



Research Highlights

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The Future of Human Life Expectancy: Have We Reached the Ceiling or is the Sky the Limit?

After remaining fairly constant for most of human history, life expectancy (the average number of years a person can expect to live) has nearly doubled in the past century. The maximum life span—the longest number of years a human being has lived—has increased spectacularly as well. There is little disagreement over these facts. Scholarly opinion diverges, however, as to whether these increases will continue or whether human longevity is approaching its limit.

In 1990, the Behavioral and Social Research (BSR) Program of the National Institute on Aging (NIA) began sponsoring academic centers for research on the demography of aging. Support for this type of research is increasingly important, since improved projections of life expectancy—which give us some idea of the future size of the elderly population—are key in informed planning for the allocation of public and private resources. This brief highlights some of this research.

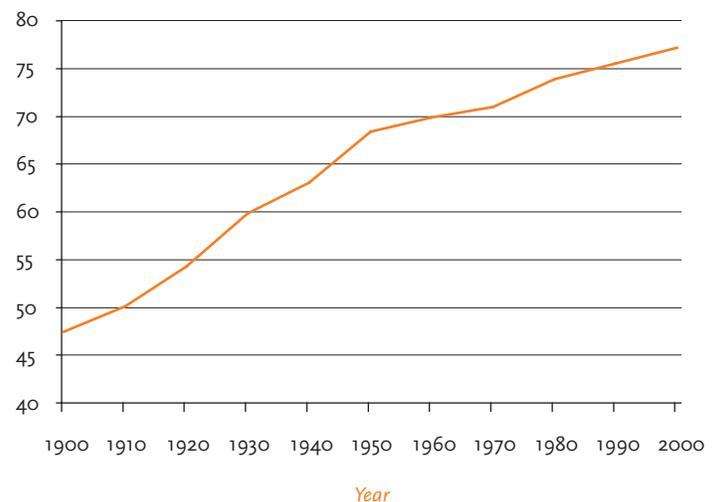
Through the first half of the 20th century in the United States, improved nutrition and the control of infectious diseases drastically reduced child and infant mortality—developments that produced astonishing advances in life expectancy. By 1950, penicillin and sulfa drugs had yielded the first substantial decrease in U.S. adult mortality. In the latter part of the century, continued improvements in living standards, health behaviors, and medical care also lowered mortality from chronic diseases, especially heart disease and stroke.

This trend was mirrored in all industrial nations. Shripad Tuljapurkar examined the G7 countries (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States) and showed that mortality in all these nations declined exponentially and at a roughly constant rate from 1950 to 1994. In 1930, life expectancy at birth in the United States was 58 for men and 62 for women. By 2001, the average U.S. life expectancy was 74 for men and 80 for women. French men live an average of 75 years, while French women average 83 years. Japan leads industrial nations with an average life expectancy of 78 for men and 84 for women.

Figure 1 depicts the trend in life expectancy in the United States and shows a plateau from about 1955 to 1975. During that period, scientists speculated that the end of advances in life expectancy had been reached. However, research by economist David Cutler finds that the already low level of infectious-disease mortality (in combination with the lack of progress in mortality from the chronic diseases of old age) was a leading reason for the plateau. Cutler shows that, beginning around 1960, death from cardiovascular disease began a rapid decline—owing largely to advances in medical treatment and reductions in smoking—and longevity consequently resumed its ascent.

The trend toward longer life has also raised concerns about the quality of life at older ages. However, many of the same forces that have led to lower mortality have influenced morbidity as well. As demographer Kenneth Manton and others have shown, disability rates trended downward during the 1990s.

Figure 1
Life Expectancy at Birth in the United States, 1900–2000



SOURCE: E. Arias, "United States Life Tables, 2001," *National Vital Statistics Reports* 52, no. 14 (2004): table 11.

Is it likely or even possible that mortality rates will continue to fall and fuel further increases in life expectancy? This question is an area of intense discussion. And the corollary question of whether a maximum human life span exists has scholarly camps pitched on both sides of the issue.

The most prominent advocate for the limited-lifespan perspective is James Fries. In 1980, Fries made the stark prediction that humans were born with a maximum potential life expectancy. He proposed that this limit was normally distributed throughout the population, with a mean of 85 and a standard deviation of 7 years. This prediction became known as the Fries Hypothesis. Supporting this proposition, scholars such as S. Jay Olshansky and Bruce Carnes contend that living organisms are subject to a “biological warranty” period. Olshansky and Carnes argue that, if most humans on average are capable of living to 100, there should be little evidence of significant functional decline and pathology among people living to the average lifespans currently attained (75-80 years). As they demonstrate, however, there is substantial decline in functioning of all human biological systems by age 80.

