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WHAT'S HAPPENING TO U.S. MORTALITY RATES?

By Anqi Chen, Alicia H. Munnell, and Geoffrey T. Sanzenbacher*

Introduction

A key factor affecting the cost of the Social Security program is how long beneficiaries live. Life expectancy is determined by mortality rates – that is, the probability of dying at each age. While mortality rates have been declining over time, progress has not been uniform. Sometimes mortality rates decline very rapidly, and sometimes they decline slowly. Moreover, rates of improvement vary by age. For example, during most of the 20th century the mortality of infants and the working-age population fell faster than the mortality of retirees. This "age-gradient" matters for Social Security, since mortality improvements for young adults tend to help Social Security's finances by expanding the size of the workforce paying into the system, while improvements at, say, age 65 tend to worsen it by increasing spending on benefits for longer-lived retirees.

This *brief* explores the swings in the rate at which mortality has improved since 1900 and the importance of the age gradient in these improvements over the period. It also takes a closer look at the years since 1969, when detailed data on cause of death are available. In retrospect, the factors leading to the speeding up and slowing down of mortality improvement are relatively clear. The future, as always, is harder to predict. This *brief* is the first of two on mortality rates; the second one will provide an international perspective.

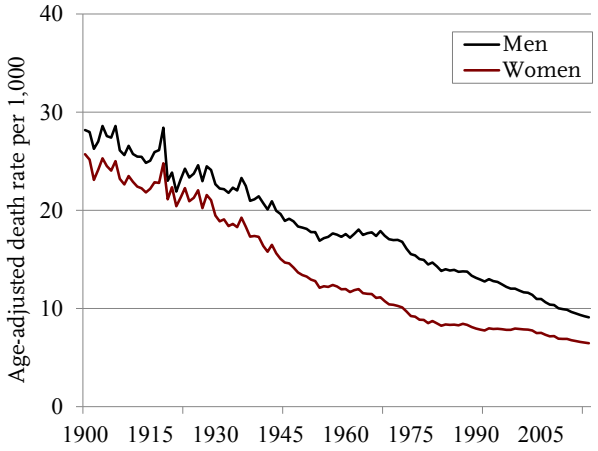
The discussion proceeds as follows. The first section provides an overview of mortality trends and the age patterns since 1900. The second section focuses on the swings in mortality improvement in the last 40 years and the patterns by education level and by disease. The third section discusses the major drivers of these outcomes – such as developments in medicine, greater access to health care, the decline in smoking, and the rise in obesity. The fourth section explores the major factors that will influence the rate of improvement in mortality over the next 75 years. The final section concludes that the key debate for the long term is whether the future will mirror the past, with mortality rates of improvement fluctuating around 1 percent per year, or whether the big gains are behind us, with mortality improving less rapidly in the future.

* Anqi Chen is a research associate at the Center for Retirement Research at Boston College (CRR). Alicia H. Munnell is director of the CRR and the Peter F. Drucker Professor of Management Sciences at Boston College's Carroll School of Management. Geoffrey T. Sanzenbacher is a research economist at the CRR. The authors thank Stephen Goss and Karen Glenn for helpful comments.

Trends in Mortality

The mortality rate is simply the percentage of people who die each year. But calculating mortality rates over time in a meaningful way is not quite so simple. Without some standardization for the age composition of the population, mortality rates would rise when the average age of the total population rises, for example, due to a drop in fertility.[1] Therefore, when presenting mortality rates over time, demographers make an adjustment that keeps the population's age composition constant.[2] Figure 1 shows the U.S. age-adjusted mortality rate from 1900 to the present. In 1900, about 28 men out of 1,000 died in a given year; by 2016 that number had dropped to nine. Mortality rates have always been higher for men than for women, although the gap has narrowed in recent years.

Figure 1. Age-Adjusted Mortality Rates for All Causes, 1900-2016

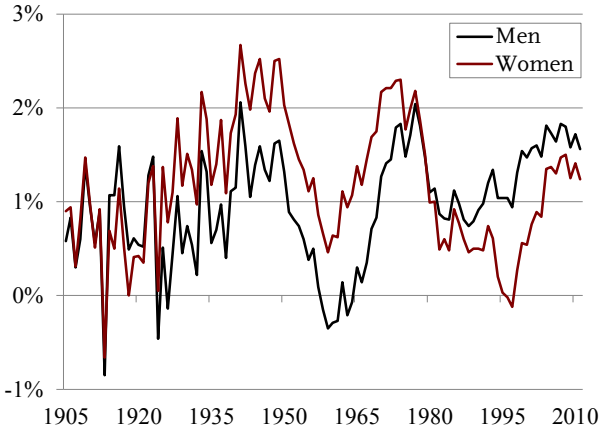


Sources: U.S. Social Security Administration (2017a, b).

