In our world in which reams of granular data related to health are routinely collected, easy-to-understand summary metrics are needed to set health targets, to evaluate policy outcomes, to uncover emerging threats, and to compare levels and trends in health and mortality across populations. Life expectancy is monitored almost everywhere. But despite growing awareness, life-span variation has not been systematically monitored by any country in the world. We suggest four reasons why this might be the case, and also demonstrate why this does not need to persist. First, given that we already monitor life expectancy, it was unclear to policy-makers whether there was an added benefit to monitoring life-span variation. The examples shown here demonstrate the independence of the two indices. Although life expectancy might still be the best metric for the speed of survival improvements in the population as a whole, life-span variation is its complement, needed to monitor the equality in survival improvement.

Second, as with studies of income inequality, it remains unclear which indicator for measuring life-span variation is the most appropriate. Although there is no gold standard, the high correlation between indices suggests that trends would be broadly similar no matter which index is chosen. Third, officials in statistical offices are not trained to measure life-span variation. Although this is true, all statistical offices produce life tables. Calculating an index of life-span variation is a relatively straightforward procedure from the life table. Fourth, metrics of variability are more difficult to understand than metrics of average levels. But this criticism could equally be leveled at indices of income differentials, yet the widespread adoption of the Gini coefficient by statistical offices suggests that the benefit of monitoring income variation outweighs the disadvantage of a more theoretically complex measure. In our view, this is also true for monitoring mortality.

Many countries and international organizations monitor premature death, but the cut-off age varies across jurisdictions. For instance, Statistics Canada defines premature deaths as those under age 75, the U.S. Centers for Disease Control and Prevention uses age 80 as the cut-off, while the New York City Department of Health uses age 65 (SM). Alternatively, a metric of life-span variation could be easy to understand, be used in various mortality regimes, and be sensitive to deaths that we would normally consider premature, but use mortality over the whole age range to capture this.

Life-span variation might be reduced by decreasing disparities in the social environment, medical care, and how individuals behave and interact within their social sphere. If an average level of health is deemed important enough to regularly monitor and report, we should also regularly summarize the spread around this average. A healthy population is one in which people live for a long time on average—and long lives are enjoyed by everyone. ■

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