LESSON 7

Mortality Measures and Levels

Aynalem

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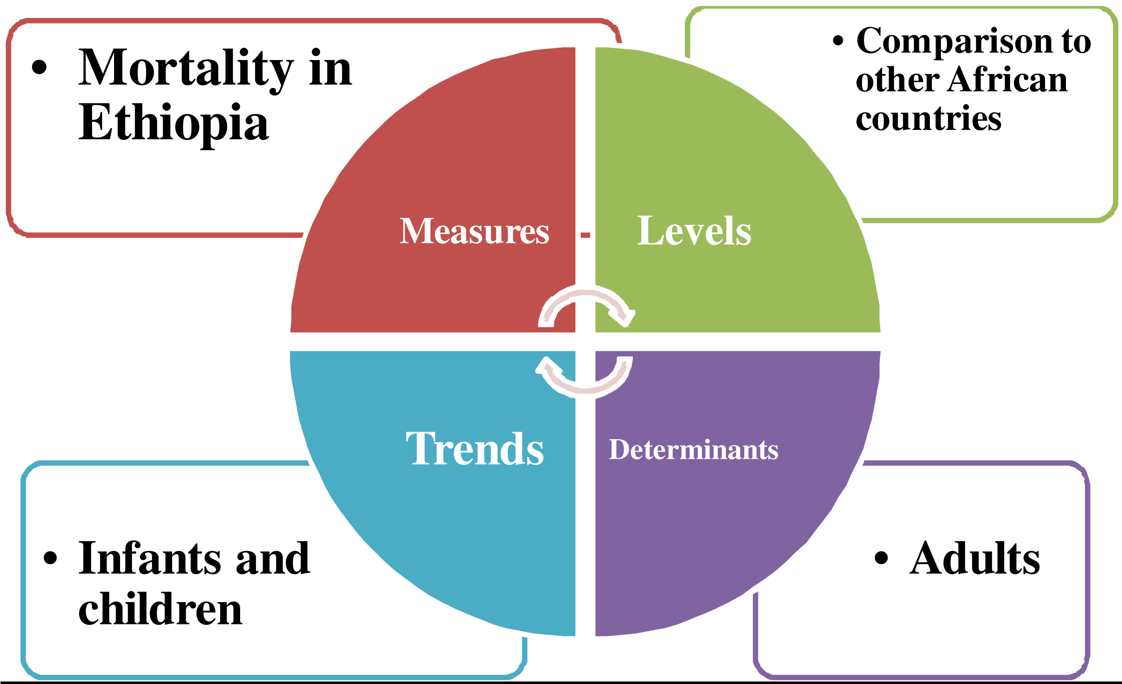
LESSON 7 MORTALITY