With the notable exception of the flu pandemic in 1918, mortality rates have generally dropped year after year. Early gains came from improvements in the infrastructure that guaranteed clean water and the removal of waste. Then the discovery and general availability of antibiotics helped bring infectious diseases under control. In the wake of these advances, infant mortality dropped sharply in the first half of the 20th century. In contrast, gains in the second half of the 20th century were spread more evenly across the age distribution, as Medicare and Medicaid increased access to primary medical care for the elderly, poor, and disabled. Continued improvements in education and in the overall standard of living have also contributed to the decline in mortality.

The question of interest for this discussion is the pace at which mortality rates have been declining – rapidly or slowly – and at what ages. Figure 2 shows the annual improvement in mortality rates for men and women since 1900. To separate longer-term trends from short-run fluctuations, these rates of improvement are averaged over a rolling 10-year period and centered on the middle year of the averaging period. Several points are worth noting. First, the rate of change varies significantly over time for both men and women. Second, the historical pattern of women's mortality improving faster than their male counterparts has reversed in recent decades. Finally, the United States is in a downward part of the cycle today. That is, the rate of improvement has been dropping for both men and women in recent years.

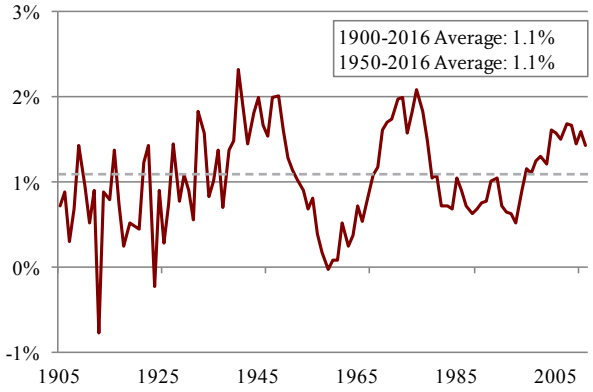
Figure 2. Average Annual Improvement in Age-Adjusted Mortality Rates for Rolling 10-year Periods, 1900-2016



Sources: Authors' calculations from U.S. Social Security Administration (2017 a, b).

Figure 3 puts men and women together to show changes in the age-sex-adjusted mortality rate since 1900. Over the entire period, mortality has improved at an average rate of about 1.1 percent, and the rate of improvement since 1950 has been the same.

Figure 3. Average Annual Improvement in Age-Sex-Adjusted Mortality Rates for Rolling 10-year Periods, 1900-2016

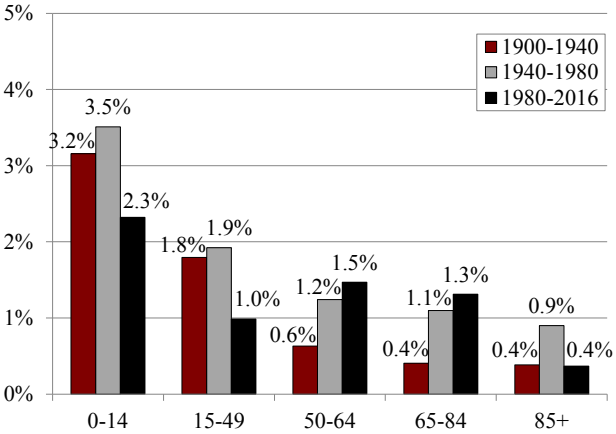


Sources: Authors' calculations from U.S. Social Security Administration (2017 a, b).

While Figure 3 shows substantial variance over time in the rate of mortality improvement, it does not capture how the improvements vary by age. As noted above, understanding the age variation is important because mortality improvement at younger ages, say below 30, actually makes the actuarial status of the Social Security program better, whereas improvement at older ages worsens it. Therefore, Figure 4 presents average mortality improvement by age group in selected timeframes. It shows that while the relative rate of mortality improvement at ages 0-14 has decelerated somewhat in recent years, it remains higher than that at older ages.

While some of these differences in the rates of mortality improvement may seem small, they can have a large effect on life expectancy over a 75-year period, the span used for evaluating Social Security's finances.[3] And given the importance of the age gradient in mortality improvement, it is necessary to look at the implications of alternative assumptions

Figure 4. Average Annual Improvement in Age-Adjusted Mortality Rates for Rolling 10-year Periods, By Age Group



Sources: Authors' calculations from U.S. Social Security Administration (2017 a, b).

not only at birth but also at, say, age 65. As shown in Table 1, an annual rate of mortality improvement of 0.5 percent instead of 1.5 percent means that an individual born today would be expected to live to 82.1 instead of 89.6 – a difference of 7.5 years.[4] More importantly for Social Security, individuals born today who survive to 65 would be expected to live an additional 21.7 years with an annual rate of improvement of 0.5 percent and an additional 28.0 years with an annual rate of 1.5 percent – a difference of 6.3 years.

