They say 60 is the new 40. Thanks to improvements in health and medicine, people are living longer than ever, and they are generally healthier and have better cognition at every age. As average life spans have lengthened, age is no longer the only—or the best—measure to compare the well-being or behavior of different generations.

This fundamental change in life span has profound implications for economic, health, demographic, sociological, policy, and other research. Many studies use age to define population groups. They may compare the leisure patterns or health of different cohorts of people of the same age. They may project improvements in life expectancy by age according to past patterns. Or they may use age as one explanatory variable among many in a regression on, say, variation in retirement saving over time. To "control for age" in a study means to take into account the effect of age, when looking at the effect of some other variable. But does a study control for age if it treats being 60 in 1940 and being 60 in 2010 as the same, when these positions along the life course are very different?

Chronological age represents the distance from the beginning of life. But in some cases, either the distance to the end of life or a relative position along the life course may be more informative. These alternative ways of comparing people of the "same age" over time have long been neglected in research, perhaps because there had been no readily available means for redefining the age of an observed individual or group. We aim to remove that obstacle.

This brief proposes two alternative measures of age that rely on remaining life expectancy and the ratio of life expectancy to the expected total life span. For many purposes, they may be more suitable for measuring past and projecting future trends and for studying needs, conditions of old age, and responses to policy changes. We have also created a web-based interactive tool that visualizes the
relationships between different measures of age over time and provides downloadable data for easy conversion between the measures.

**Alternative Measures of Age in Past Research**

Alternative measures of age have, on rare occasions, been proposed and used in different disciplines to study specific issues. Our measures are most similar to those outlined by Bayo and Faber (1981), who focused on equivalent retirement ages. They proposed four alternatives for adjusting retirement age for changes in life expectancy, two of which are almost identical to ours. But our approach is more general; our measures can be applied to more issues beyond retirement.

Age is often used in research as a proxy for other variables, including physical and cognitive ability, the ability to assume certain social roles, and the likelihood of experiencing medical problems. By controlling for age, researchers indirectly control for these other variables, for which data are less available or measurement more difficult. But when a data sample spans a long period of time, the use of chronological age as a proxy may be less suitable.

Despite recent setbacks in life expectancy in the United States (Kochanek et al. 2017), people are living longer overall. Remaining life expectancy for 60-year-old men increased six years over the past five decades, rising from 16 in 1967 to 22 in 2017. The increase for 60-year-old women was less dramatic but still substantial at 4.6 years, rising from 20.3 in 1967 to 24.9 in 2017. Over the next five decades, life expectancy is likely to increase 3.5 years for men and 3 years for women, according to projections by the Social Security Administration (SSA; Bell and Miller 2005).

Improvements in mortality rates came with improvements in physical and cognitive ability, health, and other characteristics, whose relationship to age has changed. A 60-year-old man today is on average healthier and more able than a 60-year-old man was 50 years ago. How do we compare him to a man with the same physiological and mental characteristics 50 years ago, without using chronological age?

To answer this question, researchers in medicine, psychology, and sociology have considered alternative measures of age that account for differentials in the rate of change of individual characteristics over time and across individuals. According to Karasik and colleagues (2005), biological age "estimates the functional status of an individual in reference to his or her chronological peers on the basis of how well he or she functions in comparison with others of the same chronological age." Birren and Cunningham (1985) defined biological age relative to a person's potential life span, social age based on a person's roles and habits in society, and psychological age based on a person's cognitive and emotional capacities as seen in their ability to adapt to a changing environment.

Steuerle and Spiro (1999) implicitly defined a new measure of age by using life expectancy instead of chronological age as a control variable in studying labor force participation over time. Milligan and Wise (2012) used the mortality rate—the flip side of life expectancy—for the same purpose, as well as for a cross-country comparison of labor force participation. Both studies argue that individuals' capacity
for work is better predicted by their mortality than by chronological age. Mortality, however, is not a perfect control for work ability. Many people with disabilities can live longer today than they would have half a century ago but are still unable to work. Cutler, Meara, and Richards-Shubik (2013) took a different approach by controlling for health status instead of mortality or chronological age when assessing work capacity, but Coile, Milligan, and Wise (2016) found that the two measures produce similar results.

Methods

We define two alternative measures of age, one based on life expectancy and the other on relative life expectancy—the ratio of life expectancy to the total expected life span. Life expectancy for each sex, as published in the Social Security Administration’s Period Life Tables (Bell and Miller 2005), is a function of age and calendar year: \( e = e(a, y) \). The relative life expectancy at some age \( a \) is the ratio of life expectancy to life expectancy plus age: \( r(a, y) = e(a, y) / (a + e(a, y)) \). The life tables provide mortality and life expectancy separately for men and women from birth to age 119 in each year between 1900 and 2014. In addition, the SSA provides projections of mortality and life expectancy from 2015 to 2100.

