Technical Notes

The life table program—Three series of complete life tables are prepared by the National Center for Health Statistics (NCHS) for the U.S. population—decennial, annual preliminary, and annual final. The U.S. decennial life tables are based on decennial census data and deaths for a 3-year period around the census year. Preliminary life tables are based on a substantial sample (approximately 90 percent) of death records. Estimates of life expectancy from the preliminary series are published annually. The annual final life tables (referred to in this section as "annual life tables") are based on a complete count of all reported deaths.

Available since 1945, the annual life tables are based on deaths occurring during the calendar year and on midyear postcensal population estimates provided by the U.S. Census Bureau. From 1945 to 1996, the annual life tables were abridged life tables and were constructed by reference to a standard table (4). Beginning with 1997 mortality data, complete life tables are constructed using a new methodology (5,6). Also for 1997, life expectancy and other life table values were shown for ages 85 to 100 years for the first time as part of the annual U.S. life tables. Previously, the annual life tables were closed at age 85. Extension of the oldest age interval was implemented by NCHS for several reasons: survival in the United States is such that approximately one-third of the population survives beyond age 85; improvements have occurred in age reporting at older ages; and high-quality old-age mortality data are available from the Medicare program.

Geographic coverage—The geographic areas covered in life tables before 1929–31 were limited to the death-registration areas. Life tables for 1900–1902 and 1909–11 were constructed using mortality data from the 1900 death-registration States (10 States and the District of Columbia) and for 1919–21 from the 1920 death-registration States (34 States and the District of Columbia). The tables for 1929–31 through 1958 cover the coterminous United States. Decennial life table values for the 3-year period 1959–61 were derived from data that include both Alaska and Hawaii for each year (tables 10 and 11). Data for each year shown in table 12 include Alaska beginning in 1959 and Hawaii beginning in 1960. However, it is not believed that the inclusion of these two States materially affects life table values.

Revised life table values, 1961–89—Life table values for 1960–69, 1970–79, and 1980–89 were constructed using the U.S. decennial life tables for 1959–61, 1969–71, and 1979–81, respectively, as the standard tables. The life table values for years prior to 1989 appearing in this publication are based on revised intercensal estimates of the populations for those years. As a result, the life table values for these years may differ from the life table values for those years published in *Vital Statistics of the United States* for 1989 and earlier years. Life table values for 1991 and later are based on postcensal population estimates and will be recalculated when intercensal estimates become available.

New Jersey data, 1962–64—The life tables for 1962 and 1963 for the six population groups involving race do not include data from New Jersey, which omitted the item on race from its certificates of live birth, death, and fetal death in use at the beginning of 1962. The item was restored during the latter part of 1962. However, the certificate revision without this item was used for most of 1962 as well as for 1963. For computing vital rates, populations by age, race, and sex (excluding New Jersey) were estimated to obtain comparable denominators. Approximately 7 percent of the New Jersey death records for 1964 did not contain the race designation. When the records were being electronically processed for this State, the "race not stated" deaths were proportionally allocated to white or to black.

Nonresidents—Beginning in 1970, the deaths of nonresidents of the United States have been excluded from the life table statistics.

Estimation of life table functions—For some years, it was necessary to estimate life table functions for some race-sex groups. In tables 10 and 11, figures for the black population during the periods 1949–51 and 1959–61 were estimated using figures for the nonwhite population. Life table functions were also missing in tables 10 and 11 for race-sex groups for the periods from 1900–1902 to 1939–41. Figures were missing for the following groups:

Years	*Race and sex*
1900–1902	Total white, total black
1909–11	Total white, total black
1919–21	Total, male, female, total white, total black
1929–31	Total, male, female, total white, total black

These figures were estimated by weighted averages using population distributions as the weights. For example, life expectancy at age 20 years for the total black population was estimated by a weighted average of black male and black female life expectancies at age 20, using as weights the population distribution by sex of the black population age 20 years.