Table 1. Remaining Years of Life at Various Rates of Mortality Improvement, 2016 Birth Cohort

Avg. rate of improvement	At birth	At age 65 (in 2081)
0.5 percent	82.1	21.7
1.0 percent	85.9	24.8
1.5 percent	89.6	28.0
Range	7.5	6.3

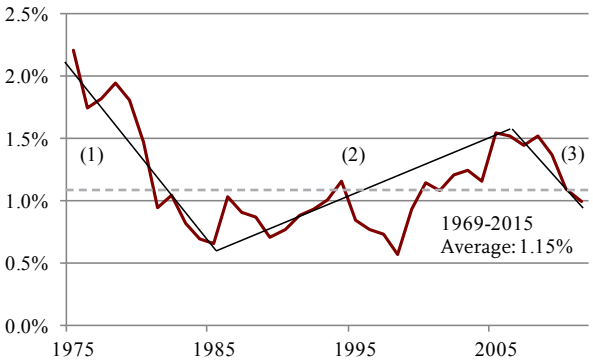
Note: See endnote 5.
Source: Authors' calculations from Goss et al. (2016).

Assuming the age gradient remains relatively stable, the question is what annual rate of improvement to assume over the next 75 years. A good starting point is to consider the factors that have led to recent fluctuations and then consider the extent to which they are likely to continue in the future.

Mortality Improvement in Last 40 Years

Figure 5 identifies three separate trends in mortality improvement over the last 40 years: 1) a slowdown before 1985; 2) an increase between 1985 and the mid-2000s; and 3) a slowdown since 2005.

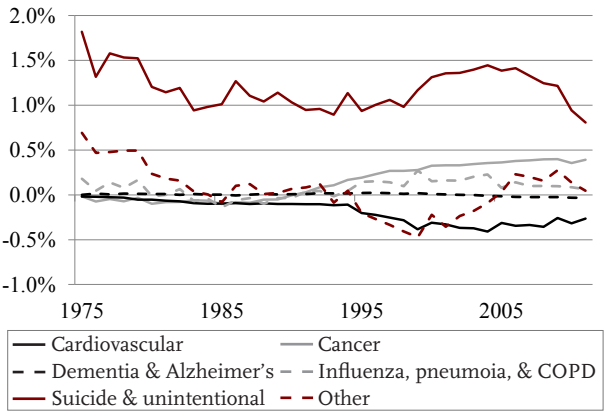
Figure 5. Average Annual Improvement in Age-Adjusted Mortality Rates for Rolling 10-year Periods, 1969-2015



Note: Each point represents a 10-year average annual improvement. For example, the 10-year rate of mortality improvement in 1975 is the average of the annual rates of mortality improvement over the period 1970-1979.
Sources: Authors' calculations from National Center for Health Statistics (1969-2015) and Surveillance, Epidemiology, and End Results Program (SEER) (1969-2015).

Underlying these disparate trends are variations in mortality improvement by cause of death.[6] As shown in Figure 6, the rate of improvement in mortality from cardiovascular disease (heart disease and stroke) has been the major determinant of the overall improvement.[7] In addition, during this period, improved mortality from advances in cancer treatment has begun to have a more prominent impact on improvements in the overall mortality rate. The challenge is then to identify the developments that led to the fluctuations in these rates of improvement.

Figure 6. Average Annual Improvement in Age-Adjusted Mortality Rates for Rolling 10-year Periods, By Cause of Death, 1969-2015



Source: Authors' calculations from National Center for Health Statistics (1969-2015) and SEER (1969-2015).

Drivers of Mortality Improvement

The story appears to be one of positive developments in drugs, technology, and access to health care that have been partially offset by the effects of smoking and obesity.

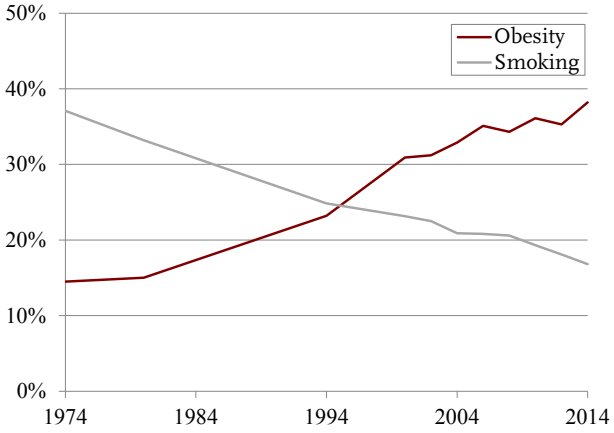
Drug and Technology Advancements. A number of major breakthroughs in drugs and medical technology have contributed to a decrease in mortality from cardiovascular diseases. In the 1970s, studies showed that aspirin – a long-time medicine cabinet staple – could help prevent heart attacks and strokes for people who have already had one.[8] Today, over 50 million Americans take aspirin regularly for cardiovascular disease prevention.[9] In 1987, the first commercial statin received Federal Drug Administration approval. Statins lower cholesterol and can help lower the risk of coronary heart disease as well as the frequency of heart attacks. Today, an estimated 30 million people worldwide are using statins.[10] On the technology front, the development of stents – wire mesh tubes that prop open an artery – in the mid-1980s has helped reduce the likelihood of heart attacks.[11]

Access to Health Care. In 1965, the creation of Medicare and Medicaid expanded primary health care access to the elderly, the poor, and the disabled. Since then, national health expenditures have expanded dramatically, rising from 5.6 percent of Gross Domestic Product (GDP) in 1965 to over 17.8 percent in

2016.[12] It seems likely that this expansion of health care access and spending is related to the reductions in death rates.