Learning objectives



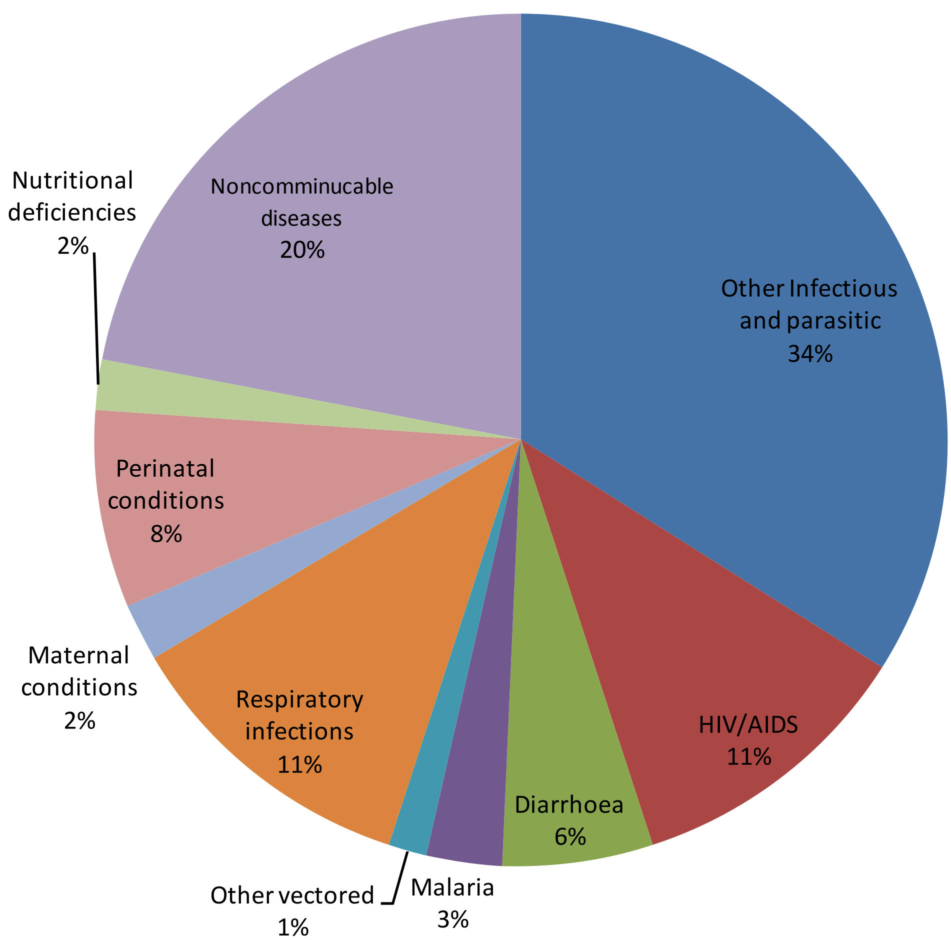
Introduction

There are no vital registration systems or monitoring regimes in Ethiopia to give accurate statistics on the numbers and causes of death. The country's Statistical Authority has been reporting mortality figures on a regular basis, regardless. The numbers come from a series of national demographic surveys as well as the 1984 and 94 censuses. However, censuses and sample surveys are fraught with reporting errors and, typically, give an underestimate of actual mortality, leading to a rosy survival picture and higher values on the life table calculation (see below) of survivorship probabilities, and typically show higher life expectancy at a given age than is truly the case.

Causes of death

Three categories of preventable illnesses labeled "infectious and parasitic" "respiratory infections" and "HIV/AIDS" account for almost two-thirds of the yearly deaths in Ethiopia (Fig.7.1). In others words, close to two thirds of the deaths taking place yearly in Ethiopia are preventable. The total number of deaths in the WHO report - 1,106,000 – compares favorably (in terms of accuracy), with the total implied by the reported crude death rate (CDR) of 15 per thousand. The latter gives a figure of 1,156,500 deaths.

Figure 7.1 Percentage Distribution of the Top Ten Causes of Death in Ethiopia (2002)



Source: [1]

Table 7.1 The number of Deaths by Cause ('000s) - 2002

HIV/AIDS	121.7
Other Infectious and parasitic	375.5
Diarrhoea	63.2
Malaria	31.9
Other vectored	16.2
Respiratory infections	126.7
Maternal conditions	23.7
Perinatal conditions	82.8
Nutritional deficiencies	21.4
Noncomminucable diseases	242.8
Total	1105.9

Source: [1]

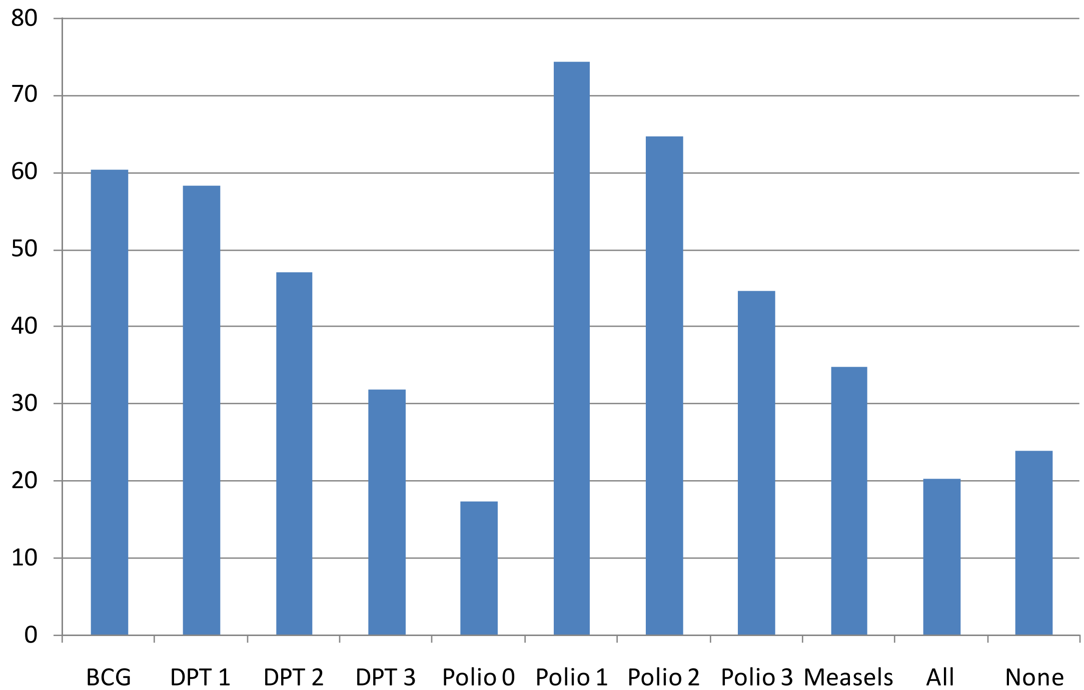
The first item on the list above - HIV/AIDS - appears to have reached a plateau in Ethiopia but remains a public health threat of major proportions.