Annual life tables were initiated in 1945 for white males, white females, all other males, and all other females. The figures in table 12 by race and sex for the following years were estimated using a procedure other than the abridged life table methodology (12).

Years	*Race and sex*
1900–45	Total
1900–47	Male
1900–47	Female
1900–50	White
1900–44	White male
1900–44	White female

Annual life table functions were not calculated for the black population prior to 1970. In table 12, life expectancy for the black population for years prior to 1970 is estimated using figures for the total nonwhite population.

Population bases for computing life tables—The population used for computing life table values shown in this section (furnished by the U.S. Census Bureau) represents the resident population of the United States. The age-specific populations used for computing the 2000 life table values are based on the July 1, 2000, population estimates that are consistent with the 1990 census (13). The 1990 census counts by race and age were modified. Race was modified to be consistent with the Office of Management and Budget categories and historical categories for mortality data. The modification procedures for race and age are described in a census report (14).

Detailed populations from the 2000 census were not available when this report was prepared. A comparison of summary 2000 census results and the estimates for 2000 used in this report indicates differences for some population groups. Differences between the 2000 enumerated population and the population estimates for 2000 used in this report could result in the underestimation or overestimation of life expectancy. When the necessary population estimates based on the

2000 census become available, life expectancy and other life table estimates will be recalculated and presented in an upcoming report. Meanwhile, considerable caution should be used in interpreting the statistics presented in this report.

Medicare data—Death rates at the oldest ages based on Medicare data are known to be more accurate than those based on vital statistics and census data. Consequently, q_x values calculated for ages 85 to 99 years are based on Medicare data prepared by the Health Care Financing Administration (HCFA). Medicare data were limited to the group insured for hospital insurance as age reporting is considered best among this group (6,10,11). For the 2000 life tables, 1997 Medicare data were used as 2000 data were not available in time for the preparation of this report.

Methodology

A more detailed treatment of the methodology used to calculate these life tables is contained in a separate report (5). Calculation of the complete life table is derived from the probability of death (q_x), which depends on the number of deaths (D_x) and the midyear population (P_x) for each single year of age (x) observed during the calendar year of interest.

Adjustment for deaths for which age was not reported—An adjustment must be made to account for the small proportion of deaths each year for which age is not reported. The data are aggregated into 5-year age groups for those age 5 years and over and into single years of age for those under 5 years. The number of deaths in each age category is adjusted proportionally to account for those with not-stated ages. The following factor is used to make the adjustment. This factor (F) is calculated for each race-sex group for which life tables are constructed.

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

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 times the number of deaths in each age group. Table I shows values for F by race and sex used to adjust the 2000 mortality data.

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 (1). Graduation techniques are often used to eliminate these anomalies and to derive a smooth curve by age. Beer's ordinary minimized fifth difference formula is used to obtain smoothed values of P_x and D_x (see reference 5 for details on the application of Beer's method).

Calculation of q_0—q_0 is calculated by using a birth cohort method employing a separation factor (f) defined as the proportion of infant deaths in year t occurring to infants born in the previous year (t–1). f can be calculated by categorizing infant deaths by date of birth. The probability of death in the first year is calculated as

$$q_0 = \frac{D_0\,(1-f)}{B^t} + \frac{D_0\, f}{B^{t-1}} \qquad [2]$$

where D_0 is the number of infant deaths adjusted for not-reported age, and B^t and B^{t-1} are the numbers of births in years t and t–1, respectively. Table II shows separation factors and numbers of births by race and sex for 1999–2000.

