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U.S. State Life Tables, 2018

by Elizabeth Arias, Ph.D., Brigham Bastian, B.S., Jiaquan Xu, M.D., and Betzaida Tejada-Vera, M.S., Division of Vital Statistics

Abstract

Objectives—This report presents complete period life tables for each of the 50 states and the District of Columbia by sex based on age-specific death rates in 2018.

Methods—Data used to prepare the 2018 state-specific life tables include 2018 final mortality statistics; July 1, 2018 population estimates based on the 2010 decennial census; and 2018 Medicare data for persons aged 66–99. The methodology used to estimate the state-specific life tables is the same as that used to estimate the 2018 national life tables, with some modifications.

Results—Among the 50 states and the District of Columbia, Hawaii had the highest life expectancy at birth, 81.0 years in 2018, and West Virginia had the lowest, 74.4 years. Life expectancy at age 65 ranged from 17.5 years in Kentucky to 21.1 years in Hawaii. Life expectancy at birth was higher for females in all states and the District of Columbia. The difference in life expectancy between females and males ranged from 3.8 years in Utah to 6.2 years in New Mexico.

Keywords: state life expectancy • survival • death rates • National Vital Statistics System

Introduction

This report presents the first set of annual complete period life tables for each of the 50 states and the District of Columbia (D.C.) for the year 2018. Life tables were produced for the total, male, and female populations of each state and D.C. based on age-specific death rates for 2018. The methodology used to estimate the state-specific life tables is the same as that used to estimate the annual U.S. life tables, with some minor modifications described in the Technical Notes of this report (1).

There are two types of life tables: the cohort (or generation) life table and the period (or current) life table. The cohort life table presents the mortality experience of a particular birth cohort—all persons born in the year 1900, for example—from the moment of birth through consecutive ages in successive calendar years. Based on age-specific death rates observed through consecutive calendar years, the cohort life table reflects the mortality experience of an actual cohort from birth until no lives remain in the group. To prepare just a single complete cohort life table requires data over many years. It is usually not feasible to construct cohort life tables based entirely on observed data for real cohorts due to data unavailability or incompleteness (2). For example, a life table representation of the mortality experience of a cohort of persons born in 1970 would require the use of data projection techniques to estimate deaths into the future (3,4).

Unlike the cohort life table, the period life table does not represent the mortality experience of an actual birth cohort. Rather, the period life table presents what would happen to a hypothetical cohort if it experienced throughout its entire life the mortality conditions of a particular period in time. For example, a period life table for 2018 assumes a hypothetical cohort that is subject throughout its lifetime to the age-specific death rates prevailing for the actual population in 2018. The period life table could be characterized as rendering a "snapshot" of current mortality experience and shows the long-range implications of a set of age-specific death rates that prevailed in a given year. In this report the term "life table" refers only to the period life table and not to the cohort life table.

Life tables can be classified in two ways according to the length of the age interval in which data are presented. A complete life table contains data for every single year of age. An abridged life table typically contains data by 5- or 10-year age intervals. A complete life table can easily be aggregated into 5- or 10-year age groups. U.S. decennial life tables and, beginning in 1997, U.S. annual life tables, are complete life tables. This report presents the first in a series of annual complete period state-specific life tables.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Center for Health Statistics
National Vital Statistics System

Data and Methods

The data used to prepare the U.S. state life tables for 2018 are state-specific final numbers of deaths for the year 2018; July 1, 2018 state-specific population estimates based on the 2010 decennial census; and state-specific death and population counts for Medicare beneficiaries aged 66–99 for the year 2018 from the Centers for Medicare & Medicaid Services. Data from the Medicare program are used to supplement vital statistics and census data for ages 66 and over. The methodology used to estimate the 2018 complete life tables for the 50 states and D.C. presented in this report is the same as what is used to estimate the annual U.S. national life tables, with some modifications. For some states, very small age-specific or zero numbers of deaths in childhood ages sometimes required the use of additional smoothing techniques not necessary in the construction of the national life tables. A modification to the estimation of death rates in the oldest ages was also necessary due to the lack of state-specific census population estimates for ages 85–100. The methodology with modifications used to construct the first set of annual U.S. state life tables is described in detail in the Technical Notes of this report.

Explanation of the columns of the life table

Column 1. Age (between x and $x + 1$)—Shows the age interval between the two exact ages indicated. For instance, "20–21" means the 1-year interval between the 20th and 21st birthdays.

Column 2. Probability of dying (q_x)—Shows the probability of dying between ages x and $x + 1$. For example, for males who reach age 20 in Massachusetts, the probability of dying before reaching their 21st birthday is 0.000601 (Table MA–2). This column forms the basis of the life table; all subsequent columns are derived from it.

Column 3. Number surviving (l_x)—Shows the number of persons from the original hypothetical cohort of 100,000 live births who survive to the beginning of each age interval. The l_x values are computed from the q_x values, which are successively applied to the remainder of the original 100,000 persons still alive at the beginning of each age interval. For example, out of 100,000 male babies born alive in Massachusetts in 2018, 99,243 will survive to their 21st birthday (Table MA–2).

Column 4. Number dying (d_x)—Shows the number dying in each successive age interval out of the original 100,000 live births. For example, out of 100,000 males born alive in Massachusetts in 2018, 60 will die between ages 20 and 21 (Table MA–2). Each figure in column 4 is the difference between two successive figures in column 3.

Column 5. Person-years lived (L_x)—Shows the number of person-years lived by the hypothetical life table cohort within an age interval x to $x + 1$. Each figure in column 5 represents the total time (in years) lived between two indicated birthdays by all those reaching the earlier birthday. Therefore, the figure 99,213 for males in the age interval 20–21 is the total number of years lived between the 20th and 21st birthdays by the 99,243 males in Massachusetts (column 3) who reached their 20th birthday out of 100,000 males born alive (Table MA–2).

Column 6. Total number of person-years lived (T_x)—Shows the total number of person-years that would be lived after the beginning of the age interval x to $x + 1$ by the hypothetical life table cohort. For example, the figure 5,776,560 is the total number of years lived after attaining age 20 by the 99,243 males reaching that age in Massachusetts (Table MA–2).

Column 7. Expectation of life (e_x)—The expectation of life at any given age is the average number of years remaining to be lived by those surviving to that age, based on a given set of age-specific rates of dying. It is derived by dividing the total person-years that would be lived beyond age x by the number of persons who survived to that age interval (T_x/l_x). Thus, the average remaining lifetime for males in Massachusetts who reach age 20 is 58.2 years (5,776,560 divided by 99,243) (Table MA–2).

Standard errors of the probability of dying and life expectancy

Although they are based on complete counts of death, the life table functions presented in this report are subject to error. Therefore, standard errors of the two most important functions, the probability of dying and life expectancy, are also presented. The mortality data on which the state life tables are based are not affected by sampling error because they are based on complete counts of deaths and, as a result, standard errors reflect only stochastic (random) variation. While measurement errors such as age misreporting on death certificates or census data are known to affect mortality estimates, they are not considered in the calculation of the standard errors of the life table functions. In most cases, standard errors for life expectancy at birth and the probability of dying are small due to large numbers of deaths. However, for some states with small populations, particularly at the youngest ages, the standard errors presented are relatively large.

Results

Complete life tables for the 50 states and D.C.

A set of complete period life tables for each state and D.C. is available online from "U.S. State Life Tables, 2018" at: https://ftp.cdc.gov/pub/Health_Statistics/NCHS/Publications/NVSR/70-01/. Table I lists table titles for each of these tables. Table numbering is based on the federal information processing standards, or FIPS, alpha code for the state combined with a table code. The table code is denoted as 1 for the total population, 2 for males, 3 for females, and 4 for the standard errors of the probability of dying and life expectancy. For example, Table FL–2 refers to the complete period life table for males in Florida.

Life expectancy in the 50 states and D.C.

Table A shows life expectancy at birth for the total, male, and female populations for the 50 states, D.C., and the United States. In 2018, among the 50 states and D.C., Hawaii ranked first as having the highest life expectancy for the total population, with

Table A. Life expectancy at birth, rank, and standard error, by sex: Each state, the District of Columbia, and United States, 2018

