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Life table analysis

Workshop on data analysis and report writing for civil registration based vital statistics

Nadi, Fiji

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Bloomberg
Philanthropies



DATA FOR
HEALTH INITIATIVE



Pacific
Community
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ESCAP

Economic and Social Commission for Asia and the Pacific

Overview

- Life table analysis and review of life table functions
- Model life tables
- Decomposition of life expectancy



What is a life table?

- A life table summarises a cohort's mortality experience
- Shows, for a person at each age, what the probability is that they will die before their next birthday.
- From this starting point, a number of statistics can be derived and thus also included in the table:
 - the probability of surviving any particular year of age
 - the remaining years someone can expect to live once they have reached a certain age
 - the proportion of the original birth cohort still alive
 - life expectancy
- Life tables are calculated separately for males and females because of their different mortality patterns.



What don't life tables do?

- They don't tell us who will die in a population
- They are an estimate based on a number of modelled factors – it doesn't mean that's precisely how long you will live
- They can't foresee future events



Example life table

Age Interval	n^m_x	n^q_x	l_x	n^d_x	nL_x	T_x	e_x^0
<1 year	0.0640	0.0620	100000	6199	96,868	6,544,328	65.44
1-4	0.0077	0.0303	93801	2840	369,496	6,447,460	68.74
5-9	0.0017	0.0084	90961	761	452,900	6,077,964	66.82
10-14	0.0010	0.0048	90200	429	449,925	5,625,064	62.36
15-19	0.0008	0.0042	89771	377	447,912	5,175,139	57.65
20-24	0.0013	0.0063	89394	565	445,556	4,727,227	52.88
25-29	0.0018	0.0087	88829	776	442,202	4,281,672	48.20
30-34	0.0023	0.0113	88053	993	437,779	3,839,470	43.60
35-39	0.0028	0.0137	87060	1191	432,318	3,401,690	39.07
40-44	0.0029	0.0146	85870	1251	426,212	2,969,373	34.58
45-49	0.0046	0.0229	84618	1940	418,222	2,543,161	30.05
50-54	0.0070	0.0343	82678	2833	406,265	2,124,939	25.70
55-59	0.0105	0.0511	79845	4078	388,937	1,718,675	21.53
60-64	0.0188	0.0896	75766	6789	361,591	1,329,737	17.55
65-69	0.0288	0.1340	68977	9241	321,227	968,146	14.04
70-74	0.0462	0.2062	59736	12317	266,702	646,918	10.83
75-79	0.0678	0.2874	47419	13626	201,109	380,216	8.02
80-84	0.1329	0.4853	33793	16401	123,455	179,108	5.30
85+	0.3125	1.0000	17392	17392	55,653	55,653	3.20

Cohort life table

- Shows the probability of a person from a given cohort dying at each age over the course of their lifetime. As an example a cohort may be all males born in 1900 or all females born in the year 2000.
- The cohort life table is based on age-specific probabilities of death, which are calculated using observed deaths data from the cohort.
- A cohort life table uses a combination of observed mortality rates for past years and projections about mortality rates for the cohort in future years. Projections are needed if the entire haven't all died yet as we would expect with our females born in the year 2000 example.
- Cohort estimates of life expectancy are regarded as the most accurate measure of how long a person of a given age would be expected to live, compared to period life expectancy.
- In most cases, generation of cohort life tables are used to study historic periods.



Period life table



- Constructed from mortality rates from different age groups observed during a given time period (e.g. a year)
- Illustrates “...what would happen to a cohort if it were subjected for all of its life to the mortality conditions of that period” (Preston, S., Heuveline, P. & Guillot, M., (2001))
- It is what we call a synthetic or hypothetical cohort
- Does not take improvements in mortality into account so will produce a lower life expectancy than a cohort table
- Useful comparing across time, across countries etc and a more useful tool for analysis

Life table assumptions



1. It uses a hypothetical closed population (migration in or out of the population is not considered)
1. People experience homogenous risks across age and time (which may not be the case, especially in the older age groups)
1. No measurement of change over time (over time survival within an age group gradually increases as people are in general, living longer, healthier lives)



Abridged vs unabridged



- **Unabridged** = single years of life (also known as complete)
- **Abridged** = 5 year cohorts of life (but may be more aggregated if populations are small)
- In many countries, life tables are based on an average of age-specific death rates for a 3-year time period, generally around a census taking. In many cases, the life tables are prepared every 10 years. For example, a country or state would collect age-specific death rates for 1999, 2000, and 2001. The census for year 2000 would be used for the base population.