Behavioral Factors. On the behavioral side, the last half century has witnessed a decline in smoking and an increase in obesity (see Figure 7).

Figure 7. Prevalence of Obesity and Current Cigarette Smoking Among U.S. Adults, 1974-2014



Sources: Fryar, Carroll, and Ogden (2012); and Centers for Disease Control and Prevention (2016).

Smoking affects mortality with an average delay of two to three decades.[13] The prevalence of smoking among men peaked at close to 80 percent in the 1940s and 1950s and began to decline steadily in the late 1960s. The unfavorable impact on their mortality grew from 1950 to 1990, after which the decline in smoking began to have a favorable effect on mortality improvement. Smoking among women peaked more than a decade later, albeit at a much lower level than for men. The unfavorable impact of smoking on mortality of women increased from 1980 to 2000, and the favorable effect on mortality improvement from decreased smoking is just now beginning to be observed.

Mortality improvements as a result of declines in smoking were tempered by the adverse effects of obesity.[14] The obesity rate in adults began to rise dramatically beginning in the 1980s and reached close to 40 percent by 2014. Behavioral factors such as physical inactivity and diets high in sodium and fatty acid are associated with obesity. These risk factors, in turn, increase the risk of heart disease, stroke, Type 2 diabetes, high systolic blood pressure, and certain types of cancer. These risk factors are estimated to be responsible for more than one fifth of all deaths in U.S. adults.[15]

Explaining the Trends in Mortality Improvement

Taking into account the drivers of mortality improvement can help explain the three separate trends over the last 40 years: the "slowdown, speed-up, slowdown" pattern.

1. Declining mortality improvement until 1985. This period could be characterized as one in which the new drugs and technology for heart disease and stroke identified in the 1970s and 1980s were only beginning to have a positive effect and the impact of male smoking two or three decades earlier continued to have a negative effect on mortality improvement. Further, the initial surge in mortality improvement due to the introduction of Medicare and Medicaid had petered out.

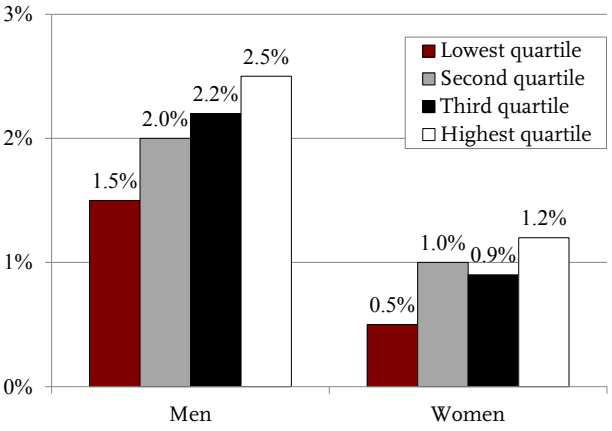
2. Rise in mortality improvement between 1985 and the mid-2000s. On the favorable side, the new drugs and technology became more universal and the decline in male smoking began to have a favorable impact. In addition, the decline in female smoking had a positive effect in the 2000s. At the same time, improvements were tempered by the rise in obesity.

3. Decline in mortality improvement since 2005. The decline could be attributed to the exhaustion of the positive effects of the cardiovascular drugs and technology. That is, once everyone at risk of heart disease is already taking a statin, further dissemination cannot increase the rate of mortality improvement. Similarly the gains from the decline in male smoking have mostly run their course, although the gains in the decline in female smoking continue. And the negative effects of obesity are hampering improvements in mortality.

Regardless of whether mortality rates were improving slower or faster, the gains experienced in recent decades have been skewed towards those with more education and higher income. This pattern can be shown using data from the *National Longitudinal Mortality Study*, which consists of individual-level observations from the *Current Population Survey*

matched to data from death certificates obtained from the National Center for Health Statistics. Individuals are grouped by quartiles of educational attainment, and a regression equation is used to estimate the rate of mortality for men and women in each group. As shown in Figure 8, those in the highest quartile saw much higher rates of mortality improvement than those in the bottom.

Figure 8. Average Annual Rate of Improvement in Mortality by Gender and Education Quartile, 1979-2011



Source: Sanzenbacher et al. (2016).

The question is whether recent patterns in mortality improvements say anything about mortality projections over the next 75 years.

Mortality Improvements Looking Forward

Future mortality improvements will depend on the net effect of the key drivers, which could play out differently than in the past. Not surprisingly, given all of the uncertainties involved, experts differ on the most likely path.

Drivers of Mortality Improvement

The key drivers will continue to be medical advancements; changes in access to affordable health care; and personal behaviors such as smoking, diet, and physical activity.

