LIFE EXPECTANCY

1. Definition:

LIFE EXPECTANCY most often is referenced as at birth and derived through life table calculations, although such calculations allow for estimation of life expectancy at a series of age intervals. Life expectancy at birth is a standardized summary measure, sometimes used as an overall gauge of health, based on a population's age structure and mortality experience. As such, it is an index of the level of mortality within a population, and it represents a *hypothetical* number of years a newborn would live, on average, if he or she experienced the prevailing or some other set levels of mortality within each age group as he or she aged.

2. Calculation:

[Note: Due to the complexity and subtleties of life table construction, the following is not intended as a "how to" primer. (Please see the references listed at the end as starting points for learning more about life tables and their mechanics.) Instead, the following highlights the uses and meanings of life table statistics, especially life expectancy.]

There are several methods available, with perhaps subtle differences among them, for calculating a life table and the resulting byproduct of life expectancy. For this illustration, the method described by Schoen (see references below) is used, which is relatively simple and accurate for producing abridged, period life tables (using ages 0, 1-4, 5-9, 10-14, . . ., 80-84, and 85 years and older). Abridged refers to life tables that contain data for age groups instead of single-year ages. Period means the current (or some other particular period's) age-specific death rates are applied to the life table's hypothetical cohort, instead of tracking a real cohort throughout their lives to see what levels of mortality the cohort actually experienced. Therefore, in the life table the l_x column values and all those in the columns to the right are hypothetical, including life expectancy (e_x).

LIFE TABLE FOR ILLINOIS RESIDENTS, 1999-2001

Age at Start of Interval	Probability of Dying During Interval	Of 100,000 Born Alive: Number Living at Start of Interval	Number Dying During Interval	Stationary Population: In the Interval	In Interval and All Subsequent Intervals	Average Years of Remaining Lifetime
x	$_nq_x$	l_x	$_nd_x$	$_nL_x$	T_x	e_x
0	0.00842	100,000	842	99,229	7,682,595	76.8
1	0.00132	99,158	131	396,306	7,583,366	76.5
5	0.00072	99,027	71	494,956	7,187,060	72.6
10	0.00093	98,956	92	494,632	6,692,103	67.6
15	0.00347	98,864	343	493,535	6,197,472	62.7
20	0.00499	98,521	491	491,374	5,703,937	57.9
25	0.00443	98,030	434	489,090	5,212,563	53.2
30	0.00555	97,595	542	486,695	4,723,473	48.4
35	0.00760	97,054	737	483,565	4,236,779	43.7
40	0.01161	96,316	1,118	479,004	3,753,214	39.0
45	0.01766	95,199	1,681	472,041	3,274,211	34.4
50	0.02458	93,517	2,299	462,316	2,802,169	30.0
55	0.03950	91,219	3,603	447,796	2,339,853	25.7
60	0.06192	87,615	5,425	425,422	1,892,057	21.6
65	0.09363	82,190	7,695	392,871	1,466,635	17.8
70	0.14175	74,495	10,560	347,266	1,073,764	14.4
75	0.20809	63,935	13,304	287,616	726,498	11.4
80	0.31556	50,631	15,977	216,239	438,882	8.7
85	1.00000	34,654	34,654	222,643	222,643	6.4

In this Illinois example, three years of deaths (1999-2001) surrounding the 2000 census year were used to calculate the age-specific death rates in the life tables (used to calculate the probability of dying). Using three years of mortality minimizes the effects of influenza epidemics, heat waves and other periodic or one-time mortality impacts. The following is a brief description of the life table columns shown in the above table.

x - the age in years at the start of the interval. The interval implied is the age at the start through to, but not including, the next stated age.
$_nq_x$ - the probability of dying during the interval.
l_x – the number alive at the start of the age interval of a hypothetical birth cohort of 100,000 (or some other arbitrary starting number, called a radix).
$_nd_x$ – the number dying during the age interval of a hypothetical birth cohort of 100,000 experiencing the $_nq_x$ values at each interval.

$_nL_x$ – the number of person-years lived during the age interval of a hypothetical birth cohort of 100,000 experiencing constant rates of mortality, number of births, age structure and size (called the stationary population).
T_x - the total number of person-years lived in the age interval and all subsequent age intervals of the stationary population.
e_x - the expectation of life remaining at the start of the age interval. e_x is calculated T_x / l_x

3. Example:

In the above life table for Illinois, life expectancy at birth (beginning of age interval 0) was 76.8 years (about the same value as for the United States during this identical period). The life expectancy at age 1 year was 76.5 years, decreasing only a fraction of a full year of life expectancy compared to age 0. This is often the case because the probability of dying during the first year of life often is much higher than immediate subsequent years. (Where infant mortality rates are high, often the life expectancy at age 1 year is used for comparative purposes.) In the same manner, life expectancy at age 65 years in this example is 17.8 years.