Calculation of q_x for ages 1–84—q_x is calculated assuming that l_x (number of survivors at exact age x in the life table population) declines linearly between x and x+1, i.e., that deaths between exact age x and x+1 occur on average at age x+½. This simplification is generally considered acceptable when age intervals are 1 year of age in length (1). Under this assumption, $l_x = L_x + \frac{1}{2}d_x$ where L_x is the average life table population at risk of dying between ages x and x+1 and d_x is the number of deaths occurring between age x and x+1. q_x is then

$$q_x = \frac{d_x}{l_x} = \frac{d_x}{L_x + \frac{1}{2}d_x}$$

One can make the same assumption for the observed population, i.e., that the observed population aged x at risk of dying at the beginning of the year (N_x) declines linearly between ages x and x+1. Under this assumption, $N_x = P_x + \frac{1}{2}D_x$ where P_x is the midyear population or average observed population at risk of dying between ages x and x+1 and D_x is the observed number of deaths occurring between ages x and x+1. q_x is calculated as

$$q_x = \frac{D_x}{N_x} = \frac{D_x}{P_x + \frac{1}{2}D_x} \qquad [3]$$

For $x = 1$ to 4, D_x is the observed number of deaths adjusted for not-stated age and P_x is obtained by Beer's interpolation formula. For $x = 5$ to 84, both D_x and P_x are obtained by interpolation (5).

Use of Medicare data at ages 85 to 99 years—There is ample evidence that the rate of increase in q_x declines above age 85 (5,11,15–17). The change in q_x for ages over 85 years can be expressed using the formula

$$q_x = q_{x-1} \bullet e^{k_x} \qquad [4]$$

where k_x denotes the age-specific rate of mortality change with age (11,16). Solving for k_x gives

$$k_x = \ln(q_x) - \ln(q_{x-1}) \qquad [5]$$

Values for k_x are then obtained from the Medicare data. Table III shows values for k by age, race, and sex based on 1997 Medicare data. These data show clearly a declining rate of increase in q_x above age 85. These k_x values are then used to obtain q_x values for ages 85 to 99 using equation 4. This method allows for flexibility in cases where the Medicare data are not available in a timely fashion. In these cases, Medicare data for the previous year can be used to calculate k_x values. Finally, ${}_{\infty}q_{100}$ is set equal to 1.0 since all will die at some point in this open-ended age interval. Once q_x is obtained for each

Table I. Values for *F* used to adjust for not-stated age based on 2000 mortality data

Race and sex	Total deaths	Total deaths for which age was not stated	F
Total	2,403,351	356	1.00014815
Male	1,177,578	289	1.00024548
Female	1,225,773	67	1.00005466
White	2,071,287	275	1.00013279
Male	1,007,191	231	1.00022940
Female	1,064,096	44	1.00004135
Black	285,826	72	1.00025196
Male	145,184	50	1.00034451
Female	140,642	22	1.00015645

Table II. Births in 1999 and 2000, deaths in 2000 of infants born in 1999 and 2000, and separation factors by race and sex: United States

	Total			White			Black		
	Both sexes	Male	Female	Both sexes	Male	Female	Both sexes	Male	Female
Births									
1999	3,959,417	2,026,854	1,932,563	3,132,501	1,605,603	1,526,898	605,970	307,670	298,300
2000	4,058,814	2,076,969	1,981,845	3,194,005	1,636,081	1,557924	622,598	316,115	306,483
Deaths in 2000 of infants born in									
1999	3,461	1,925	1,536	2,225	1,244	981	1,072	592	480
2000	24,578	13,797	10,782	15,921	8,935	6,986	7,701	4,311	3,391
Separation factor (f)	0.123	0.122	0.125	0.123	0.122	0.123	0.122	0.121	0.124

Table III. *k* values by age, race, and sex based on insured Medicare data: United States, 1997