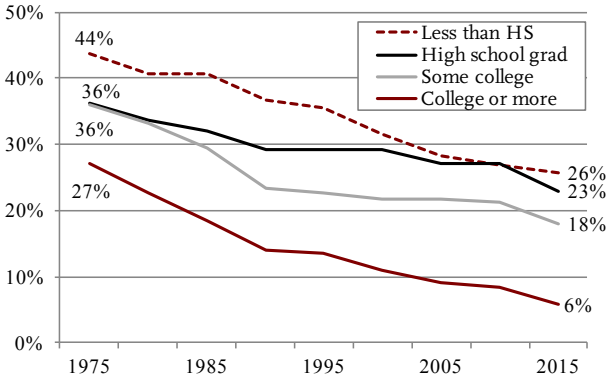
Drug and Technology Advancements. Mortality improvement in the near term will depend on the medical drug and technology developments from the last 10 years. Some of the many major medical advances include the Human Genome Project, stem cell research, HIV cocktails, laparoscopic surgery, targeted cancer therapies, and the cure for hepatitis-C. While several developments, such as the elimination of hormone therapy for menopausal women, may help increase mortality improvements for heart disease,[16] it is difficult to foresee the effectiveness of new drugs and treatments.[17]

Access to Health Care. The United States is unlikely to be able to replicate the impact of Medicare and Medicaid on the health of major population groups. The expansion of coverage under the Affordable Care Act has been much more modest. And health spending, which now accounts for 18 percent of GDP, cannot continue to grow at its historical pace.

Behavioral Factors. Future mortality rates will also depend crucially on both the prevalence and the effects of smoking and obesity on mortality. Several studies have attempted to forecast the potential net effect of these two behaviors on life expectancy. The results are mixed.[18] The current slowdown in mortality improvements might suggest that the negative effects of increasing obesity are dominating.[19]

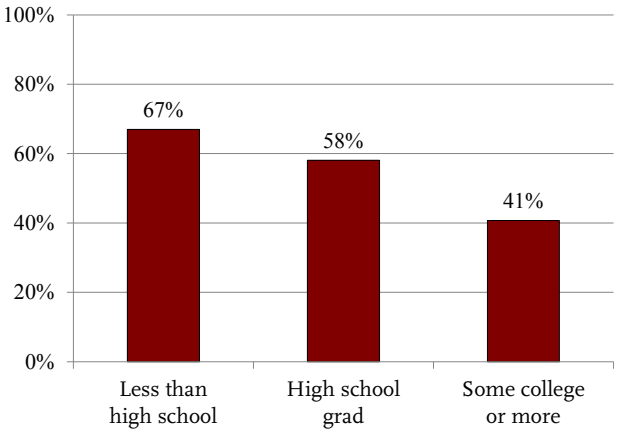
Even if the pace of mortality improvement increases overall, the pattern by education is likely to persist. Risky behaviors continue to vary by educational attainment. Specifically, those with less education are less likely to have stopped smoking and less likely to exercise – a key factor to stave off obesity (see Figures 9 and 10 on the next page).

Figure 9. Age-adjusted Prevalence of Current Cigarette Smoking among Adults Ages 25+, By Education, 1974-2015



Source: National Center for Health Statistics (2017).

Figure 10. Percentage of Adults Ages 18+ who Did Not Participate in Any Physical Activity, By Education, 2015



Note: Physical activity is defined as leisure-time aerobic and muscle-strengthening activities that meet the federal 2008 Physical Activity Guidelines.
Source: National Center for Health Statistics (2017).

Projecting the Future in Mortality Improvement

While all experts agree that mortality rates will continue to improve and lifespans will increase, they disagree about the pace of future improvements. At one extreme, the pessimists believe that most advanced countries are close to the biological limit to longevity and anticipate that historical rates of mortality improvement cannot continue.[20] At the other extreme, the optimists expect high rates of mortality improvement based on the observation that the highest observed lifespan of any country has increased at approximately a constant rate.[21]

Most projections by researchers and government agencies fall between these extremes. For example, one popular projection method used by demographers is the Lee-Carter model.[22] This model takes in historical age-specific mortality rates and produces mortality rate forecasts by age and projection year. It does not incorporate any knowledge about medical, behavioral or social influences and does not allow for any deceleration in age-specific mortality rates. Recent estimates by Lee, reported by the Social Security actuaries, produced an annual age-sex-adjusted rate of mortality improvement of 0.99 percent over the period 2011-2089.[23] This number is quite close to the historical rate of 1.1 percent over the period 1900 to the present reported above.