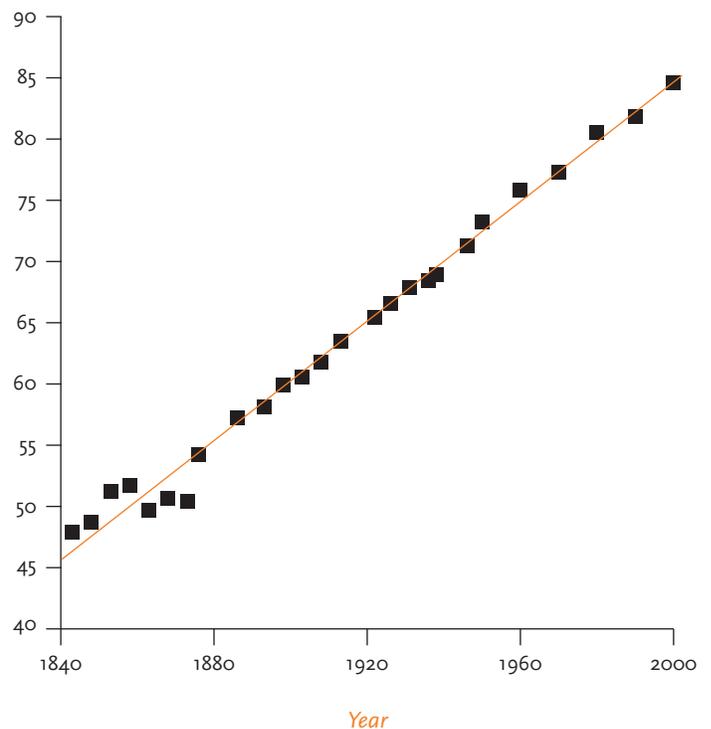
Olshansky and Carnes also contend that human longevity is most likely reaching a statistical limit because we are fast approaching the lowest possible limit of death rates. It would take an 85 percent decline in all-cause mortality from the 1985 level to yield an eventual life expectancy of 100 years. Olshansky and Carnes argue that, barring major medical advances, the period of rapid increases in human life span in industrialized countries is coming to an end. They further argue that human life expectancy in the United States is unlikely to exceed 90 years in the 21st century.

As high as Olshansky and Carnes’ estimate seems, it is lower than that predicted by scholars in the opposing camp. Demographer James Vaupel, perhaps the foremost proponent of the mortality-reduction perspective, shows that every published estimate of the maximum life expectancy has been broken within a few years of its prediction. Plotting death rates for individuals 80 and older, Vaupel and colleagues find that population death rates for these “oldest old” decrease over time, while mortality rates peak and actually decrease for the oldest old. This deceleration of mortality rates begins around age 80, with a leveling off or decline after 110.

Figure 2 shows that record life expectancy rates for females across eight different countries have increased linearly by about three months per year for the past 160 years. This linear increase shows no sign of leveling off; if it continues, an average life expectancy of 100 for women in these countries could be reached within 60 years.

Vaupel and other scholars argue that if life expectancy in developed countries were approaching an imminent maxi-

Figure 2
Record Life Expectancy of Females in Selected Countries, 1840–2000



NOTE: Data represented in the figure are taken from six countries: Australia, Iceland, Japan, New Zealand, Norway, and Sweden.

SOURCE: J. Oeppen and J.W. Vaupel, "Broken Limits to Life Expectancy," *Science* 296, no. 5570 (2002): 1029-31.

imum, the pace of improvement in countries with higher life expectancies would be lower than in countries with lower life expectancies. Instead, no such correlation is observed—and Vaupel argues that very long lives are the probable destiny of most people alive today. In fact, centenarians now constitute the fastest-growing segment of the U.S. population, increasing in number from 3,700 in 1940 to roughly 61,000 today. The Census Bureau projects that one in every nine baby boomers (9 million of the 80 million people born between 1946 and 1964) will survive into their late 90s, and that one in 26 (or 3 million) will reach 100.

Occupying the middle ground in this debate are scholars ranging from demographers and economists to evolutionary and molecular biologists. For example, in attempting to explain the rapid increases in life expectancy, Nobel Laureate Robert Fogel has proposed the theory of *technophysio evolution* to describe the synergy between technological and physiological improvements that have given human beings an unprecedented degree of control over their environment and the factors that affect mortality. Modern humans are remarkably robust compared with humans of the past, owing in large part to improved nutrition but also to medical advances.

In trying to explain why we grow old and die, evolutionary biologists have theorized that those genetic mutations that arise only in older people—those people past the age of reproduction—will not affect the survival probabilities of these people’s offspring. But over successive generations, these late-acting deleterious mutations will accumulate in the population. Evolutionary biologists speculate that this accumulation is one of the reasons for the increase in mortality rates in those who are only slightly older than the age of reproduction.