Area	Rank	Total	Standard error	Rank	Male	Standard error	Rank	Female	Standard error
Hawaii	1	81.0	0.118	4	78.0	0.172	1	84.0	0.156
California	2	80.8	0.021	1	78.4	0.031	2	83.1	0.028
New York	3	80.5	0.030	3	78.1	0.044	4	82.8	0.039
Minnesota	4	80.5	0.056	2	78.4	0.082	5	82.6	0.074
Connecticut	5	80.4	0.072	5	77.9	0.107	3	82.9	0.094
Massachusetts	6	80.1	0.051	9	77.7	0.075	6	82.5	0.067
Washington	7	80.0	0.049	6	77.9	0.071	10	82.1	0.065
Colorado	8	80.0	0.058	8	77.7	0.085	7	82.3	0.076
New Jersey	9	79.8	0.046	11	77.3	0.067	8	82.3	0.059
Rhode Island	10	79.8	0.131	12	77.2	0.192	9	82.2	0.173
Oregon	11	79.7	0.065	10	77.5	0.096	11	81.9	0.086
Utah	12	79.6	0.079	7	77.7	0.117	18	81.5	0.105
Vermont	13	79.3	0.183	13	77.0	0.269	12	81.7	0.245
North Dakota	14	79.3	0.161	14	77.0	0.224	13	81.7	0.226
Wisconsin	15	79.3	0.057	15	76.9	0.084	14	81.6	0.076
Iowa	16	79.2	0.077	18	76.8	0.111	15	81.6	0.103
New Hampshire	17	79.1	0.117	19	76.7	0.174	17	81.5	0.154
Nebraska	18	79.1	0.099	16	76.8	0.142	21	81.4	0.133
Idaho	19	79.0	0.105	17	76.8	0.153	22	81.3	0.139
Virginia	20	79.0	0.047	20	76.6	0.069	23	81.3	0.063
South Dakota	21	78.9	0.154	22	76.5	0.220	20	81.4	0.209
Florida	22	78.9	0.032	24	76.2	0.047	16	81.6	0.042
Illinois	23	78.8	0.040	23	76.2	0.058	24	81.3	0.052
United States	…	78.7	…	…	76.2	…	…	81.2	…
Montana	24	78.7	0.138	21	76.5	0.197	27	81.1	0.188
Arizona	25	78.7	0.055	28	76.0	0.080	19	81.5	0.071
Maine	26	78.6	0.121	29	75.9	0.179	25	81.2	0.157
Maryland	27	78.5	0.058	30	75.8	0.087	26	81.1	0.075
Texas	28	78.4	0.026	26	76.0	0.038	28	80.8	0.035
Pennsylvania	29	78.1	0.040	32	75.5	0.059	29	80.8	0.053
Wyoming	30	78.1	0.185	25	76.1	0.267	35	80.3	0.252
Kansas	31	78.0	0.083	31	75.7	0.120	34	80.3	0.112
Alaska	32	78.0	0.168	27	76.0	0.240	36	80.2	0.232
Nevada	33	77.9	0.081	33	75.4	0.119	32	80.5	0.106
Delaware	34	77.8	0.150	36	74.8	0.226	30	80.6	0.195
Michigan	35	77.7	0.046	34	75.4	0.066	38	80.1	0.061
District of Columbia	36	77.7	0.184	38	74.6	0.272	31	80.5	0.245
North Carolina	37	77.6	0.045	35	74.9	0.066	37	80.2	0.058
Georgia	38	77.2	0.044	37	74.7	0.064	39	79.7	0.059
New Mexico	39	77.2	0.106	41	74.2	0.157	33	80.4	0.138
Indiana	40	76.8	0.056	39	74.4	0.081	42	79.3	0.075
Ohio	41	76.8	0.043	40	74.2	0.062	40	79.3	0.057
Missouri	42	76.6	0.059	42	73.9	0.087	43	79.3	0.079
South Carolina	43	76.5	0.066	43	73.7	0.098	41	79.3	0.087
Arkansas	44	75.6	0.086	45	73.0	0.124	45	78.2	0.116
Oklahoma	45	75.6	0.073	44	73.1	0.106	46	78.2	0.098
Louisiana	46	75.6	0.069	47	72.7	0.101	44	78.5	0.091
Tennessee	47	75.5	0.057	46	73.0	0.082	47	78.1	0.075
Kentucky	48	75.3	0.068	48	72.6	0.099	49	77.9	0.091
Alabama	49	75.1	0.067	49	72.1	0.099	48	78.0	0.089
Mississippi	50	74.6	0.088	50	71.7	0.126	50	77.5	0.119
West Virginia	51	74.4	0.114	51	71.7	0.164	51	77.3	0.152

… Category not applicable.

NOTE: Life expectancies shown in this table are rounded, but rankings are based on unrounded life expectancies.

SOURCE: National Center for Health Statistics, National Vital Statistics System, Mortality.

a life expectancy at birth of 81.0 years. California ranked first for males, with a life expectancy of 78.4 years. West Virginia ranked 51st, with the lowest life expectancy among the 50 states and D.C. for the total, male, and female populations, with life expectancies at birth of 74.4, 71.7, and 77.3 years, respectively. In comparison, life expectancy at birth for the entire United States was 78.7, 76.2, and 81.2 for the total, male, and female populations, respectively. Figure 1 presents a map of the United States with state-specific life expectancy at birth grouped into quartiles. It shows that states with the lowest life expectancy at birth are mostly southern states, and states with the highest life expectancy at birth are predominantly western and northeastern states.

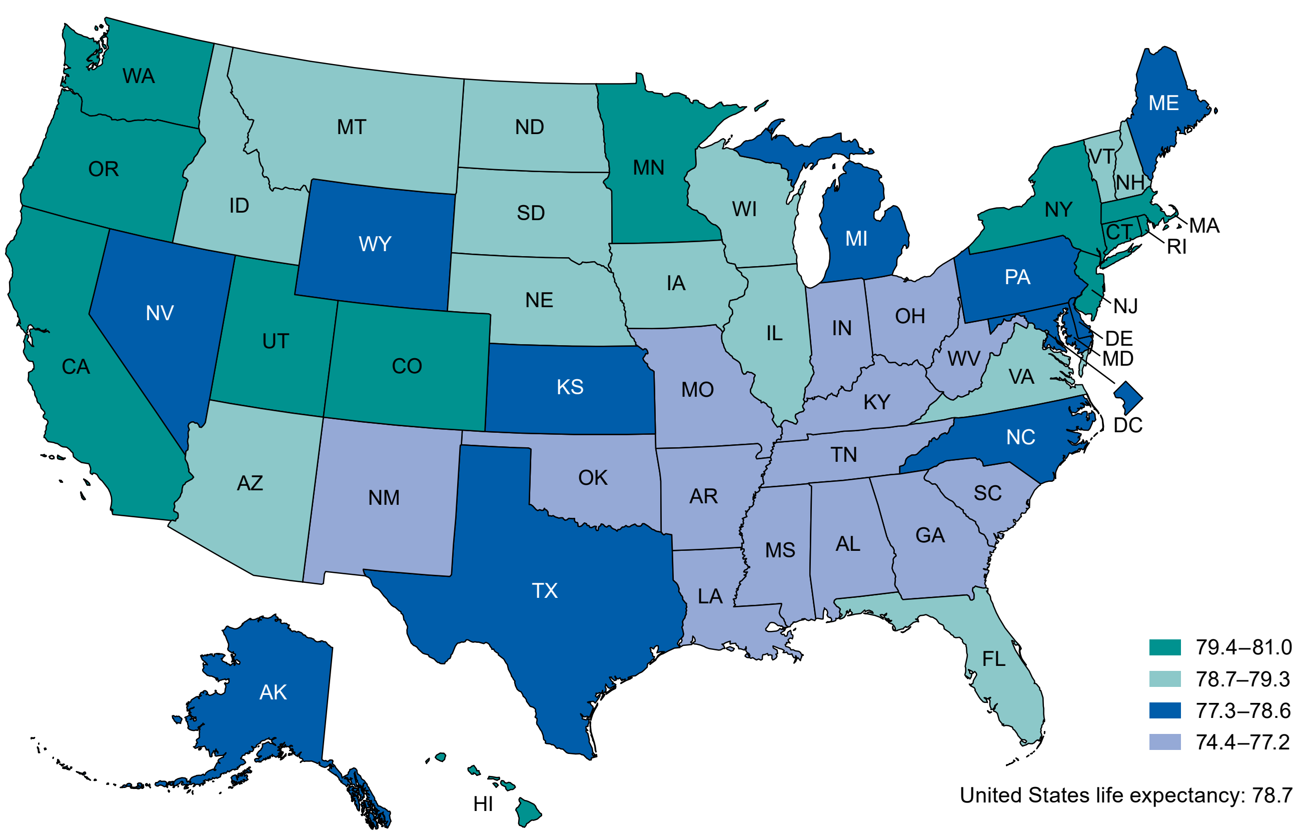
The difference in life expectancy between the sexes in the United States was 5.0 years in 2018, ranging from a high of 6.2 years in New Mexico to a low of 3.8 years in Utah (Figure 2). With a few exceptions, the states with the largest sex differences are those with lower life expectancy at birth, while the smallest sex differences are found mostly among states with higher life expectancy.

Table B shows life expectancy at age 65 for the total, male, and female populations for the 50 states, D.C., and the United States. In 2018, Hawaii ranked first for the total, male, and female populations, with life expectancy at age 65 of 21.1, 19.3, and 22.6 years, respectively. Kentucky ranked 51st, with the lowest life expectancy among the 50 states and D.C. for the total and female populations, with life expectancy at age 65 of 17.5 and 18.6, respectively. For males, Mississippi ranked 51st, with a life expectancy at age 65 of 15.9 years. In comparison, life expectancy at age 65 for the entire United States was 19.5, 18.1, and 20.7 for the total, male, and female populations, respectively. Figure 3 shows that states with the lowest life expectancies at age 65 are mostly concentrated in the south, and those with the highest life expectancies are mostly in the west and northeast.