In terms of government agencies, the Congressional Budget Office (CBO) has shifted its approach over time. Prior to 2013, the CBO was using mortality improvement that aligned with the Trustees' projections developed by the SSA actuaries. In 2013, in response to recommendations by the 2011 Technical Panel, CBO adopted a relatively simple approach of assuming death rates would decline at 1 percent per year in the future.[24] As of mid-2016, however, CBO – recognizing the importance of the age gradient – changed to an extrapolation of past age-sex-specific trends in death rates, seemingly along the lines of the Lee and Carter approach. In 2016, these extrapolations produced an annual average rate of mortality improvement of 0.93 percent over the next 75 years.[25]

The Social Security actuaries use a "by cause" model that incorporates five categories of death (cardiovascular, cancer, respiratory disease, violence, and all others). Based on this analysis – and the results of recent projections by clinicians and researchers at Johns Hopkins University[26] – the actuaries conclude that the United States will see a slowing in the rates of mortality improvement from cardiovascular disease at least over the next 25 years. This finding, combined with the assumption that the nation will not be able to replicate the improvement in sanitation, the expansion of access to medical care, and the explosion of spending on medicine and health research, yields an age-sex-adjusted rate of mortality improvement of 0.77 percent over the next 75 years.

Conclusion

Mortality rates are a key input into Social Security cost projections. Mortality rates are constantly improving, but the pace of progress varies. Sometimes mortality rates improve very rapidly and sometimes more slowly. The cycles over the last 40 years have reflected developments in medical drugs and technology, access to health care, and risky behaviors such as smoking and those associated with obesity. The gains in mortality improvement have been skewed toward those with higher educational attainment and more income.

Future mortality improvements will continue to depend on medical developments and the prevalence of smoking and obesity, especially for lower educational groups. The key debate for long-range projections hinges on whether the future will mirror the past, with mortality rates of improvement fluctuating around the long-term rate of about 1 percent per year, or whether the big gains are behind us, with mortality improving less rapidly in the future.

Endnotes

1 For example, the "Baby Boom" period of high fertility was followed by a sharp drop in fertility – a "Baby Bust." As a result, the average age of the U.S. population is increasing. This pattern results in the appearance of higher mortality, even though it is really just due to a transitory demographic phenomenon and the fact that older people die more frequently than younger ones.

2 The analysis standardizes the mortality rates using the 2010 U.S. Census population.

3 Life expectancy is estimated from mortality rates in three steps: 1) compute survival rates from mortality rates – that is, a 1-percent chance of dying turns into a 99-percent chance of surviving; 2) calculate the probability of, say, a 65-year-old living to 66, to 67, to 68 and so on, where each year's rate is the product of the previous survival rates; and 3) sum the conditional survival rates to determine the number of years the 65-year-old is expected to live.

4 These estimates are based on cohort, rather than period, life expectancies. Under the period method, for a 65-year-old in 2017 the mortality rates at 66, 67, 68 etc. are the rates applicable to individuals currently at those ages in 2017. In contrast, a cohort approach takes into account that mortality rates for individuals would likely decline in the future. Thus, for a 65-year-old in 2017, the mortality rate at 66 would be that for a 66-year-old in 2018; at 67 that for a 67-year-old in 2019, etc. Since mortality rates are projected to decline in the future, the period approach significantly understates how long someone is actually likely to live.

5 The remaining life expectancies are calculated using the mortality improvement age-gradient from the Social Security Administration for the period 2011-2089, scaled up or down proportionately to reflect the average rate of improvement indicated. This forecast assumes 1.6 percent annual mortality improvement for individuals ages 0-14; 0.9 percent improvement for those ages 15-49; 1.1 percent improvement for those ages 50-64; 0.9 percent for those ages 65-84; and 0.5 percent for those ages 85+. The "scaling up" simply multiplies these rates of improvement by the indicated rate divided by Social Security's assumed intermediate average rate of improvement over the period 2011-2089.

6 The Multiple Cause Death Data provide individual death records for U.S residents and are available through the *U.S. National Vital Statistics System* (NVSS) of the Centers for Disease Control and Prevention (CDC). Between 1969 and 2015, over 100 million deaths were recorded and each death record contains information on the underlying cause of death, additional multiple causes, and – depending on the year selected – demographic data. It is important to note that the underlying cause of death may not provide a complete picture of trends in morbidity and mortality since most diseases and injuries have multiple potential causes. Death certificates are also written before autopsies, which can often provide more accurate information, but autopsies are not performed for every death. Data from death certificates used in this analysis are still useful in assigning deaths to specific diseases but do not provide enough information on multiple causes or risk factors that may be responsible for future mortality.

7 Appendix Table A1 outlines ICD code classifications.

8 American Heart Association (2015).

9 Although aspirin is widely used, studies have also shown that it should not be used by those with low risk of cardiovascular disease (Kennedy et al. 2015).

10 Endo (2010).

11 Iqbal, Gunn, and Serruys (2013).

12 Centers for Medicare and Medicaid Services (2017).

13 Smoking in the United States increased throughout the early and mid-20th century. By 1963, Americans on average smoked over 4,000 cigarettes per capita annually. Simultaneously, a strong body of epidemiologic studies had emerged in the 1950s linking tobacco use with mortality. In 1964, the Surgeon General's Report concluded that there was a causal relationship between smoking and lung cancer. The 1971 Surgeon General's Report focused on the relationship between smoking and mortality from chronic heart diseases. Several subsequent Surgeon General Reports and studies have linked smoking with increased risks for heart disease, stroke, and other cancers. By the 1960s, smoking among men began to decline and the same occurred for women in the 1980s. See U.S. Department of Health and Human Services (2014); and Mokdad et al. (2004).