Unadbridged vs. abridged life table

A **complete** life table uses individual years of age

Complete Period Life Table (Male, 2001)

Age	q_x	Age	q_x	Age	q_x	Age	q_x
0	0.0024						
1	0.0003	26	0.0007	51	0.0042	76	0.0480
2	0.0003	27	0.0007	52	0.0047	77	0.0521
3	0.0003	28	0.0007	53	0.0053	78	0.0564
4	0.0002	29	0.0007	54	0.0060	79	0.0612
5	0.0002	30	0.0007	55	0.0067	80	0.0663
6	0.0001	31	0.0007	56	0.0074	81	0.0719

An **abridged** life table uses age groups*, based on the assumption that death rates are similar at neighboring ages. Where populations are very small – ten year groupings may be used.

Age (year)	Dx	Correction	Dx ($r = 2.3$)	dx	lx	qx	Lx	Tx	ex
0-4	37.00	1.058	39.15	10.14	100.00	0.10	474.65	4404.25	44.04
5-9	2.50	1.186	2.97	0.77	89.86	0.01	447.38	3929.60	43.73
10-14	0.50	1.329	0.66	0.17	89.09	0.00	445.03	3482.23	39.09
15-19	2.00	1.489	2.98	0.77	88.92	0.01	442.68	3037.20	34.16
20-24	4.90	1.668	8.17	2.12	88.15	0.02	435.45	2594.53	29.43
25-29	9.50	1.869	17.76	4.57	86.03	0.05	418.73	2159.08	25.10

*In most abridged life tables, it is good practice to set up using separate age groups for <1 year olds, 0-4 year olds, and the oldest ages as mortality patterns differ significantly during these ages. However, as shown in the table, where populations are small, it may be better to use a combined age group depending on population size and mortality patterns.

Life table Columns: age interval (x, x+n)

- Age interval: age interval from exact age x to age $x + n$, e.g. exact age 40 to age $40 + 5$
- Lower age interval: where the age band starts
- Years in interval: Number of years in the age band

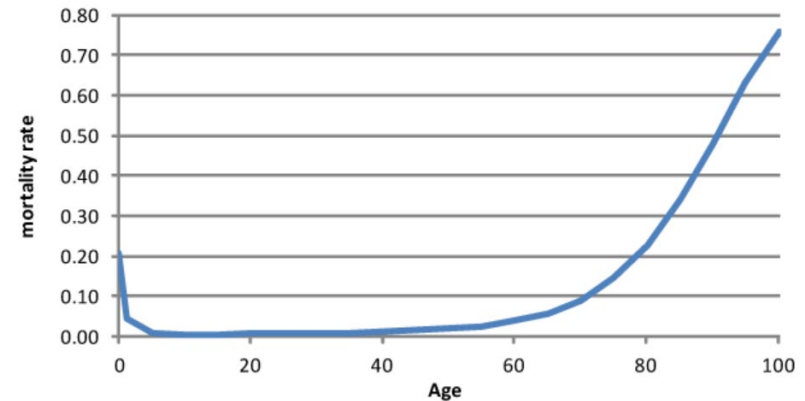
Age interval (years)	Lower age interval value (x)	Years in interval n_x
<1	0	
1-4	1	
5-9	5	
10-14	10	
15-19	15	
20-24	20	
25-29	25	
30-34	30	
35-39	35	
40-44	40	
45-49	45	
50-54	50	
55-59	55	
60-64	60	
65-69	65	
70-74	70	
75-79	75	
80-84	80	
≥85	85	1