Summary

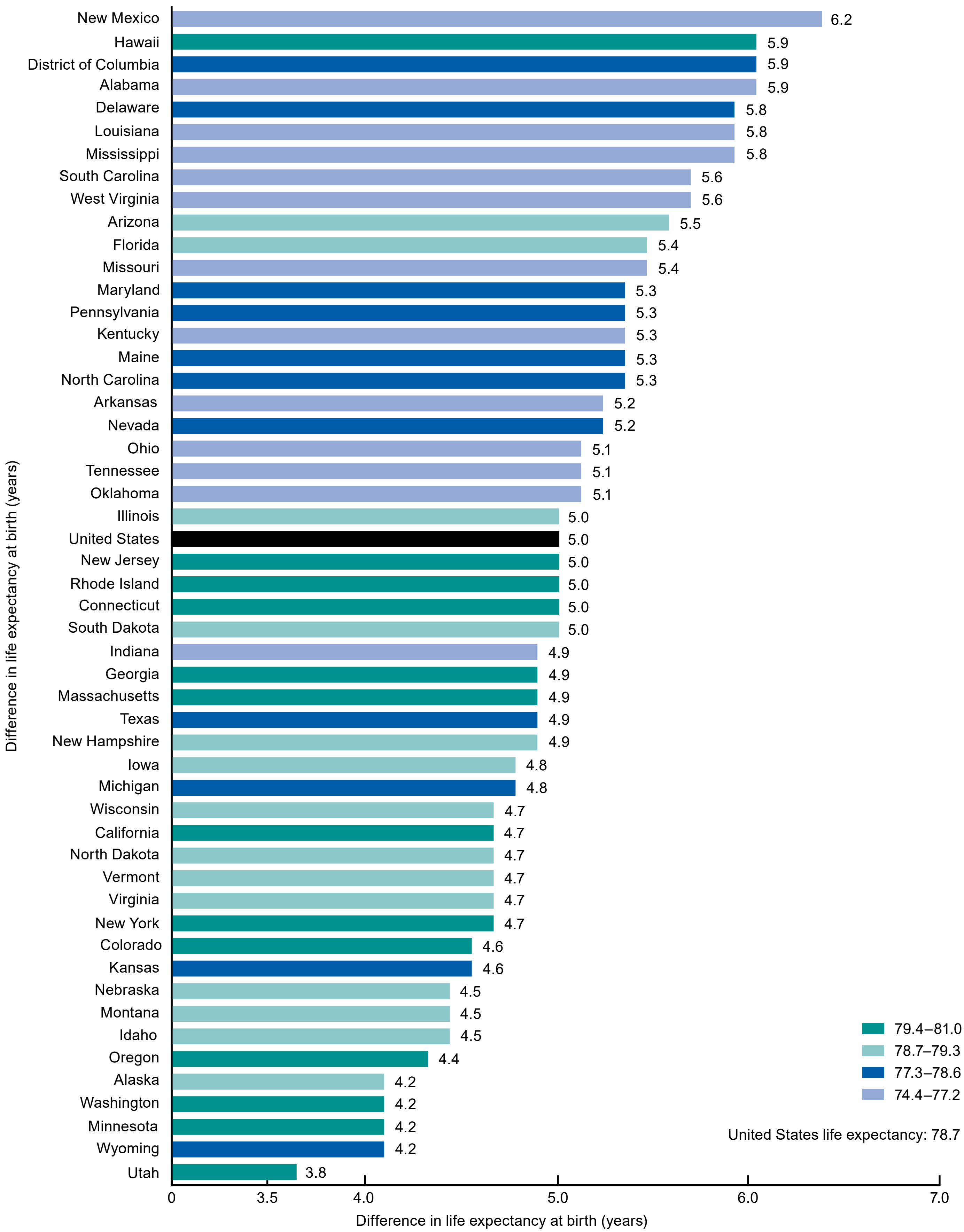
This report presents the first ever annual complete period life tables for the 50 states and D.C. and represents the first in a planned series of annual state life tables. Historically, complete period state life tables have been published once a decade as part of the decennial life table program, beginning with the set for the 1939–1941 decennial period (5). Only one other set of state-level life tables has been published by the National Center for Health Statistics. Those tables were part of a project to produce census tract-level life tables and were generated primarily for the purpose of evaluating the validity of the census tract-level life tables (6). They are not strictly comparable with the complete life tables presented in this report because they were based on 5 years of pooled data (2011–2015) and were abridged rather than complete life tables.

Figure 1. Life expectancy at birth: Each state, the District of Columbia, and United States, 2018



SOURCE: National Center for Health Statistics, National Vital Statistics System, Mortality.

Figure 2. Difference between male and female life expectancy at birth: Each state, the District of Columbia, and United States, 2018



NOTE: The color key reflects the range of life expectancy at birth for both sexes for each area.
SOURCE: National Cemter for Health Statistics, National Vital Statistics System, Mortality.

Table B. Life expectancy at age 65, rank, and standard error, by sex: Each state, the District of Columbia, and United States, 2018

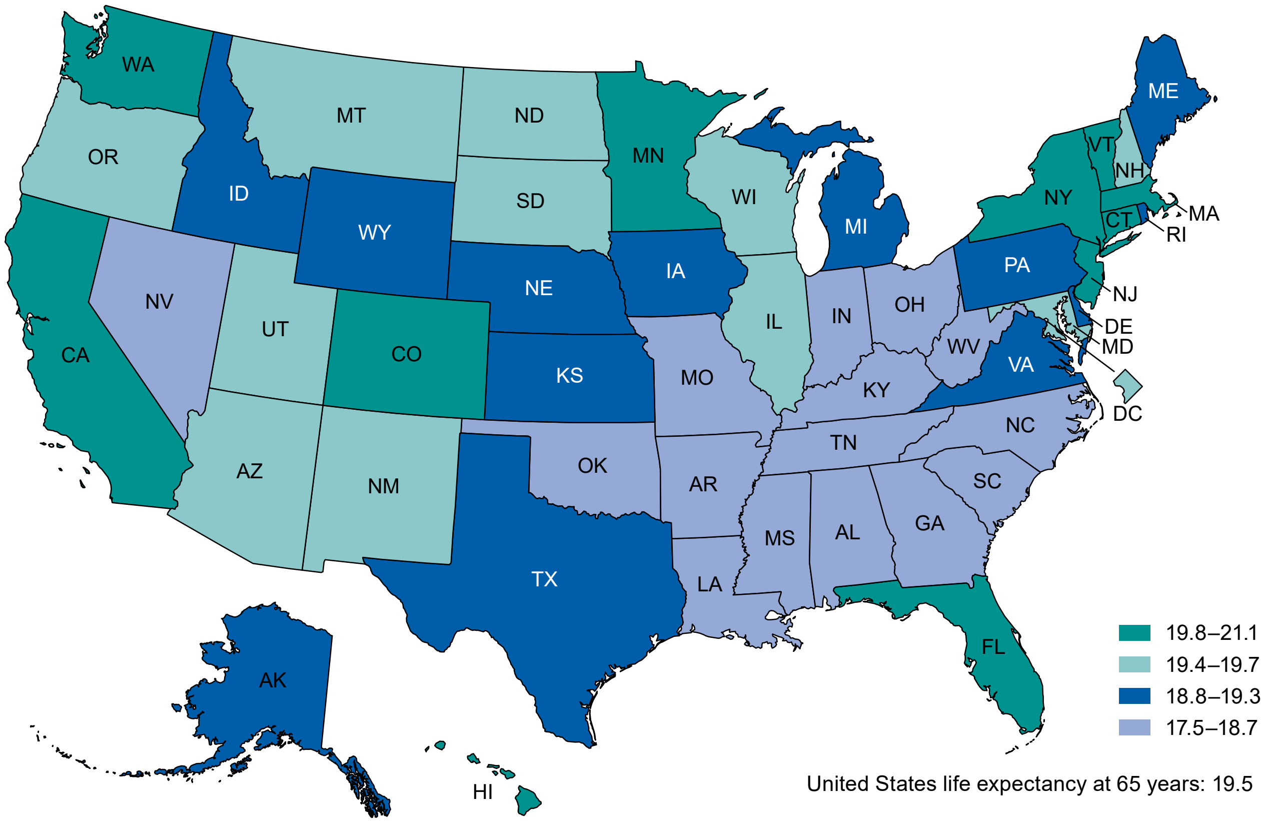
Area	Rank	Total	Standard error	Rank	Male	Standard error	Rank	Female	Standard error
Hawaii	1	21.1	0.065	1	19.3	0.091	1	22.6	0.090
California	2	20.3	0.013	2	19.0	0.019	2	21.6	0.018
Connecticut	3	20.3	0.039	3	18.9	0.056	3	21.4	0.054
New York	4	20.2	0.018	6	18.7	0.025	4	21.3	0.024
Colorado	5	20.0	0.032	4	18.8	0.045	9	21.1	0.043
Minnesota	6	20.0	0.032	5	18.7	0.044	7	21.1	0.044
Florida	7	19.9	0.016	10	18.4	0.023	5	21.2	0.022
Massachusetts	8	19.9	0.028	13	18.4	0.040	8	21.1	0.039
New Jersey	9	19.9	0.026	12	18.4	0.037	10	21.1	0.035
Washington	10	19.8	0.028	8	18.6	0.039	13	20.9	0.038
Vermont	11	19.8	0.083	9	18.6	0.118	12	20.9	0.114
South Dakota	12	19.7	0.079	17	18.3	0.106	6	21.1	0.112
North Dakota	13	19.7	0.091	19	18.2	0.124	11	21.0	0.129
Oregon	14	19.7	0.035	11	18.4	0.050	17	20.8	0.048
Arizona	15	19.6	0.028	15	18.3	0.041	15	20.9	0.038
District of Columbia	16	19.6	0.113	23	18.1	0.167	14	20.9	0.149
Rhode Island	17	19.5	0.073	21	18.1	0.102	18	20.8	0.100
Utah	18	19.5	0.048	7	18.6	0.069	29	20.4	0.066
United States	…	19.5	…	…	18.1	…	…	20.7	…
Montana	19	19.5	0.066	16	18.3	0.093	19	20.8	0.088
New Mexico	20	19.5	0.051	24	18.0	0.073	16	20.8	0.069
New Hampshire	21	19.5	0.058	14	18.3	0.082	26	20.5	0.080
Wisconsin	22	19.5	0.030	20	18.2	0.042	20	20.6	0.042
Maryland	23	19.4	0.031	25	18.0	0.045	22	20.5	0.043
Illinois	24	19.4	0.022	26	18.0	0.031	23	20.5	0.030
Idaho	25	19.3	0.056	22	18.1	0.079	25	20.5	0.077
Iowa	26	19.3	0.042	31	17.8	0.059	21	20.6	0.059
Virginia	27	19.3	0.027	28	17.9	0.038	27	20.5	0.036
Nebraska	28	19.3	0.055	30	17.9	0.077	24	20.5	0.077
Alaska	29	19.2	0.089	18	18.2	0.123	32	20.2	0.127
Delaware	30	19.2	0.071	29	17.9	0.102	28	20.4	0.096
Maine	31	19.1	0.057	32	17.8	0.080	31	20.3	0.078
Pennsylvania	32	19.1	0.020	33	17.7	0.029	30	20.3	0.028
Wyoming	33	19.0	0.092	27	17.9	0.127	34	20.0	0.130
Michigan	34	18.9	0.023	35	17.6	0.032	35	20.0	0.032
Texas	35	18.9	0.016	36	17.5	0.022	33	20.1	0.021
Kansas	36	18.8	0.045	34	17.6	0.063	38	19.9	0.063
Nevada	37	18.7	0.044	37	17.5	0.063	36	20.0	0.060
North Carolina	38	18.7	0.023	38	17.3	0.034	37	20.0	0.032
South Carolina	39	18.6	0.032	39	17.2	0.047	39	19.8	0.043
Missouri	40	18.4	0.030	40	17.1	0.043	41	19.6	0.042
Ohio	41	18.4	0.021	41	17.0	0.030	40	19.6	0.030
Georgia	42	18.4	0.025	43	17.0	0.035	42	19.6	0.033
Indiana	43	18.3	0.029	42	17.0	0.041	43	19.5	0.041
Louisiana	44	17.9	0.036	46	16.5	0.050	44	19.2	0.049
Tennessee	45	17.9	0.029	44	16.6	0.041	47	19.0	0.039
Arkansas	46	17.9	0.044	45	16.5	0.062	45	19.1	0.061
Oklahoma	47	17.6	0.039	48	16.3	0.056	49	18.8	0.054
West Virginia	48	17.6	0.051	47	16.4	0.071	50	18.7	0.071
Alabama	49	17.6	0.034	50	16.1	0.047	48	18.9	0.046
Mississippi	50	17.5	0.045	51	15.9	0.063	46	19.0	0.061
Kentucky	51	17.5	0.035	49	16.2	0.050	51	18.6	0.049

… Category not applicable.