> The first AIDS case was detected in Ethiopia in 1986. The prevalence of HIV remained very low in the 1980s but spread quite rapidly during the 1990s. It has been estimated at6.6 percent of the adult population in 2002, and the epidemic is considered generalized in Ethiopia. By the end of 2001, there were 2.1 million children and adults in Ethiopia living with HIV/AIDS. Although Ethiopia constitutes only 1 percent of the world's population, it contributes 7 percent of the world's HIV/AIDS cases, and in terms of the number of infected persons, Ethiopia ranks fifth after South Africa, Nigeria, Kenya and Zimbabwe in SSA. Tuberculosis is also widespread. [2]

With nearly a quarter a million deaths nationally (Table 7.1), non-communicable diseases – malignant neoplasms, cardiovascular diseases, diabetes mellitus, respiratory and digestive diseases, congenital abnormalities and injuries - have also started to take a tall. Most are diseases, primarily, of the relatively well-off urban residents.

The picture changes dramatically when children are taken separately. The 2005 Demographic and Health Survey (DHS) report offers a glimpse into the health risks Ethiopian children face. Birth weight is the first indicator of the survival chances of a child. The lower the weight is below the ideal of 2.5 kg., the higher the risks. Unfortunately, only a tiny fraction (3%) of births are weighed [3]. The DHS report states that "twenty-three percent of births in rural areas compared with 10 percent in urban areas have a reported birth weight less than 2.5 kg." [3]. After birth weight, the most important predictor of child survival is immunization status. Figure 7.2 shows the percentage of Ethiopian children under five years of age who have received immunization, by type of immunization.

Fig. 7.2 Percentage of children < 5 who have received immunization, by type of immunization.



Source: Based on [2]