	Total			White			Black		
Age	Both sexes	Male	Female	Both sexes	Male	Female	Both sexes	Male	Female
84–85	0.092590	0.089728	0.103281	0.093742	0.09136	0.10428	0.071864	0.066047	0.082589
85–86	0.090210	0.087018	0.100251	0.091842	0.08897	0.10185	0.070794	0.064457	0.081079
86–87	0.087830	0.084308	0.097221	0.089942	0.08658	0.09942	0.069724	0.062867	0.079569
87–88	0.085450	0.081598	0.094191	0.088042	0.08419	0.09699	0.068654	0.061277	0.078059
88–89	0.083070	0.078888	0.091161	0.086142	0.0818	0.09456	0.067584	0.059687	0.076549
89–90	0.080690	0.076178	0.088131	0.084242	0.07941	0.09213	0.066514	0.058097	0.075039
90–91	0.078310	0.073468	0.085101	0.082342	0.07702	0.0897	0.065444	0.056507	0.073529
91–92	0.075930	0.070758	0.082071	0.080442	0.07463	0.08727	0.064374	0.054917	0.072019
92–93	0.073550	0.068048	0.079041	0.078542	0.07224	0.08484	0.063304	0.053327	0.070509
93–94	0.071170	0.065338	0.076011	0.076642	0.06985	0.08241	0.062234	0.051737	0.068999
94–95	0.068790	0.062628	0.072981	0.074742	0.06746	0.07998	0.061164	0.050147	0.067489
95–96	0.066410	0.059918	0.069951	0.072842	0.06507	0.07755	0.060094	0.048557	0.065979
96–97	0.064030	0.057208	0.066921	0.070942	0.06268	0.07512	0.059024	0.046967	0.064469
97–98	0.061650	0.054498	0.063891	0.069042	0.06029	0.07269	0.057954	0.045377	0.062959
98–99	0.059270	0.051788	0.060861	0.067142	0.0579	0.07026	0.056884	0.043787	0.061449

single year of age, the other life table functions may be easily calculated.

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

$$l_x = l_{x-1}\,(1 - q_{x-1}) \qquad [6]$$

Decrement function (d_x)—The number of deaths occurring between age x and $x + 1$ is calculated from the survivor function.

$$d_x = l_x - l_{x+1} = l_x\, q_x \qquad [7]$$

Note that ${}_\infty d_{100} = {}_\infty l_{100}$ since ${}_\infty q_{100} = 1.0$.

Person-years lived (L_x)—Person-years lived for ages 1 to 99 years is calculated assuming that the survivor function declines linearly between age x and $x + 1$. This gives the formula

$$L_x = \tfrac{1}{2}\,(l_x + l_{x+1}) = l_x - \tfrac{1}{2} d_x \qquad [8]$$

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

$$L_0 = f\, l_0 + (1 - f)\, l_1$$

${}_\infty L_{100}$ is calculated by surviving the life table cohort from age 100 using equations 4, 5, and 6 until L_x at these ages is essentially zero (somewhere between ages 110 and 120). q_x for these ages can be extrapolated from the Medicare data using equation 4. However, k_x values must be estimated for these ages. k_x can be modeled as a linear function of age

$$k_x = k_{85} + (x - 85)s \qquad [9]$$

where s is the slope of the change in k_x by age and k_{85} is calculated as $[\ln(q_{88}/q_{81})]/7$ in order to minimize the effects of random fluctuations (11,17). s can be obtained by treating equation 9 as a linear regression model. Calculated values for s are shown in table IV. The predicted values for k_x are then used to calculate q_x above age 100 using equation 4. The corresponding L_x values for ages 100 years and over are then summed to give ${}_\infty L_{100}$.

Person-years lived at and above age x (T_x)—T_x is calculated by summing L_x values at and above age x.

$$T_x = \sum_{t=0}^{\infty} L_{x+t} \qquad [10]$$

Life expectancy at age x (e_x)—Life expectancy at exact age x is calculated as

$$e_x = \frac{T_x}{l_x} \qquad [11]$$

Table IV. Slope of the change in *k* values (*s*) by race and sex

Race and sex	*s*
Total, both sexes	–0.002379
Male	–0.002710
Female	–0.003031
White, both sexes	–0.001902
Male	–0.002390
Female	–0.002427
Black, both sexes	–0.001074
Male	–0.001586
Female	–0.001512