14 Obesity is defined as adults with BMI greater than or equal to 30.

15 Danaei et al. (2009).

16 Hormone replacement therapy was once thought to help protect women from post-menopausal heart attacks. Beginning in 2002, however, results from clinical trials showed that prolonged use of hormone therapy may have the opposite effect. In fact, two clinical trials were ended prematurely because of the serious risks of heart attack.

17 One example is the drug Serelaxin, a heart failure medication that was granted "breakthrough therapy" designation by the FDA; this drug was not successful in meeting key required goals in phase III of its clinical trials.

18 Some studies, such as Stewart, Cutler, and Rosen (2009), have found that the negative effects of increasing obesity will outweigh the positive effects from declines in smoking. Other studies, such as Prospective Studies Collaboration (2009) and Preston et al. (2014), have estimated that the positive effects from declines in smoking will outweigh the rise in obesity.

19 However, recent studies have also shown that the increase in the prevalence of obesity has either leveled off or decreased. See Rokholm, Baker, and Sørensen (2010).

20 Dong, Milholland, and Vijg (2016); and Olshansky, Carnes, and Désesquelles (2001).

21 Oeppen and Vaupel (2002).

22 Lee and Carter (1992).

23 Goss et al. (2016).

24 Congressional Budget Office (2013).

25 Congressional Budget Office (2017).

26 Canudas-Romo et al. (2016).

References

American Heart Association. 2015. "Heart Disease and Aspirin Therapy." Dallas, TX. Available at: http://news.heart.org/heart-disease-aspirin-therapy/

Canudas-Romo, Vladimir, Eva DuGoff, Albert W. Wu, Saifuddin Ahmed, and Gerard Anderson. 2016. "Life Expectancy in 2040: What Do Clinical Experts Expect?" *North American Actuarial Journal* 20(3): 276-285.

Centers for Disease Control and Prevention. 2016. *Trends in Current Cigarette Smoking among High School Students and Adults, United States, 1965-2011*. Atlanta, GA: U.S. Department of Health and Human Services.

Centers for Disease Control and Prevention. *National Vital Statistics System,* 1969-2015. Atlanta, GA: U.S. Department of Health and Human Services.

Centers for Medicare & Medicaid Services. 2017. "NHE Fact Sheet." Available at: https://www.cms.gov/research-statistics-data-and-systems/statistics-trends-and-reports/nationalhealthexpenddata/nhe-fact-sheet.html

Congressional Budget Office. 2017. *The 2017 Long-Term Budget Outlook*. Washington, DC.

Congressional Budget Office. 2013. *The 2013 Long-Term Budget Outlook*. Washington, DC.

Danaei, Goodarz, Eric L. Ding, Dariush Mozaffarian, Ben Taylor, Jürgen Rehm, Christopher J. L . Murray, and Majid Ezzati. 2009. "The Preventable Causes of Death in the United States: Comparative Risk Assessment of Dietary, Lifestyle, and Metabolic Risk Factors." *PLoS Medicine* 6(4): e1000058.

Dong, Xiao, Brandon Milholland, and Jan Vijg. 2016. "Evidence for a Limit to Human Lifespan." Nature 538 (7624): 257-259.

Endo, Akira. 2010. "A Historical Perspective on the Discovery of Statins." *Proceedings of the Japan Academy. Series B, Physical and Biological Sciences* 86(5): 484-493.

Fryar, Cheryl D., Margaret D. Carroll, and Cynthia L. Ogden. 2012. "Prevalence of Overweight, Obesity, and Extreme Obesity among Adults: United States, Trends 1960-1962 through 2009-2010." Hyattsville, MD: National Center for Health Statistics.

Goss, Stephen, Karen Glenn, Michael Morris, K. Mark Bye, and Felicitie Bell. 2016. *Human Longevity and Implications for Social Security Actuarial Status*. Actuarial Note No. 158. Baltimore, MD: Social Security Administration, Office of the Chief Actuary.

Iqbal, Javaid, Julian Gunn, and Patrick W. Serruys. 2013. "Coronary Stents: Historical Development, Current Status and Future Directions." *British Medical Bulletin* 106(1): 193-211.

Kennedy, Kevin Vijay Nambi, Hani Jneid, Mahboob Alam, Sukhdeep S.Basra, P. Michael Ho, Anita Deswal, Christie M. Ballantyne, Laura A. Petersen, Salim S.Virani. 2015. "Frequency and Practice-level Variation in Inappropriate Aspirin Use for the Primary Prevention of Cardiovascular Disease: Insights from the National Cardiovascular Disease Registry's Practice Innovation and Clinical Excellence Registry." *Journal of the American College of Cardiology* 65(2): 111-121.