NOTE: Life expectancies shown in this table are rounded, but rankings are based on unrounded life expectancies.

SOURCE: National Center for Health Statistics, National Vital Statistics System, Mortality.

Figure 3. Life expectancy at 65 years: Each state, the District of Columbia, and United States, 2018



SOURCE: National Center for Health Statistics, National Vital Statistics System, Mortality.

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Technical Notes

The methods used to estimate the 2018 complete life tables for the 50 states and the District of Columbia (D.C.) are the same as those used to estimate the U.S. annual life tables, with two modifications (1). First, for states with zero death counts at single ages 1–4, linear interpolation was used to replace those zero death counts. For a few states, linear interpolation was used to replace zero and negative death counts resulting from the application of the Beers' smoothing technique to very small death counts for ages 6–12. Second, a modification was made to the estimation of the age-specific death rates for ages 66–99 years. Because state age-specific census population estimates for ages 85–100 are not available, it was necessary to modify the age range where vital and Medicare death rates are blended and where Medicare data are used exclusively (details of the methodology and modifications are provided below).

Data for calculating life table functions

The data used to prepare the U.S. state life tables (Table I) include state-specific final death counts from the National Vital Statistics System (NVSS), state-specific population estimates from the U.S. Census Bureau, and state-specific death and population counts for Medicare beneficiaries aged 66–99 from the Centers for Medicare & Medicaid Services (CMS).

Vital statistics data

Death counts used for computing the life tables presented in this report are state-specific final numbers of deaths for 2018 collected from death certificates filed in state vital statistics offices and reported to the National Center for Health Statistics (NCHS) as part of NVSS.

Census population data

The population data used to estimate the life tables shown in this report are state-specific postcensal population estimates based on the 2010 decennial census and are available from the U.S. Census website at: https://www2.census.gov/programs-surveys/popest/datasets/2010-2018/state/asrh/sc-est2018-alldata6.csv.

Medicare data

Data from the Medicare program are used to supplement vital statistics and census data for ages 66–99 for the total population and by sex for each state and D.C.

Medicare data are considered to be more accurate than vital statistics and census data at the oldest ages because Medicare enrollees must have proof of age to enroll (7). However, the reliability of Medicare data beyond age 100 declines because of the small percentage of persons who enrolled at the start of the Medicare program in 1965 for whom it was not possible to verify exact age (7).

To estimate death rates for the state-specific Medicare populations in 2018, sex- and age-specific numbers of deaths and population counts for the population aged 66–99 in each state and D.C. from the 2018 Medicare file were used. The data file is created by CMS for the Social Security Administration and shared with NCHS under a special agreement. The 2018 file contains state-specific 2018 mid-year Medicare population counts (June 30, 2018) and calendar year Medicare death counts (January 1 through December 31, 2018). Age for both death and mid-year population counts is calculated as age at last birthday.

Preliminary adjustment of the data

Adjustments for unknown age

An adjustment is made to account for the small proportion of deaths each year for which age is not reported on the death certificate. The number of deaths in each age category is adjusted proportionally to account for those with not-stated age. An adjustment factor (F) is used to distribute deaths with nonstated ages. F is calculated for the total population and by sex for each state and D.C. as:

$$F = \frac{D}{D^a} \quad [1]$$

where D is the total number of deaths and D^a is the total number of deaths for which age is stated. F is then applied by multiplying it by the number of deaths in each age group.

Interpolation of P_x and D_x

Anomalies—both random and those associated with reporting age at death—can be problematic when using vital statistics and census data by single years of age to estimate the probability of death (2,8). Graduation techniques are often used to eliminate these anomalies and to derive a smooth curve by age. Beers' ordinary minimized fifth difference formula is used to obtain smoothed values of population counts (P_x) and death counts (D_x) from 5-year age groupings of ${}_nP_x$ from age 0–99 and ${}_nD_x$ from age 5–99, and where ${}_nD_x$ has first been adjusted for not-reported age on the death certificate (see reference 8 for details on the application of Beers' method). Beers' interpolation is not applied to deaths at ages 0–4.

For states with zero death counts in the age range 1–4 years, it was necessary to replace those counts using linear interpolation; otherwise, zero death counts would have resulted in the discontinuation of the age-specific mortality distribution. In a few other cases, application of Beers' interpolation of deaths in the age range 6–12 years resulted in zero or negative death counts due to very small numbers of deaths, so linear interpolation was also applied. The assumption of linearity is warranted because mortality declines more or less linearly between ages 1 and 10 or so, and the results led to smooth age patterns of mortality (see Table II for a list of states and ages where linear interpolation was used).

Table I. Complete period life tables: 50 states and the District of Columbia, 2018

Available from: https://ftp.cdc.gov/pub/Health_Statistics/NCHS/Publications/NVSR/70-01/

Table title
AK–1. Life table for the total population: Alaska, 2018
AK–2. Life table for males: Alaska, 2018
AK–3. Life table for females: Alaska, 2018
AK–4. Standard errors of the probability of dying and life expectancy: Alaska, 2018
AL–1. Life table for the total population: Alabama, 2018
AL–2. Life table for males: Alabama, 2018
AL–3. Life table for females: Alabama, 2018
AL–4. Standard errors of the probability of dying and life expectancy: Alabama, 2018
AR–1. Life table for the total population: Arkansas, 2018
AR–2. Life table for males: Arkansas, 2018
AR–3. Life table for females: Arkansas, 2018
AR–4. Standard errors of the probability of dying and life expectancy: Arkansas, 2018
AZ–1. Life table for the total population: Arizona, 2018
AZ–2. Life table for males: Arizona, 2018
AZ–3. Life table for females: Arizona, 2018
AZ–4. Standard errors of the probability of dying and life expectancy: Arizona, 2018
CA–1. Life table for the total population: California, 2018
CA–2. Life table for males: California, 2018
CA–3. Life table for females: California, 2018
CA–4. Standard errors of the probability of dying and life expectancy: California, 2018
CO–1. Life table for the total population: Colorado, 2018
CO–2. Life table for males: Colorado, 2018
CO–3. Life table for females: Colorado, 2018
CO–4. Standard errors of the probability of dying and life expectancy: Colorado, 2018
CT–1. Life table for the total population: Connecticut, 2018
CT–2. Life table for males: Connecticut, 2018
CT–3. Life table for females: Connecticut, 2018
CT–4. Standard errors of the probability of dying and life expectancy: Connecticut, 2018
DC–1. Life table for the total population: District of Columbia, 2018
DC–2. Life table for males: District of Columbia, 2018
DC–3. Life table for females: District of Columbia, 2018
DC–4. Standard errors of the probability of dying and life expectancy: District of Columbia, 2018
DE–1. Life table for the total population: Delaware, 2018
DE–2. Life table for males: Delaware, 2018
DE–3. Life table for females: Delaware, 2018
DE–4. Standard errors of the probability of dying and life expectancy: Delaware, 2018
FL–1. Life table for the total population: Florida, 2018
FL–2. Life table for males: Florida, 2018
FL–3. Life table for females: Florida, 2018
FL–4. Standard errors of the probability of dying and life expectancy: Florida, 2018
GA–1. Life table for the total population: Georgia, 2018
GA–2. Life table for males: Georgia, 2018
GA–3. Life table for females: Georgia, 2018
GA–4. Standard errors of the probability of dying and life expectancy: Georgia, 2018
HI–1. Life table for the total population: Hawaii, 2018
HI–2. Life table for males: Hawaii, 2018
HI–3. Life table for females: Hawaii, 2018
HI–4. Standard errors of the probability of dying and life expectancy: Hawaii, 2018
IA–1. Life table for the total population: Iowa, 2018
IA–2. Life table for males: Iowa, 2018
IA–3. Life table for females: Iowa, 2018
IA–4. Standard errors of the probability of dying and life expectancy: Iowa, 2018
ID–1. Life table for the total population: Idaho, 2018
ID–2. Life table for males: Idaho, 2018
ID–3. Life table for females: Idaho, 2018
ID–4. Standard errors of the probability of dying and life expectancy: Idaho, 2018
IL–1. Life table for the total population: Illinois, 2018
IL–2. Life table for males: Illinois, 2018
IL–3. Life table for females: Illinois, 2018
IL–4. Standard errors of the probability of dying and life expectancy: Illinois, 2018
IN–1. Life table for the total population: Indiana, 2018
IN–2. Life table for males: Indiana, 2018
IN–3. Life table for females: Indiana, 2018
IN–4. Standard errors of the probability of dying and life expectancy: Indiana, 2018
KS–1. Life table for the total population: Kansas, 2018
KS–2. Life table for males: Kansas, 2018
KS–3. Life table for females: Kansas, 2018
KS–4. Standard errors of the probability of dying and life expectancy: Kansas, 2018

Table I. Complete period life tables: 50 states and the District of Columbia, 2018—Con.