But empirical observations are at odds with this theory, and evolutionary scholars are beginning to try to account for the fact that we live, on average, long past the age of reproduction. For instance, James Carey and Debra Judge propose that older individuals may contribute to the propagation of their genes by contributing to the reproductive success of their children and grandchildren. Increased longevity, they argue, makes it possible for older individuals to nurture and pass on resources to the younger generation, which may enhance that generation’s reproductive fitness. A deeper understanding of survival at older ages hinges, in part, on intensified research into the interactions between fertility and longevity.

Although not an explanation for *why* we live so long, biological research into survival attributes such as telomere length, oxidative damage, caloric restriction, and gene expression attempts to describe *how* we live so long. Medical breakthroughs in these areas could have profoundly positive effects on human life expectancy. Conversely, events such as a global pandemic of an airborne infectious disease could adversely affect life expectancy. Recently, Olshansky and his colleagues have reported analyses which suggest that the sharp increase over the past 20 years in the numbers of obese Americans could shorten average U.S. life expectancy by as much as two to five years. Demographer Samuel Preston notes that Olshansky et al.’s analysis is too simplistic and does not account for the range of influences on longevity captured in Fogel’s concept of technophysio evolution. Moreover, Preston contends that recent demographic predictions do in fact incorporate the rise in rates of obesity. Both scholars agree that relatively modest behavioral changes are required to alter the course of the epidemic, and that a serious public health campaign—similar to that launched against smoking—could succeed in doing so. Nonetheless, a full understanding of the forces driving mortality decline still eludes us, and the future path of technophysio evolution is uncertain.

The goal of modern mortality forecasting is not only to identify underlying age patterns and trends, but also to quantify this uncertainty—to place confidence bounds around it. Demographer Ronald Lee has spent his career attempting to do just that, working with colleagues over the years in many

NIA-sponsored projects to develop a better forecasting method. This *stochastic forecasting method* uses time-series models to make long-term forecasts of age-specific mortality with confidence intervals. Based on historical trends, the model assumes that the aggregate effect of all the factors that have shaped mortality in the past will continue at the same rate in the future. To ensure robustness, the model makes estimates of past rates of decline based on historical data for periods of at least several decades. For a given starting point, the model generates a large number (about 1,000) of alternative future trajectories of life expectancy that produce a probability distribution of forecast values in each future year. Population values at the minimum and maximum ends of the range would have the smallest chances of occurring, while those toward the middle would be more likely to occur.

One forecasting model projects life expectancy in the United States to rise to 86 by 2075 and to 88 by the end of the century

The U.S. Census Bureau uses the stochastic forecast as a benchmark for its long-run forecast of life expectancy, and a Social Security Technical Advisory Panel recently recommended the adoption of the method. The Population Division of the United Nations also uses this method for some of its long-range projections. Using the stochastic forecasting method, Tuljapurkar and colleagues project a median life expectancy in the United States that is substantially higher than official forecasts. The model projects life expectancy in the United States to rise to 86 by 2075 and to 88 by the end of the century. Tests in several populations indicate that projections made with this method are quite accurate over relatively short time horizons.

The stochastic forecasting model assumes that the current rate of decline in mortality for each age will remain constant over time. Instead of being constant, however, rates of mortality improvement have tended to decline over time at younger ages, while rates of improvement have risen at older ages.

Demographer John Wilmoth has contributed insights to the debate, suggesting that those who project life expectancy trends commonly make the serious error of extrapolating further into the future than the available historical data warrant. Wilmoth also advises against an undue emphasis on trends. Although life expectancy continues to increase, the pace of that increase has slowed relative to the increases of the first half of the 20th century. However, the rate of mortality decline has in general increased. Wilmoth argues that these findings

are not contradictory: Because of the age pattern of human mortality risks (high among infants and children, low among adolescents and young adults, and rising rapidly after age 30), reductions in infant and child death rates bring more dramatic improvements in life expectancy than do similar reductions at older ages. Neither side of the life expectancy debate, argues Wilmoth, should claim these trends as robust evidence for their case.

Although the evidence that human life is approaching a finite limit is inconclusive, Wilmoth points out that the average limit proposed by Fries decades ago, a life expectancy at birth of around 85 years, is within the range produced by demographic forecasts for the middle of this century. The question of greatest relevance for public policy and fiscal planning is exactly where in the range the true figure will fall. The BSR program will continue to support research that provides a scientific foundation for those policy deliberations that rely on life expectancy projections.

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The National Institute on Aging

The National Institute on Aging supports 13 research centers on the demography and economics of aging, based at the University of California at Berkeley, the University of Chicago, Harvard University, the University of Michigan, the National Bureau of Economic Research, the University of North Carolina, the University of Pennsylvania, Pennsylvania State University, Princeton University, RAND Corporation, Stanford University, the University of Southern California/University of California at Los Angeles, and the University of Wisconsin.

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