Lee Ronald D. and Lawrence R. Carter. 1992. "Modeling and Forecasting U.S. Mortality." *Journal of the American Statistical Association* 87(419).

Mokdad, Ali H., James S. Marks, Donna F. Stroup, and Julie L. Gerberding. 2004. "Actual Causes of Death in the United States, 2000." *Journal of the American Medical Association* 291(10): 1238-1245.

National Center for Health Statistics (US), and National Center for Health Services Research. 2017. "Health, United States, 2016: With Chartbook on Long-term Trends in Health." Washington, DC: US Department of Health and Human Services, Public Health Service, Health Resources Administration, National Center for Health Statistics.

National Center for Health Statistics, National Vital Statistics System, Centers for Disease Control and Prevention. 1969-2015. *Multiple Cause-of-Death Mortality Data*. Washington, DC.

Mortality Study. Washington, DC. Oeppen, Jim and James W. Vaupel. 2002. "Broken Limits to Life Expectancy." *Science* 296(5570): 1029-1031.

Olshansky, S. Jay, Bruce A. Carnes, and Aline Désesquelles. 2001. "Prospects for Human Longevity." Science 291(5508): 1491-1492.

Prospective Studies Collaboration. 2009. "Body-Mass Index and Cause-Specific Mortality in 900,000 Adults: Collaborative Analyses of 57 Prospective Studies." *The Lancet* 373(9669): 1083-1096.

Preston, Samuel H., Andrew Stokes, Neil K. Mehta, and Bochen Cao. 2014. "Projecting the Effect of Changes in Smoking and Obesity on Future Life Expectancy in the United States." *Demography* 51 (1): 27-49.

Rokholm, Benjamin, Jennifer Lyn Baker, and Thorkild Ingvor A. Sørensen. 2010. "The Levelling Off of the Obesity Epidemic since the Year 1999 – A Review of Evidence and Perspectives." *Obesity Reviews* 11(12): 835-846.

Sanzenbacher, Geoffrey T., Anthony Webb, Natalia S. Orlova, and Candace M. Cosgrove. 2016. "Does a Uniform Retirement Age Make Sense?." *Issue in Brief* 16-1. Chestnut Hill, MA: Center for Retirement Research at Boston College.

Stewart, Susan T., David M. Cutler, and Allison B. Rosen. 2009. "Forecasting the Effects of Obesity and Smoking on US Life Expectancy." *New England Journal of Medicine* 361(23): 2252-2260.

Surveillance, Epidemiology, and End Results Program (SEER), National Cancer Institute. 1969-2015. Washington, DC.

U.S. Census Bureau. *National Longitudinal Mortality Study*, 1979-2011. Washington, DC.

U.S. Department of Health and Human Services. 2014. *The Health Consequences of Smoking – 50 Years of Progress: A Report of the Surgeon General*. Atlanta, GA: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health.

U.S Social Security Administration, Office of the Chief Actuary. 2016. *The Long-Run Demographic Assumptions for the 2016 Trustees Report*. Baltimore, MD.

U.S. Social Security Administration. 2017a. *The Annual Reports of the Board of Trustees of the Federal Old-Age and Survivors Insurance and Federal Disability Insurance Trust Funds*. Washington, DC: U.S. Government Printing Office.

U.S. Social Security Administration, Office of the Chief Actuary. 2017b. "Unpublished Data on Historical and Projected Death Rates." Baltimore, MD.

World Health Organization. 1968. *International Classification of Diseases, Eighth Revision*. Geneva, Switzerland: World Health Organization.

World Health Organization. 1977. *International Classification of Diseases, Ninth Revision*. Geneva, Switzerland: World Health Organization.

World Health Organization. 1992. *International Classification of Diseases, Tenth Revision*. Geneva, Switzerland: World Health Organization.

APPENDIX

Table A1. Cross-walk for Revisions of the International Classification of Disease (ICD)

Cause of death	ICD-8 (1969-1978)	ICD-9 (1979-1998)	ICD-10 (1999-2015)
Cardiovascular	390-398, 402, 404, 410-29, 430-438	390-398, 402, 404, 410-29, 430-438	I00-I09, I11, I13, I20-I51, I60-I69
Cancer	140-239, 162	140-239, 238.6, 162	C00-C97
Dementia and Alzheimer's	290, 293	290, 331	F00, F01, F03, G30
Influenza, pneumonia, and COPD	470-474, 480-483, 485-486, 490-493, 518-519	480-487,490-496	J09-J18, J40-J47
Suicide and unintentional	800-949, 950-959	800-949, 950-959	U03, V01-V99, W01-W99, X01-X59, X60-X84, Y85-Y87

Source: World Health Organization (1968, 1977, 1992).

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The Brookings Institution
Syracuse University
Urban Institute

Contact Information

Center for Retirement Research
Boston College
Hovey House
140 Commonwealth Avenue
Chestnut Hill, MA 02467-3808
Phone: (617) 552-1762
Fax: (617) 552-0191
E-mail: crr@bc.edu
Website: http://crr.bc.edu

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