Available from: https://ftp.cdc.gov/pub/Health_Statistics/NCHS/Publications/NVSR/70-01/

Table title
KY–1. Life table for the total population: Kentucky, 2018
KY–2. Life table for males: Kentucky, 2018
KY–3. Life table for females: Kentucky, 2018
KY–4. Standard errors of the probability of dying and life expectancy: Kentucky, 2018
LA–1. Life table for the total population: Louisiana, 2018
LA–2. Life table for males: Louisiana, 2018
LA–3. Life table for females: Louisiana, 2018
LA–4. Standard errors of the probability of dying and life expectancy: Louisiana, 2018
MA–1. Life table for the total population: Massachusetts, 2018
MA–2. Life table for males: Massachusetts, 2018
MA–3. Life table for females: Massachusetts, 2018
MA–4. Standard errors of the probability of dying and life expectancy: Massachusetts, 2018
MD–1. Life table for the total population: Maryland, 2018
MD–2. Life table for males: Maryland, 2018
MD–3. Life table for females: Maryland, 2018
MD–4. Standard errors of the probability of dying and life expectancy: Maryland, 2018
ME–1. Life table for the total population: Maine, 2018
ME–2. Life table for males: Maine, 2018
ME–3. Life table for females: Maine, 2018
ME–4. Standard errors of the probability of dying and life expectancy: Maine, 2018
MI–1. Life table for the total population: Michigan, 2018
MI–2. Life table for males: Michigan, 2018
MI–3. Life table for females: Michigan, 2018
MI–4. Standard errors of the probability of dying and life expectancy: Michigan, 2018
MN–1. Life table for the total population: Minnesota, 2018
MN–2. Life table for males: Minnesota, 2018
MN–3. Life table for females: Minnesota, 2018
MN–4. Standard errors of the probability of dying and life expectancy: Minnesota, 2018
MO–1. Life table for the total population: Missouri, 2018
MO–2. Life table for males: Missouri, 2018
MO–3. Life table for females: Missouri, 2018
MO–4. Standard errors of the probability of dying and life expectancy: Missouri, 2018
MS–1. Life table for the total population: Mississippi, 2018
MS–2. Life table for males: Mississippi, 2018
MS–3. Life table for females: Mississippi, 2018
MS–4. Standard errors of the probability of dying and life expectancy: Mississippi, 2018
MT–1. Life table for the total population: Montana, 2018
MT–2. Life table for males: Montana, 2018
MT–3. Life table for females: Montana, 2018
MT–4. Standard errors of the probability of dying and life expectancy: Montana, 2018
NC–1. Life table for the total population: North Carolina, 2018
NC–2. Life table for males: North Carolina, 2018
NC–3. Life table for females: North Carolina, 2018
NC–4. Standard errors of the probability of dying and life expectancy: North Carolina, 2018
ND–1. Life table for the total population: North Dakota, 2018
ND–2. Life table for males: North Dakota, 2018
ND–3. Life table for females: North Dakota, 2018
ND–4. Standard errors of the probability of dying and life expectancy: North Dakota, 2018
NE–1. Life table for the total population: Nebraska, 2018
NE–2. Life table for males: Nebraska, 2018
NE–3. Life table for females: Nebraska, 2018
NE–4. Standard errors of the probability of dying and life expectancy: Nebraska, 2018
NH–1. Life table for the total population: New Hampshire, 2018
NH–2. Life table for males: New Hampshire, 2018
NH–3. Life table for females: New Hampshire, 2018
NH–4. Standard errors of the probability of dying and life expectancy: New Hampshire, 2018
NJ–1. Life table for the total population: New Jersey, 2018
NJ–2. Life table for males: New Jersey, 2018
NJ–3. Life table for females: New Jersey, 2018
NJ–4. Standard errors of the probability of dying and life expectancy: New Jersey, 2018
NM–1. Life table for the total population: New Mexico, 2018
NM–2. Life table for males: New Mexico, 2018
NM–3. Life table for females: New Mexico, 2018
NM–4. Standard errors of the probability of dying and life expectancy: New Mexico, 2018
NV–1. Life table for the total population: Nevada, 2018
NV–2. Life table for males: Nevada, 2018
NV–3. Life table for females: Nevada, 2018
NV–4. Standard errors of the probability of dying and life expectancy: Nevada, 2018

Table I. Complete period life tables: 50 states and the District of Columbia, 2018—Con.

Available from: https://ftp.cdc.gov/pub/Health_Statistics/NCHS/Publications/NVSR/70-01/

Table title
NY–1. Life table for the total population: New York, 2018
NY–2. Life table for males: New York, 2018
NY–3. Life table for females: New York, 2018
NY–4. Standard errors of the probability of dying and life expectancy: New York, 2018
OH–1. Life table for the total population: Ohio, 2018
OH–2. Life table for males: Ohio, 2018
OH–3. Life table for females: Ohio, 2018
OH–4. Standard errors of the probability of dying and life expectancy: Ohio, 2018
OK–1. Life table for the total population: Oklahoma, 2018
OK–2. Life table for males: Oklahoma, 2018
OK–3. Life table for females: Oklahoma, 2018
OK–4. Standard errors of the probability of dying and life expectancy: Oklahoma, 2018
OR–1. Life table for the total population: Oregon, 2018
OR–2. Life table for males: Oregon, 2018
OR–3. Life table for females: Oregon, 2018
OR–4. Standard errors of the probability of dying and life expectancy: Oregon, 2018
PA–1. Life table for the total population: Pennsylvania, 2018
PA–2. Life table for males: Pennsylvania, 2018
PA–3. Life table for females: Pennsylvania, 2018
PA–4. Standard errors of the probability of dying and life expectancy: Pennsylvania, 2018
RI–1. Life table for the total population: Rhode Island, 2018
RI–2. Life table for males: Rhode Island, 2018
RI–3. Life table for females: Rhode Island, 2018
RI–4. Standard errors of the probability of dying and life expectancy: Rhode Island, 2018
SC–1. Life table for the total population: South Carolina, 2018
SC–2. Life table for males: South Carolina, 2018
SC–3. Life table for females: South Carolina, 2018
SC–4. Standard errors of the probability of dying and life expectancy: South Carolina, 2018
SD–1. Life table for the total population: South Dakota, 2018
SD–2. Life table for males: South Dakota, 2018
SD–3. Life table for females: South Dakota, 2018
SD–4. Standard errors of the probability of dying and life expectancy: South Dakota, 2018
TN–1. Life table for the total population: Tennessee, 2018
TN–2. Life table for males: Tennessee, 2018
TN–3. Life table for females: Tennessee, 2018
TN–4. Standard errors of the probability of dying and life expectancy: Tennessee, 2018
TX–1. Life table for the total population: Texas, 2018
TX–2. Life table for males: Texas, 2018
TX–3. Life table for females: Texas, 2018
TX–4. Standard errors of the probability of dying and life expectancy: Texas, 2018
UT–1. Life table for the total population: Utah, 2018
UT–2. Life table for males: Utah, 2018
UT–3. Life table for females: Utah, 2018
UT–4. Standard errors of the probability of dying and life expectancy: Utah, 2018
VA–1. Life table for the total population: Virginia, 2018
VA–2. Life table for males: Virginia, 2018
VA–3. Life table for females: Virginia, 2018
VA–4. Standard errors of the probability of dying and life expectancy: Virginia, 2018
VT–1. Life table for the total population: Vermont, 2018
VT–2. Life table for males: Vermont, 2018
VT–3. Life table for females: Vermont, 2018
VT–4. Standard errors of the probability of dying and life expectancy: Vermont, 2018
WA–1. Life table for the total population: Washington, 2018
WA–2. Life table for males: Washington, 2018
WA–3. Life table for females: Washington, 2018
WA–4. Standard errors of the probability of dying and life expectancy: Washington, 2018
WI–1. Life table for the total population: Wisconsin, 2018
WI–2. Life table for males: Wisconsin, 2018
WI–3. Life table for females: Wisconsin, 2018
WI–4. Standard errors of the probability of dying and life expectancy: Wisconsin, 2018
WV–1. Life table for the total population: West Virginia, 2018
WV–2. Life table for males: West Virginia, 2018
WV–3. Life table for females: West Virginia, 2018
WV–4. Standard errors of the probability of dying and life expectancy: West Virginia, 2018
WY–1. Life table for the total population: Wyoming, 2018
WY–2. Life table for males: Wyoming, 2018
WY–3. Life table for females: Wyoming, 2018
WY–4. Standard errors of the probability of dying and life expectancy: Wyoming, 2018

Table II. Application of linear interpolation for selected areas, by sex and age

Area	Male	Female
	Age (years)	
Alaska	4	2,3
Delaware	4	2,3
District of Columbia	4, 9–12	2–4
Hawaii	…	4
Idaho	2	…
Indiana	11	…
Iowa	3	3
Maine	2–4	2,4
Montana	4	1
Nebraska	…	3
New Hampshire	2	3, 6–8
New Mexico	…	3
North Dakota	1–4	2
Oregon	3	…
Rhode Island	…	4
South Dakota	…	3
Utah	4	…
Vermont	2–4	1,3,4, 7–12
West Virginia	4	…
Wyoming	3,4	2,4

… Category not applicable.

SOURCE: National Center for Health Statistics, National Vital Statistics System, Mortality.

Calculation of the probability of dying (q_x)

The first step in the calculation of a complete period life table is the estimation of the age-specific probability of dying, q_x, which is derived from the age-specific death rate, m_x (3,4). In the life table cohort,

$$m_x = \frac{d_x}{L_x}$$

where d_x is the number of deaths occurring between ages x and $x+1$, and L_x is the number of person-years lived by the life table cohort between ages x and $x+1$. The conversion of the age-specific death rate, m_x, to the age-specific probability of death, q_x, is as follows:

$$q_x = \frac{m_x}{1 + (1 - a_x)\, m_x} \qquad [2]$$

where a_x is the number of person-years lived in the age interval by members of the life table cohort who died in the interval. When the age interval is 1 year, except at infancy, $a_x = 1/2$; in other words, deaths occur on average midway through the age interval. As a result,

$$q_x = \frac{m_x}{1 + \frac{1}{2} m_x} \qquad [3]$$

Because the complete period life table is based on the age-specific death rates of a current population observed for a specific calendar year, the life table death rate is equivalent to the observed death rate of the current population:

$$m_x = \frac{d_x}{L_x} = M_x = \frac{D_x}{P_x}$$

where D_x is the Beers' smoothed (or linearly interpolated) number of deaths adjusted for not-stated age and P_x is the Beers' smoothed population at risk of dying between ages x and $x+1$. Then,

$$q_x = \frac{M_x}{1 + \frac{1}{2} M_x} = \frac{D_x}{P_x + \frac{1}{2} D_x} \qquad [4]$$

This procedure is used to estimate vital statistics age-specific probabilities of death for ages 1–84.