Life table Columns:

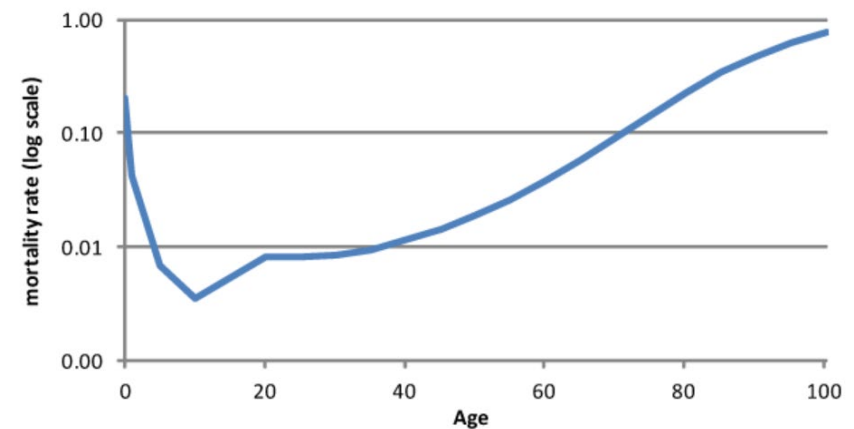
$${}_nM_x$$

- ${}_nM_x$: Age-specific death rate between the beginning of the age group x and the beginning of the next age group $x+n$
- e.g. the number of deaths of people aged exact age 40 to exact age 45 divided by the population of the same age group, over a defined period of time

${}_n m_x$ linear scale



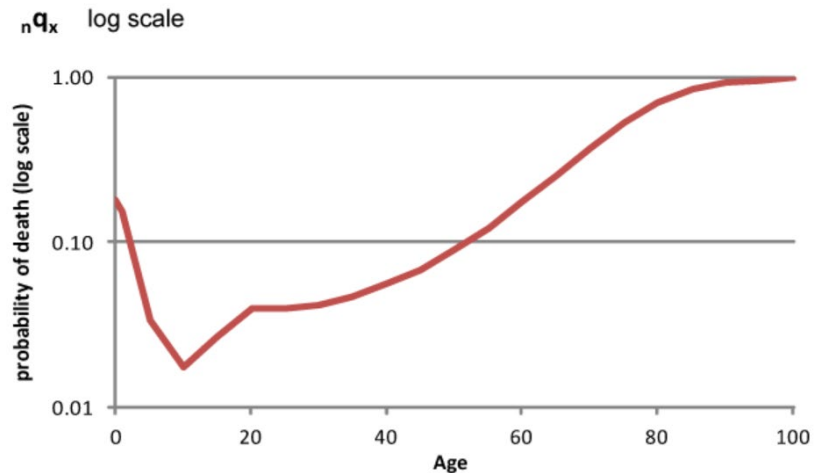
${}_n m_x$ log scale



Life table Columns: ${}_nq_x$

Probability of dying
q_x
0.0032829
0.0005415
0.0003309
0.0004464
0.0015836
0.0022859
0.0024750
0.0028965
0.0038537
0.0056205
0.0088516
0.0124261
0.0192839
0.0280817
0.0419306
0.0665278
0.1110268
0.1997428
1.0000000

- ${}_nq_x$: (Conditional) probability of dying in the interval $[x, x+n]$, given survival to age x
- e.g. ${}_5q_{40}$ is the probability of a person who has survived to age 40 surviving to exact age 45.
- q_{x+} always equals 1, i.e. everyone dies eventually
- Components needed to calculate probability of dying are mortality rate, interval and linearity



Calculating ${}_nq_x$ from ${}_nm_x$

$${}_nq_x \approx \frac{n \cdot {}_nm_x}{1 + n \cdot (1 - a_x) \cdot {}_nm_x}$$

n = interval in age group

m= mortality rate


a= linearity (follow former guidelines for calculating)