Life Expectancy Age

Life expectancy age (LEA) reflects the distance to the end of a person’s life span. It holds life expectancy fixed.

We define the life expectancy age for chronological age \( a \) and comparison year \( y \) with respect to a base year \( y_b \) as the age in the base year at which life expectancy equals the life expectancy at age \( a \) in year \( y \). In the base year, the LEA coincides with the chronological age; in any other year, the LEA is constructed to keep life expectancy the same as in the base year. For example, to find the LEA of a 65-year-old woman in 2010 relative to base year 1960, we would first use the 2010 life tables to find that female life expectancy at age 65 was 20.2 years in 2010. We would then use the 1960 life tables to find the age at which female life expectancy was 20.2 years. That age, 59.2, represents the female LEA for age 65 in 2010 with respect to base year 1960.

Looking up life tables by life expectancy requires interpolation and calculation of an inverse function. We automated this process with a computer program that performs two basic operations on the life tables: (1) interpolating the life expectancy function for all real values of age between 0 and 119, and (2) solving an equation for age given life expectancy and calendar year. We denote the interpolated version of the life expectancy function as \( \hat{e}(a, y) \). To calculate the age for a given life expectancy \( e \) and a calendar year \( y \), we solve equation \( \hat{e}(a, y) = e \) for age \( a \). We denote the function that solves the above equation \( a = \varepsilon(e, y) \). Figure 1 shows \( \varepsilon(e, y) \) as a function of life expectancy for years 1920, 1950, 1980, and 2010.
Relative Life Expectancy Age

The second alternative measure of age is the relative life expectancy age (RLEA), which reflects a relative position in the life course. Here, we look at remaining life expectancy as a share of the life span.

We define relative life expectancy for any age $a$ and year $y$ with respect to a base year $\bar{y}$ as the age in the base year at which the relative life expectancy equals the relative life expectancy at age $a$ in year $y$. Following the same example as above, female life expectancy at age 65 in 2010 was 20.2 years, resulting in the relative life expectancy of $20.2/(65+20.2)=0.24$, meaning that her remaining years will make up 24 percent of her life. To find the RLEA is to find the age in 1960, the base year, at which the relative life expectancy was the same. This age is 60.9, because the life expectancy at that age, 18.9, results in the relative life expectancy of $18.9/(18.9+60.9)=0.24$.

The calculation procedure is similar to the one described in the case of the LEA. The interpolation that yields the life expectancy function for real values of age is the same in both cases. The equation being solved to obtain age is similar, but in this case, it is defined in terms of relative life expectancy. To find age $a$ at which RLEA in year $y$ equals $r$, we solve equation $r(a, y) = r$. We denote the function that solves this equation by $\rho(r, y)$. Figure 2 shows $\rho(r, y)$ as a function of relative life expectancy for years 1920, 1950, 1980, and 2010.
How to Use the Alternative Measures of Age Tool

To make it easier for other researchers to use the alternative measures of age introduced in this brief, we created a tool that converts chronological age to alternative measures of age, and vice versa. The tool provides interactive charts and downloadable data. In addition, it illustrates the application of alternative measures of age through an example that compares employment rates over time.

The tool gives users the option to convert the chronological age into two alternative measures of age. Users select a chronological age to convert, a base year for the calculation, and a time period for which to show results for men or women. The resulting chart shows two graphs—one for the LEA and one for the RLEA—that represent values of alternative measures of age in each year of the selected time period for the selected chronological age and relative to the selected base year.

Users can also convert the two alternative measures of age into chronological age over the selected time period. In this case, users select the value of the alternative measures of age to be converted into chronological age. For example, selecting male, alternative measure of age 65, and base year 1940 yields the chart in figure 3. The blue line represents chronological ages that correspond to the LEA of 65 relative to base year 1940. The yellow line represents chronological ages that correspond to the RLEA of 65 relative to the same base year.

Source: Social Security Administration life tables and authors’ calculations.
Suppose a researcher wanted to measure rates of change in labor force participation, health, cancer incidence, volunteerism, or any other variable over time, and age was one of the factors being considered, whether in a simple two-way graph or correlation or in a more elaborate, multivariate regression in which age was one of the independent variables. For each individual observation of chronological age in a given year, the tables we provide allow for ready conversion to an alternative age. The base year here operates pretty much like a base year for a price index and is unlikely to change the conclusions from the study. These alternative measures are likely to yield different conclusions about the influence of age on the variable of interest, about the influence of any other independent variables that may now correlate differently with age, and about any projection from the past to the future. The best age measure will depend upon the goal of the research—for example, testing a theory or simply finding the best fit.
Conclusion

Life expectancy and the ratio of life expectancy to expected life span are important markers of one’s position along the life course. This brief defines two new measures of age that take these markers into account and can be used in the same way as chronological age. We document how these measures of age are calculated and suggest some applications. Our online data tool allows users to convert chronological age to the two alternative measures of age and vice versa.