Calculation of q_x at age 0

The higher mortality observed in infancy is associated with a high concentration of deaths occurring at the beginning of the age interval rather than in the middle. As a result, whenever possible, it is best to assign deaths to the appropriate birth cohorts. Therefore, the probability of death at birth, q_0, is calculated using a birth cohort method that employs a separation factor (f) defined as the proportion of infant deaths in year t occurring to infants born in the previous year ($t-1$). The value f is estimated by categorizing infant deaths by date of birth. The probability of death is then calculated as:

$$q_0 = \frac{D_0\,(1 - f)}{B^t} + \frac{D_0\,(f)}{B^{t-1}} \qquad [5]$$

where D_0 is the number of infant deaths adjusted for not-stated age in 2018, B^t is the number of live births in 2018, and B^{t-1} is the number of live births in 2017.

Probabilities of dying at the oldest ages

Medicare data are used to supplement vital statistics data for the estimation of q_x at the oldest ages because these data are more accurate given that proof of age is required for enrollment in the Medicare program. Medicare data are used here to estimate the probability of dying for ages 66–99 years.

The method described in this section consists of the following steps. First, vital statistics and Medicare death rates are blended in the age range 66–99. Second, a logistic model is used to smooth the blended death rates in the age range 85–99 and predict death rates for ages 100–120. Third, final resulting death rates, M_x, are converted to probabilities of dying, q_x.

For the national life tables, vital statistics, M_x^V, and Medicare, M_x^M, death rates are blended in the age range 66–94 years with a weighting process that gives gradually declining weight to vital statistics data and gradually increasing weight to Medicare data. And, for ages 95–99, M_x^M is used exclusively. Due to the unavailability of census state-level population estimates for ages 85–100, it was not possible to calculate M_x^V for this age span. As a result, the blending technique was modified such that M_x^V and M_x^M are blended in the age range 66–84 and M_x^M is used exclusively in the age range 85–99. Blended M_x is thus obtained as follows:

$$M_x = \frac{1}{20}[(85-x)M_x^V + (x-65)M_x^M] \qquad [6]$$

when $x = 66,...,84$

and $M_x = M_x^M$

when $x = 85,...,99$.

M_x^M is estimated as follows:

$$M_x^M = \frac{D_x^M}{P_x^M}$$

where D_x^M is the age-specific Medicare death count, and P_x^M is the age-specific Medicare mid-year population count.

The exclusive use of Medicare death rates beginning at age 85 for the state life tables is expected to have a negligible biasing effect on mortality at older ages in the life tables compared with the national life tables. As Figures I–III show, while there are large differences between Medicare and vital statistics death rates at ages 85 and over for the U.S. population, blended Medicare and vital statistics death rates are very similar to Medicare death rates for ages 85 and over.

A logistic model proposed by Kannisto is then used to smooth M_x in the age range 85–99 and predict M_x in the age range 100–120 (9). The start of the modeled age range varies by sex because it is a function of the age at which the rate of change in the age-specific death rates peaks. In current times, the rate of change in the age-specific death rate rises steadily up to approximately ages 80–85 or so and then begins to decline. As a result, it is difficult to model a large age span, such as 65–100, with one simple model without over smoothing and thus altering the underlying mortality pattern observed in the population of interest (10). Further, the observed data for the age range 65–85 or so is reliable and robust, as indicated by the very close similarity between vital statistics and Medicare death rates, so it is unnecessary to model (smooth) the entire age span (65–100).

The Kannisto model is a simple form of a logistic model in which the logit of u_x (or the natural log of the odds of u_x) is a linear function of age x (9). It is expressed as:

$$\ln\left[\frac{u_x}{1-u_x}\right] = \ln(\alpha) + \beta x \qquad [7]$$

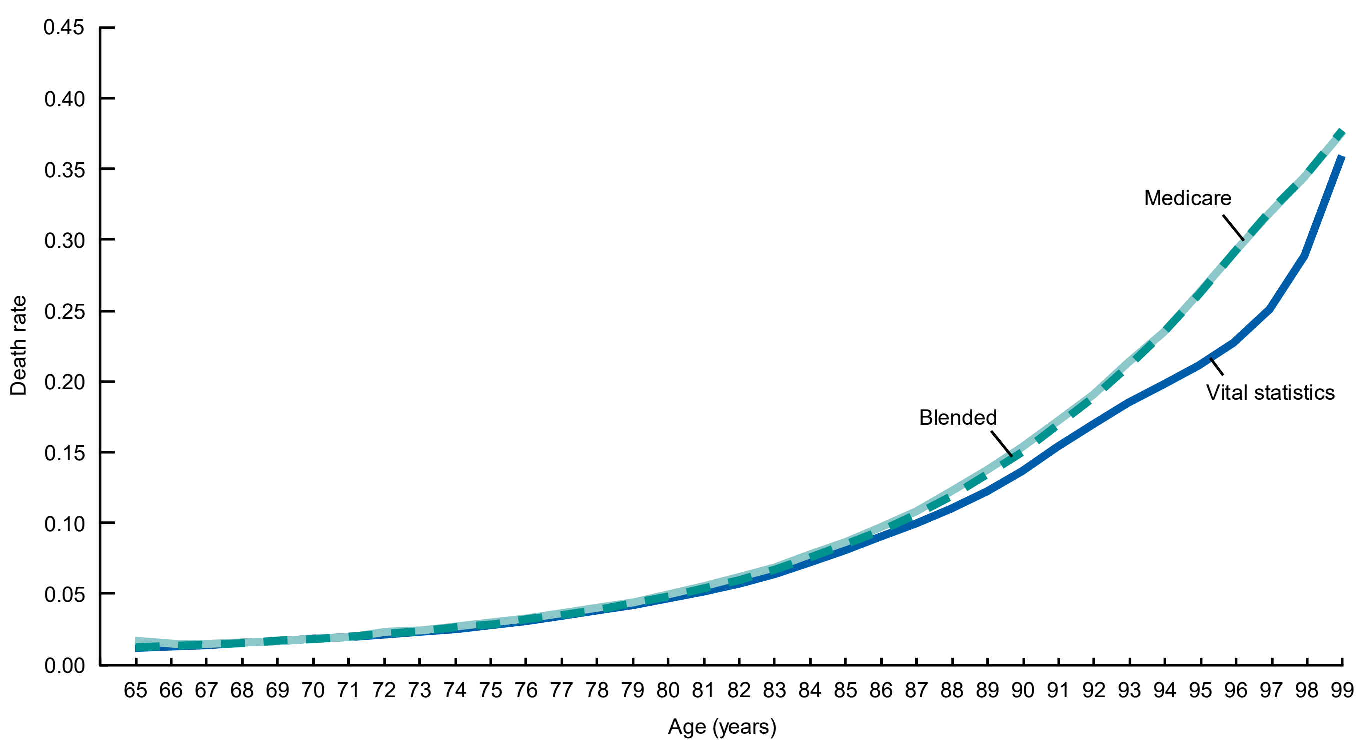
where u_x, the force of mortality (or the instantaneous death rate), is defined as:

$$u_x = \frac{\alpha e^{\beta x}}{1+\alpha e^{\beta x}}$$

Because u_x is not directly observed but is closely approximated by m_x, and $m_x = M_x$, then the logit of M_x is modeled instead. A maximum-likelihood generalized linear model estimation procedure is used to fit the following model in the age range 85–99 years:

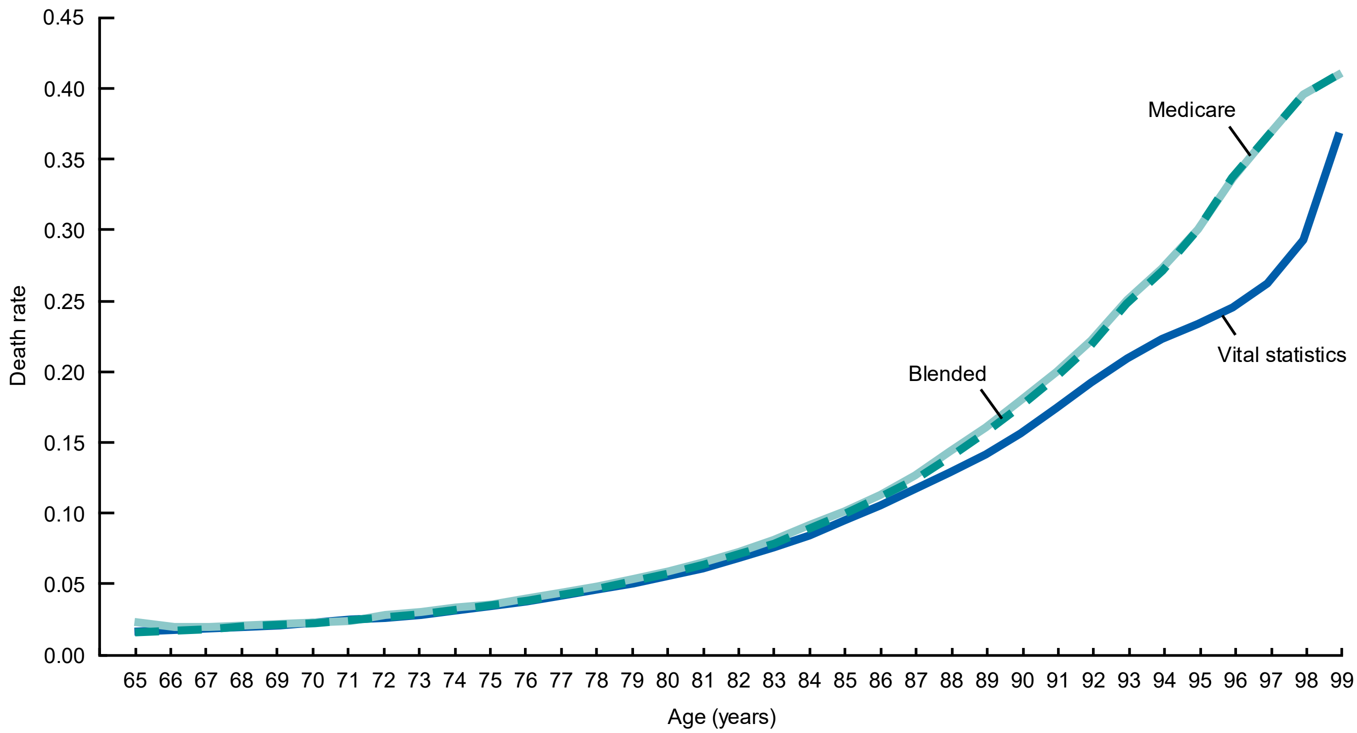
$$\ln\left[\frac{M_x}{1-M_x}\right] = \ln(\alpha) + \beta x \qquad [8]$$