${}_n p_x$ Probability of surviving

- Definition: probability of surviving between exact age x and $x+n$
- (q : probability of dying)
- Note no probability of surviving in last age band

$${}_n p_x = 1 - {}_n q_x$$

$$\therefore {}_n p_x + {}_n q_x = 1$$

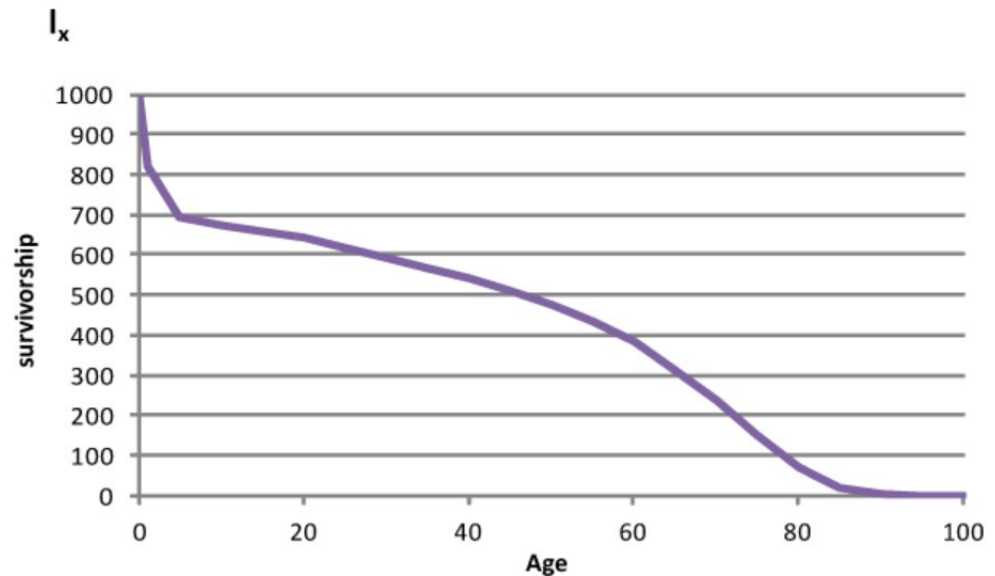


Probability of surviving
p_x
0.996717
0.999458
0.999669
0.999554
0.998416
0.997714
0.997525
0.997104
0.996146
0.994380
0.991148
0.987574
0.980716
0.971918
0.958069
0.933472
0.888973
0.800257
0.000000

Life table Columns:

l_x

- l_x : Number of survivors at exact age x
- l_{40} means the number of people surviving at exact age 40
- Based on our synthetic population (100,000 people)
- First entry for age 0 = radix
- In the end, the l_x must = 0, i.e. there are no survivors and can only decrease
- Probability of survival to exact age $x = l_x/l_0$



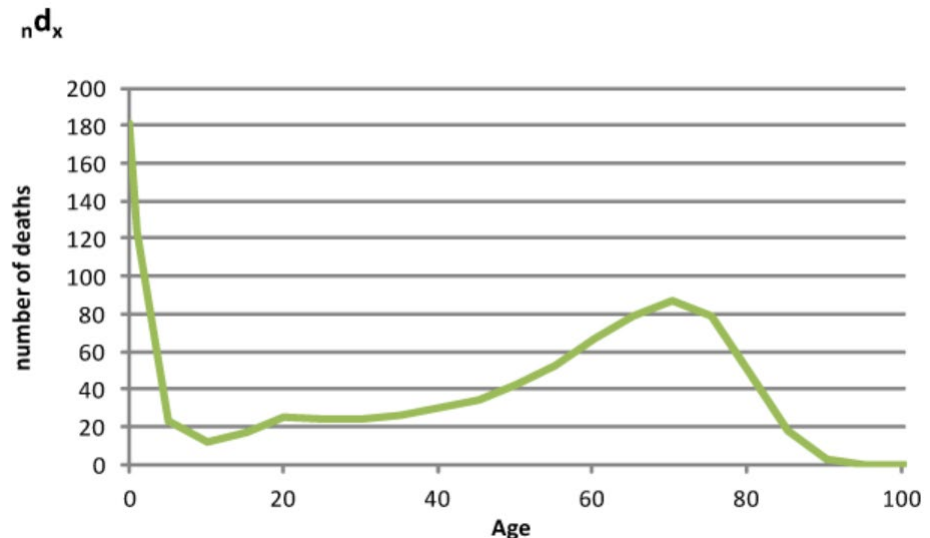
Pop surviving
l_x
100000
99672
99618
99585
99540
99383
99156
98910
98624
98244
97691
96827
95623
93779