Life tables and life expectancy can be for specific subpopulations, such as by sex, race category, ethnicity, geography, year(s) period, etc. or a combination of such characteristics *provided matching mortality and population data are available*. Expanding on the Illinois example, life expectancy at birth often is higher for females (79.5 years) than males (74.0), higher for some race categories (77.8, white) than others (70.6 years, black) and higher for some time periods (76.8, 1999-2001) than others (73.5, 1979-1981). As a further example, life expectancy differences can be compared by time period, sex and race category. In Illinois from 1979-1981 to 1999-2001, life expectancy at age 20 years improved 1.1 years for black females and 2.6 years for black males.

4. Technical Notes:

- A life table, in some respects, is an elegant way of summarizing age-specific mortality. It also represents an instance where demographic theory and practice meet. Yet more than that, life tables and life expectancy are used in many applications beyond vital statistics, especially in business applications and assessments of risk: actuarial tables, battery life, hospital stays, etc., or circumstances where binary status changes (on/off, yes/no) can be measured by duration (e.g., in hospital/discharged from hospital) and summarized by cohort.
- Besides the more practical life table interpretation of it representing the mortality experience of a birth cohort going through its entire course of life (and death), an alternative interpretation is the stationary population. The more theoretical stationary population is where the total number of the population and the age distribution do not change or, put another way, the number of births in a period (e.g., 100,000) equals the number of deaths (and assuming no migration). The life table columns (l_x and those to the right) then become predictions of population structure given these circumstances.
- While all standardized measures are designed for comparative uses, like life expectancy within a life table, they also are hypothetical based on "what if" scenarios. In our Illinois example, what would be the life expectancy at birth *if* the prevailing death rates were

applied to the life table? There are several reasons to suppose that the 76.8 years might not be correct as a prediction or estimate: it is quite unlikely that all or even most people will experience the same probabilities of dying in each age interval over the course of their lifetimes, in and out-migration will occur, periodic mortality episodes likely will happen (e.g., influenza, results of military actions, etc.), new diseases might be introduced and others better managed (i.e., advances in medicine), birth rates likely will change over time, and so forth. The only true way to assess this is to observe a birth cohort and follow it, longitudinally, until all its members have died and from that determine the experienced average life expectancy.

- What do changes in life expectancy at birth actually reflect? An increase in life expectancy generally means decreases among the age-specific death rates within a population. Those decreases could be caused by any number of reasons: reduction in infectious diseases, fewer accidents or other preventable external causes, or any health-related actions that would contribute to a decrease in mortality (smoking cessation, use of condoms, increased seat-belt usage, etc.). In other words, changes in life expectancy are multi-factorial and rarely due primarily to one or two causes. In this respect, life expectancy is similar to infant mortality, fertility rates, and other summary measures where many cause-and-effect relationships could be reflected in their values. As such, life expectancy should not be used as a stand-alone indicator when seeking understanding about health status. Instead, life expectancy should be factored in with other measures and data, such as death rates by cause and age, access to and affordability of health care, environmental conditions, etc. when assessing the health of a population.
- Life expectancy is not the same as “life span.” Conceptually, life span is the theoretical temporal limit of a single human life.
- Besides life expectancy, life tables can define the probability of surviving. For example, in the Illinois example, what is the probability of a neonate surviving to age 65? The answer is $l_{65} / l_0 = 82{,}190 / 100{,}000 = .82190$ The median age at death in the life table population is defined as wherever the $l_x = 50{,}000$ value lies. In the Illinois example, this would be about age 80 years.
- Theoretical life expectancy improvements can be measured via multiple decrement life table construction. For example, what impact does homicide have on male life expectancy at birth? In this exercise, in essence all homicide deaths are eliminated from the standard life table and the probabilities of dying from the remaining causes are recalculated. Again using Illinois as an example, based on 1989-1991 life tables, life expectancy at birth would have improved 0.48 years or about six months, on average. (For females, it was 0.14 years improvement.)
- One life table technique that can have an impact on the life table functions, including life expectancy, is data “smoothing.” That is, based on a set of principles or criteria, mortality numbers or age-specific death rates are homogenized or adjusted, usually without changing the total number of deaths for the population. For example, if a principle is that in a population a male death rate should always be higher than a female death rate for any given age group, then that would be a basis for such an adjustment. The idea is to eliminate abnormalities, especially when the numbers of deaths for age groups become small. The risk is that real or true information is being eliminated instead of data anomalies.

- Outside of vital statistics, some people add a half year to life expectancy because people who do not survive to their next birthday usually do not die the day after their previous birthday, say. That is, a failure to reach their next birthday could have occurred actually anytime during the interval and so, some think, are due a 0.5 year credit.
  (maf;7/2009)

References

[*Note: This set of references is not intended to be an exhaustive list. Instead, they are provided as starting points for a handful of common life table and life expectancy topics*.]

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