Figure I. Age-specific vital statistics, Medicare, and blended death rates for the total population: United States, 2018



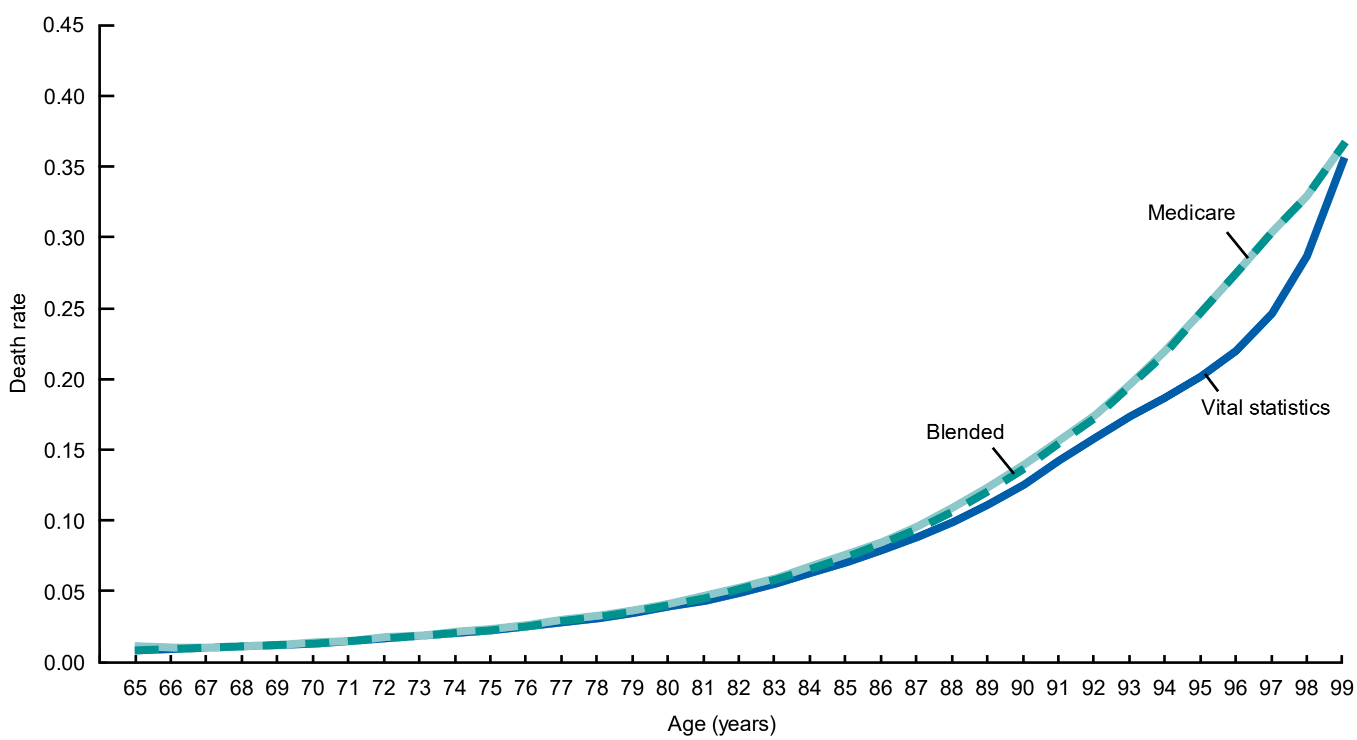
SOURCE: National Center for Health Statistics, National Vital Statistics System, Mortality.

Figure II. Age-specific vital statistics, Medicare, and blended death rates for the male population: United States, 2018



SOURCE: National Center for Health Statistics, National Vital Statistics System, Mortality.

Figure III. Age-specific vital statistics, Medicare, and blended death rates for the female population: United States, 2018



SOURCE: National Center for Health Statistics, National Vital Statistics System, Mortality.

Then, the estimated parameters are used to predict $\bar{M}_x$ as follows:

$$\bar{M}_x = \frac{e^a e^{bx}}{1 + e^a e^{bx}}, \text{ or equivalently, } \bar{M}_x = \frac{e^{a+bx}}{1 + e^{a+bx}} \quad [9]$$

where a and b are the predicted values of parameters $\ln(\alpha)$ and β, respectively, given by fitting model [8].

Finally, the predicted probability of death, q_x, for ages 85–120 is estimated by converting $\bar{M}_x$ as follows:

$$\bar{q}_x = \frac{\bar{M}_x}{1 + \frac{1}{2}\bar{M}_x} \quad [10]$$

The probability of death is extrapolated to age 120 to estimate the life table population until no survivors remain. This information is then used to estimate L_x for ages 100–120, which is used to close the table with the age category 100 and over, combined (discussed below).

Figures IV–VI show the age-specific probability of dying, q_x, estimates for each of 50 states and D.C. compared with the values for the United States in 2018. The observed probabilities for the states and D.C. are shown as green diamonds, which appear as vertical bars where they overlap, and the U.S. probabilities are shown as an intersecting connected black line. The state estimates fall about the U.S. values as expected, with a few outliers in the youngest childhood ages. These few cases are predominantly the result of a very small number of deaths, consistent with very low mortality in this age range combined with very small populations in states such as Vermont, Wyoming, and North Dakota. Overall, the age-specific estimates for the 50 states and D.C. follow the expected age pattern of mortality and are consistent with the mortality pattern observed for the entire United States.

Calculation of remaining life table functions for all groups

Survivor function (l_x)

The life table radix, l_0, is set at 100,000. For ages greater than 0, the number of survivors remaining at exact age x is calculated as:

$$l_x = l_{x-1}(1 - q_{x-1}) \quad [11]$$

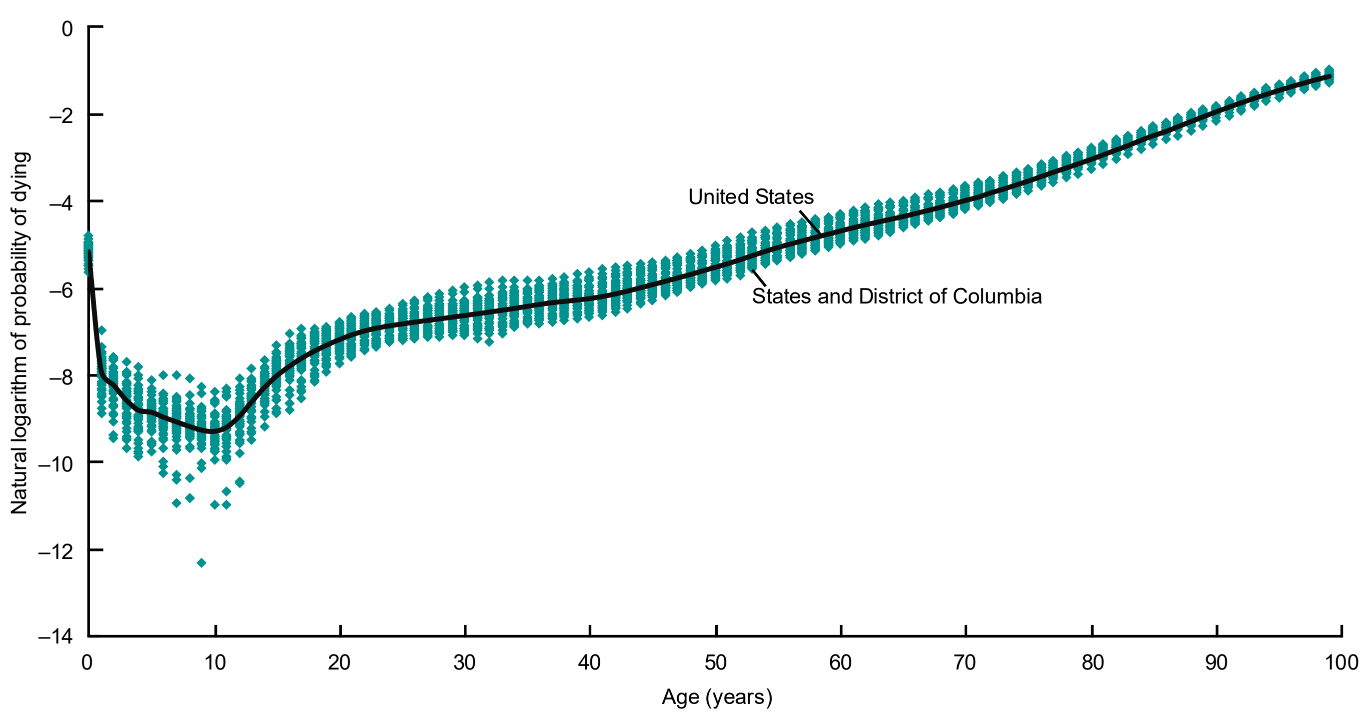
Decrement function (d_x)