Life table Columns:

${}_n d_x$

- ${}_n d_x$: number of deaths expected in the interval $[x, x+n]$ based on the synthetic population
- ${}_5 d_{40}$: number of people dying between exact age 40 and exact age 45
- Follows a roughly similar pattern to ${}_n q_x$
- Use the population surviving to calculate this (minus one cohort from the last cumulatively, e.g. for deaths expected at infancy minus number of people surviving at ages 1-4 from the whole population. In our case the whole population is 100,000) the Radix

Deaths (expected)
d_x
328
54
33
44
158
227
245
286
380
552
865
1203
1844
2633
3822
5809
9050
14474
57990



Life table Columns:

${}_nL_x$ and T_x

- ${}_nL_x$: person-years lived between ages x , $x+n$
- ${}_5L_{40}$: number of person-years lived between exact age 40 and 45
- Function of:
 - Number of survivors (l_x)
 - Number of deaths (${}_nd_x$)
 - When in the interval people die on average (${}_na_x$)
- T_x : Total person-years lived above age x
- T_{40} : number of person-years lived above exact age 40
- Cumulative ${}_nL_x$ (from bottom)



e_x Period life expectancy at age x

Definition: expected (average) number of years of life remaining for a person alive at the beginning of age interval x

Important across all ages, not just at birth

e_0

- ◆ The average number of years available to a new born is generally referred to as the ***expectation of life at birth*** and is given by the ratio:

$$e_0 = \frac{T_0}{l_0}$$

Decomposing a difference in life exp.

- A change in life expectancy does not imply age-specific mortality rates change in the same magnitude and direction
- Contributions of various causes of death in the changes in expectations of life will not be of the same magnitude and direction.
- Some age-cause-specific death rates will increase in the two groups compared, thus contributing to a decrease in expectation of life, while others may decrease in some age intervals, thus increasing expectation of life.
- Disentangling these contribution by age-specific (and age-cause-specific) death rates to the difference between two expectations of life helps interpret the dynamics of changes in the mortality.