Abridging the complete life table

An abridged or collapsed version of the complete life table can be easily calculated in which life table functions are shown for 5-year rather than single-year age intervals. It is often desirable to summarize the life table and save space when publishing life table data by single years of age (18). The abridgement of the complete life table is simplified by an important property of three of the six life table functions. The l_x, T_x, and e_x functions describe exact age x, i.e., the beginning of the age interval x to $x+n$ (n denotes the length of the age interval—for 5-year age intervals $n=5$). Life expectancy at age 20 (e_{20}), for example, has the same value regardless of whether the age interval is 20–21 years or 20–25 years. Thus, the values l_x, T_x, and e_x can be extracted at 5-year intervals from the complete life table and placed into the abridged life table (compare l_x, T_x, and e_x in table V with the same functions in table 1). It is also illustrative to compare values for e_x and l_x in tables A and B with their corresponding values presented in tables 1–9. The q_x, d_x, and L_x functions, in contrast, describe the age interval x to $x+n$. In fact, for abridged life tables, the notation for these functions is different (${}_nq_x$, ${}_nd_x$, and ${}_nL_x$). Thus, ${}_5q_{20}$ is the probability of dying between ages 20 and 25 years and will obviously be somewhat larger than q_{20}, the probability of dying between ages 20 and 21 years. Taking this into account, ${}_nq_x$, ${}_nd_x$, and ${}_nL_x$ must be recalculated in the abridged life table. It is simplest to begin with ${}_nd_x$. The calculations are made for all but the final age interval as follows:

$${}_nd_x = l_x - l_{x+n}$$

$${}_nq_x = \frac{{}_nd_x}{l_x}$$

$${}_nL_x = T_x - T_{x+n}$$

Note that for the open-ended interval, ages 100 and over: ${}_\infty d_{100} = l_{100}$, ${}_\infty q_{100} = 1.0$, and ${}_\infty L_{100} = T_{100}$. Table V shows each of the life table functions for the 2000 U.S. total population abridged from table 1.

Table V. Abridged life table for the total population: United States, 2000

Age	Probability of dying between ages x to $x+n$ ${}_nq_x$	Number surviving to age x l_x	Number dying between ages x to $x+n$ ${}_nd_x$	Person-years lived between ages x to $x+n$ ${}_nL_x$	Total number of person-years lived above age x T_x	Expectation of life at age x e_x
0–1	0.00693	100,000	693	99,392	7,686,810	76.9
1–5	0.00131	99,307	130	396,916	7,587,418	76.4
5–10	0.00082	99,177	82	495,668	7,190,502	72.5
10–15	0.00104	99,095	103	495,278	6,694,833	67.6
15–20	0.00341	98,992	338	494,200	6,199,555	62.6
20–25	0.00479	98,654	473	492,113	5,705,355	57.8
25–30	0.00494	98,181	485	489,702	5,213,242	53.1
30–35	0.00578	97,696	565	487,130	4,723,539	48.3
35–40	0.00806	97,132	783	483,813	4,236,409	43.6
40–45	0.01182	96,349	1,139	479,070	3,752,596	38.9
45–50	0.01773	95,210	1,688	472,085	3,273,527	34.4
50–55	0.02576	93,522	2,409	461,940	2,801,442	30.0
55–60	0.03968	91,113	3,615	447,124	2,339,510	25.7
60–65	0.06133	87,498	5,366	424,879	1,892,377	21.6
65–70	0.09217	82,131	7,570	392,758	1,467,498	17.9
70–75	0.13838	74,561	10,317	348,168	1,074,739	14.4
75–80	0.20557	64,244	13,207	289,331	726,571	11.3
80–85	0.31503	51,037	16,078	215,947	437,240	8.6
85–90	0.46111	34,959	16,120	133,503	221,293	6.3
90–95	0.61506	18,839	11,587	62,766	87,790	4.7
95–100	0.75434	7,252	5,470	20,388	25,024	3.5
100 years and over	1.00000	1,781	1,781	4,636	4,636	2.6

Contents

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National Center for Health Statistics

Director, Edward J. Sondik, Ph.D.
Deputy Director, Jack R. Anderson

Division of Vital Statistics

Director, Mary Anne Freedman

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DEPARTMENT OF
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Centers for Disease Control and Prevention
National Center for Health Statistics
6525 Belcrest Road
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