The number of deaths occurring between ages x and $x + 1$ is calculated from the survivor function:

$$d_x = l_x - l_{x+1} = l_x q_x \quad [12]$$

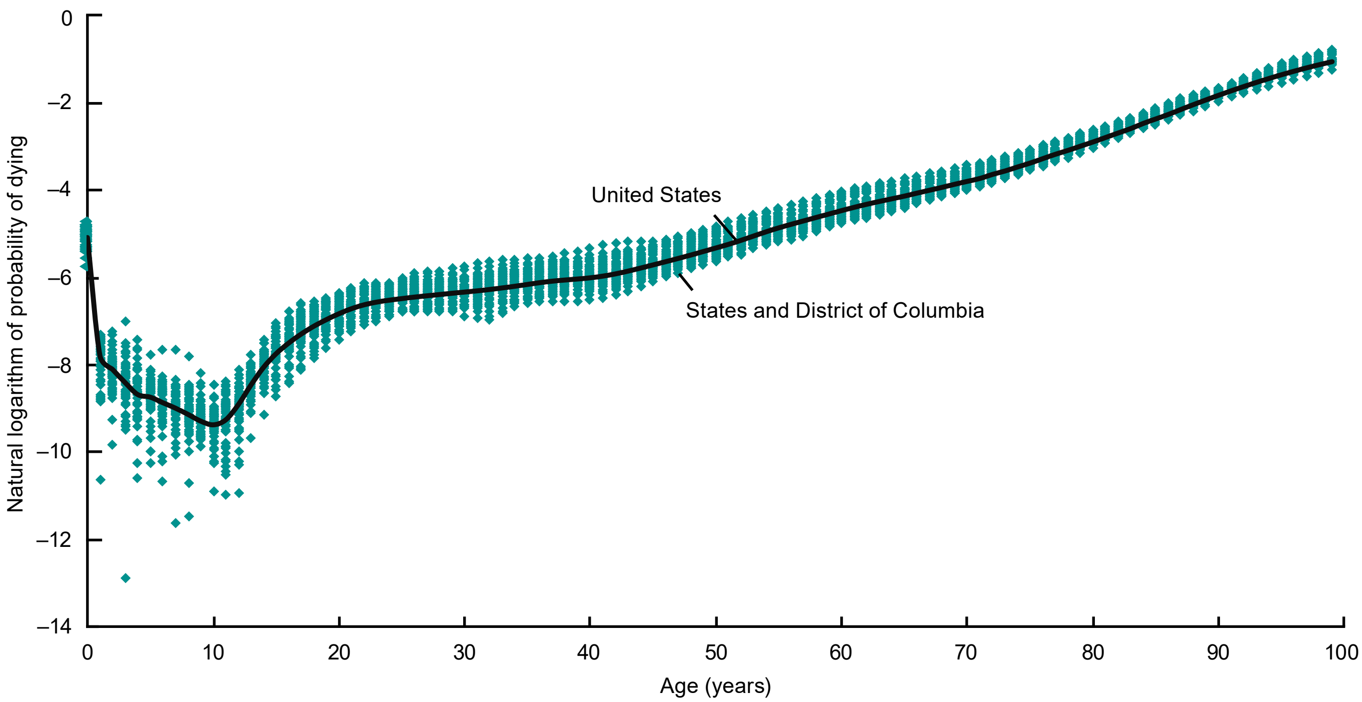
Note that ${}_{\infty}d_{100} = {}_{\infty}l_{100}$ *because* ${}_{\infty}q_{100} = 1.0$

Figure IV. Probability of dying for the total population, by age: Each state, the District of Columbia, and United States, 2018



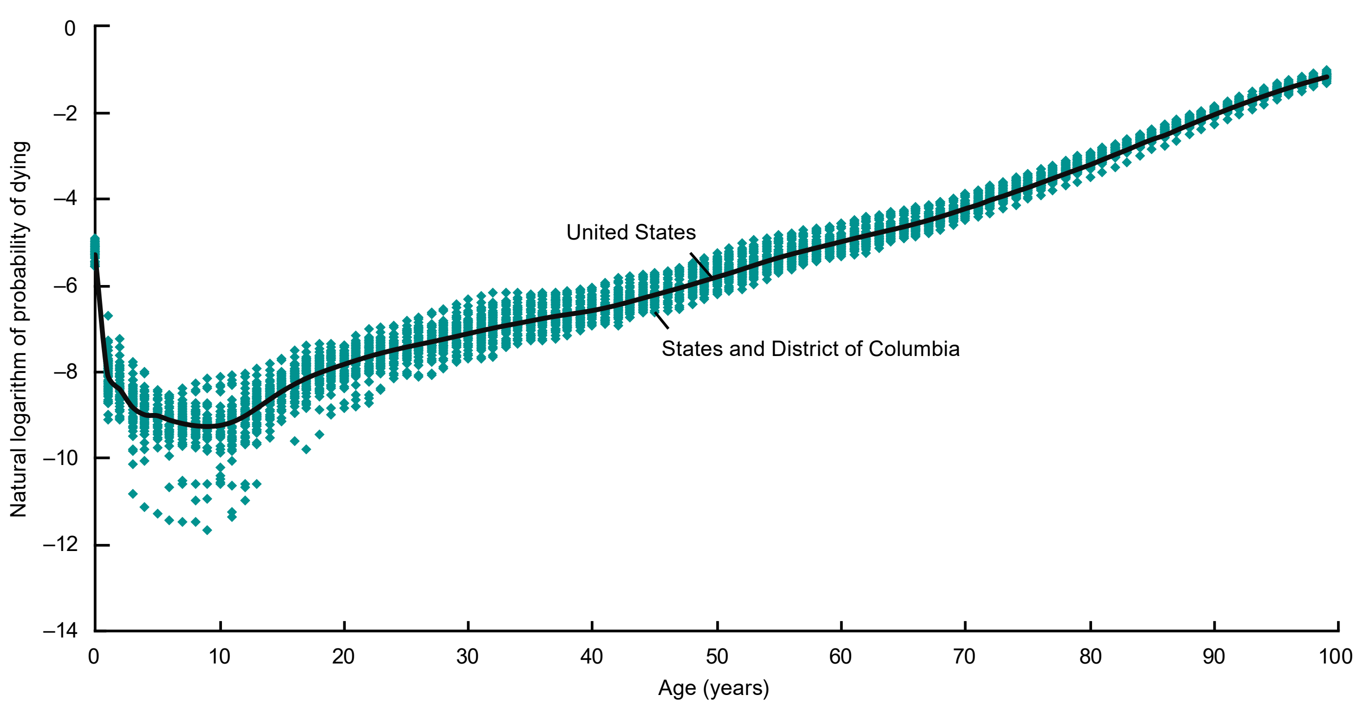
SOURCE: National Center for Health Statistics, National Vital Statistics System, Mortality.

Figure V. Probability of dying for males, by age: Each state, the District of Columbia, and United States, 2018



SOURCE: National Center for Health Statistics, National Vital Statistics System, Mortality.

Figure VI. Probability of dying for females, by age: Each state, the District of Columbia, and United States, 2018



SOURCE: National Center for Health Statistics, National Vital Statistics System, Mortality.

Person-years lived (L_x)

Person-years lived for ages 1–99 are calculated assuming that the survivor function declines linearly between ages x and $x + 1$. This gives the formula:

$$L_x = \frac{1}{2}(l_x + l_{x+1}) = l_x - \frac{1}{2} d_x \quad [13]$$

For $x = 0$, the separation factor f is used to calculate L_0:

$$L_0 = fl_0 + (1 - f)l_1 \quad [14]$$

Finally, ${}_{\infty}L_{100}$ is estimated as the sum of the extrapolated L_x values for ages 100–120.

Person-years lived at and above age x (T_x)

T_x is calculated by summing L_x values at and above age x:

$$T_x = \sum_{x=0}^{\infty} L_x \quad [15]$$

Life expectancy at age x (e_x)

Life expectancy at exact age x is calculated as:

$$e_x = \frac{T_x}{l_x} \quad [16]$$

Variances and standard errors of the probability of dying and life expectancy

The mortality data on which the life tables are based are not affected by sampling error because the data are based on complete counts of deaths, and, as a result, variances and standard errors reflect only random variation. While measurement errors such as age misreporting are known to affect mortality estimates, they are not considered in the calculation of the variances or standard errors of the life table functions.

The methods used to estimate the variances of q_x and e_x are based on Chiang (11) with some necessary modifications due to the use of statistical modeling for smoothing and prediction of old age death rates. Based on the assumption that deaths are binomially distributed, Chiang proposed the following equation for the variance of q_x:

$$Var(q_x) = \frac{q_x^2(1-q_x)}{D_x} \quad [17]$$

where D_x is the age-specific number of deaths. This equation is used to estimate $Var(q_x)$ throughout the age span with a modification where for ages less than 66 years, D_x is the deaths from vital statistics data, smoothed by interpolation and adjusted for the number of deaths with age not stated. For ages 66 and over, D_x was obtained by treating the population as a cohort population and calculated from q_x because blended vital statistics and Medicare data were used for estimation (12):

$$P_x = \frac{(P_{x-1} - 0.5D_{x-1})(2 - q_x)}{2}$$

$$D_x = \frac{q_x P_x}{1 - 0.5q_x}$$

Standard error of q_x

$$SE(q_x) = \sqrt{Var(q_x)} \quad [18]$$

Variances of the life expectancies for ages 0–99 years are estimated using Chiang's equation:

$$Var(e_x) = \frac{\sum_{x=0}^{x=99} l_x^2 \bullet [(1-.5)+e_{x+n}]^2 \bullet Var(q_x)}{l_x^2} \quad [19]$$

Chiang assumed that because $q_{100+} = 1.00$, then $Var(q_{100+}) = 0$, and therefore $Var(e_{100+}) = 0$. Silcocks et al. proposed that in the final age group life expectancy is dependent on the mean length of survival and not on the probability of survival, and, therefore, the assumption of no variance is incorrect, and $Var(e_{100+})$ can be approximated as follows (13):

$$Var(e_{100+}) \approx \frac{l_{100+}^2}{M_{100+}^4} \bullet Var(M_{100+}) \quad [20]$$

Standard error of e_x

$$SE(e_x) = \sqrt{Var(e_x)} \quad [21]$$

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Contents

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