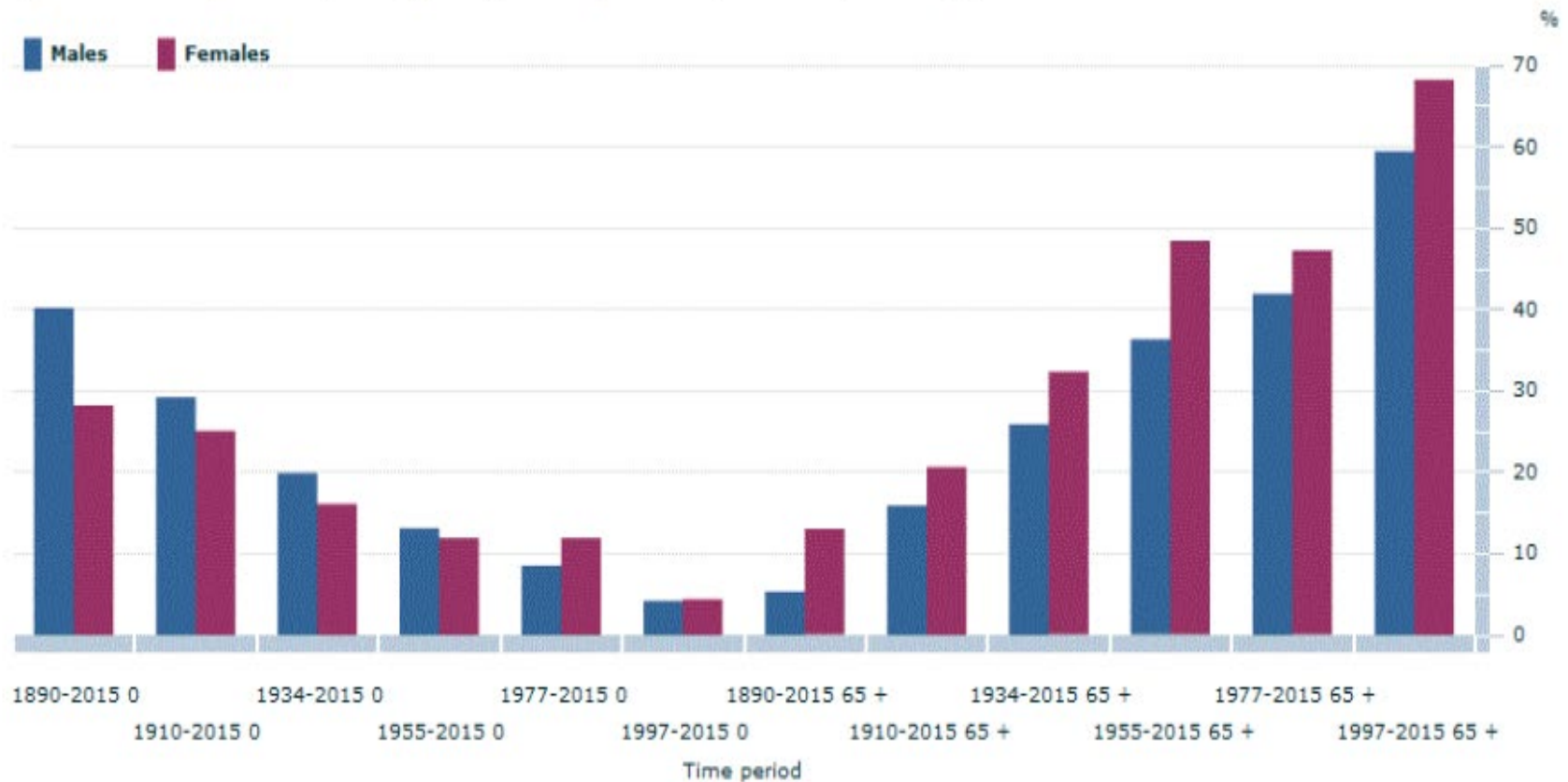
Why differences in age patterns of mortality exist?

If countries have the same life expectancy, why might the age pattern of mortality differ?

- Broad environmental factors (climate, natural disasters, crop productivity, etc.)
- Disease vectors (tuberculosis, malaria, HIV, etc.) and other causes of death
- Public health spending and interventions may benefit certain demographic groups

Example of gains in life expectancy

Figure 2 - Percentage of life expectancy gain by persons aged 0 & 65 years & over, Australia(a)



What is a model life table?

- Age-specific mortality data are not always available ie, we do not have accurate vital registration data
- Life table of a similar population, such as a neighboring country, can be useful
- Alternatively, we can construct a model life table
- Model life tables are sets of hypothetical life tables spanning the full range of life expectancies as well as different patterns of age-specific mortality



What is a model life table?

- High correlations between sets of death rates drawn from different pops
- Widely observed in populations with good data
- For e.g. when death rates are high at ages 1-4. they tend to be high at ages 40-44 and 80-84
- Can leverage small amounts of data – ie can create a model life table from just one Infant mortality rate
- Therefore possible to create model life tables depending on different relationships

Before constructing your table...

- Are there results in our first and last age groups?
- Is your data adjusted if completeness was low?
- Do our graphs of age-specific mortality have a clear and expected shape?

Activity for report

- Using the UNSW excel workbook paste in your deaths and population data into the first sheet
- Calculate life expectancy at birth for both males and females for your report
- Calculate life expectancy at 40 for both males and females





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Q&A