This tool should prove useful to a wide range of researchers, including demographers, health researchers, economists, and other social scientists. Many conclusions drawn from previous studies could be improved or even altered, when tested using these alternative measures of age in addition to or in place of chronological age.

Even among people of the same birth cohort and gender, life expectancy varies across subgroups—especially those defined by race and education. In some applications, it will be important to account for these differences. Our tool cannot currently adjust for these differences, but we are considering adding this functionality in the future.

We welcome feedback from researchers on any projects they undertake using this tool and on any projects that require more elaborate versions of the tool.
Appendix

Mapping Alternative Measures of Age onto Each Other While Holding Each Constant over Time

We denote a set of real values of age between 0 and 119 as \( A \) and the set of calendar years between 1900 and 2100 as \( Y \). We define conversion functions \( a, \alpha : A \times Y \times Y \rightarrow A \) that convert values between the chronological age and the LEA such that the life expectancy at the chronological age equals the life expectancy at the LEA:

\[
\alpha = \alpha(a, y, \bar{y}) \Leftrightarrow a = a(\alpha, y, \bar{y}) \Leftrightarrow e(a, y) = e(\alpha, \bar{y}) \quad (1)
\]

The first equality, left of the first iff, maps chronological age \( a \) in year \( y \) relative to base year \( \bar{y} \) to LEA \( \alpha \). The second term, between two iffs, does the reverse; it maps LEA to the chronological age. The last term is the condition that these two mappings preserve: the life expectancy at the chronological age in an arbitrary calendar year equals the life expectancy at the LEA in the base year.

For example, male life expectancy at age 65 in 1940 was 11.92, same as at age 73.9 in 2015; or, in the above notation, \( e(73.9, 2015) = e(65, 1940) \). If we choose 1940 as the base year, the LEA function would equal 65 for \( \alpha(73.9, 2015, 1940) \), and the chronological year function would equal 73.9 for \( a(65, 2015, 1940) \).

It follows from the definition of these two functions that the LEA equals chronological age when the calendar year is the same as the base year: \( a = a(\alpha, \bar{y}, \bar{y}) \) and \( \alpha = a(\alpha, \bar{y}, \bar{y}) \).

Using the notation introduced earlier for the function that maps life expectancy and calendar year into a chronological age, \( a = \varepsilon(\varepsilon, y) \), we can write functions \( a \) and \( \alpha \) in terms of \( e \) and \( \varepsilon \):

\[
a(\alpha, y, \bar{y}) = \varepsilon(\varepsilon(\alpha, \bar{y}), y) \quad (2)
\]

\[
\alpha(a, y, \bar{y}) = \varepsilon(\varepsilon(a, y), \bar{y}) \quad (3)
\]

In the case of the RLEA, we define the relative life expectancy as \( r(a, y) = e(a, y)/[e(a, y) + a] \) and the two conversion functions:

\[
\alpha = \alpha(a, y, \bar{y}) \Leftrightarrow a = a(\alpha, y, \bar{y}) \Leftrightarrow r(a, y) = r(\alpha, \bar{y}) \quad (4)
\]

Following the same example and using 1940 as the base year, we calculate the relative life expectancy at 65 in 1940 by dividing the life expectancy for that age and year, 11.92, by the sum of the age and life expectancy, which equals 0.15. In 2015, that same relative life expectancy was associated with age 72.
We can write the conversion functions for the RLEA in terms of the relative life expectancy function and the function that maps relative life expectancy and calendar year into age, \( a = \rho(r, y) \):

\[
a(a, y, \bar{y}) = \rho(r(a, \bar{y}), y) \tag{5}
\]
\[
a(a, y, \bar{y}) = \rho(r(a, y), \bar{y}) \tag{6}
\]

We implemented all the calculations in the R programming language. For interpolation, we used the \texttt{chebpol} package that calculates Chebyshev interpolation of a multivariate function. For equation solving, we used \texttt{uniroot} function, an R-language numerical solver.

**Note**

1 “Period Life Tables,” Social Security Administration, [https://www.ssa.gov/oact/HistEst/PerLifeTablesHome.html](https://www.ssa.gov/oact/HistEst/PerLifeTablesHome.html).

**References**


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