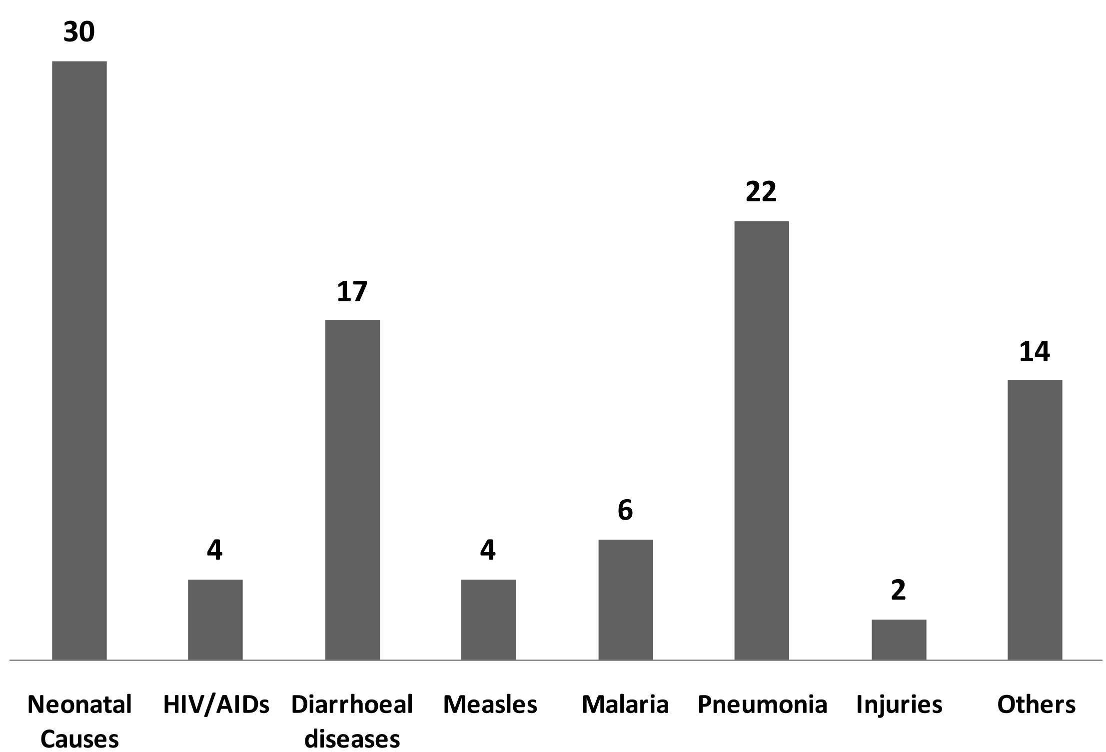
Sixty percent of Ethiopia children under five years of age have received the BCG vaccine which includes "measles, and three doses each of DPT and polio vaccine excluding polio vaccine given at birth" [2]. "Polio 0" on the graph refers to the polio vaccine given at the time of birth. Note the rapid decline in the percentage of children who have taken DPT 2 and 3 and as well as Polio 2 and 3, showing lack of continuity and due diligence on the part of institutions/mothers/parents to ensure full coverage. Only half of the children who received the first DPT shot go on to take complete it by taking the second and third. More children start the polio vaccine regime than DPT and a higher proportion – about 60% of those who started the Polio vaccine go on to complete the program. This might have to do with government support to ensure wider coverage, and better adherence to the completion requirements. As a matter of fact more children under five took Polio 1 than any other single vaccine (Fig. 1.2). The graph also shows a sad picture where-by only 20 percent of children under five have completed the entire vaccination program as prescribed by the World Health Organization (WHO). Moreover, nearly a quarter of Ethiopian children have not received any vaccination at all.

Causes of childhood mortality (under 5)

The amorphous "neonatal causes" category represents the single most important reason those who did not make it to age 5 failed to do so. According to a WHO report, the neonatal period, although brief (the first thirty days of a human life) accounts for "… more than one in three deaths in children under five" [2]. It goes on to say that on a global level:

> '….. every year over 4 million babies die in the first four weeks of life; 3 million of these deaths occur in the early neonatal period. Moreover, it is estimated that more than 3.3 million babies are stillborn every year; one in three of these deaths occurs during delivery and could largely be prevented. Ninety-eight per cent of the deaths take place in the developing world…In developing countries, the risk of death in the neonatal period is six times greater than in developed countries; in the least developed countries it is over eight times higher. With 41 neonatal deaths per 1000 live births, the risk of neonatal death is highest in Africa; the sub-Saharan regions of Eastern, Western and Central Africa have between 42 and 49 neonatal deaths per 1000 live births. ' [2].

Fig. 7.3 Percentage of Deceased Children Under Five Years of Age by Cause of Death (Ethiopia, 2005).



Source: [2]

It should be noted that the neonatal mortality includes perinatal deaths (deaths during the first week of life including still births), and those taking place in the remaining three weeks.

The reasons often cited for neonatal deaths especially in less developed countries (LDC) include:

- ***Low birth weight***
- ***Preterm births***
- ***Absence of obstetric care***
- ***Maternal nutrition and health***
- ***Maternal infections such as malaria, syphilis***
- ***Complications during birth such as obstructed labor, birth asphyxia and trauma***
- ***Infections at birth – especially neonatal tetanus, syphilis, and HIV/AIDS***
- ***Poor and unhygienic feeding practices***
- ***Multiple births***
- ***Infanticide (usually sex selective to the detriment of girls)***

The number two cause of under-five mortality in Ethiopia - pneumonia – is a major killer all around the world. According to UNICEF and the World Health Organization (WHO), "pneumonia kills more children than any other illness – more than AIDS, malaria and measles combined." [4].

Pneumonia is a lung illness affecting the respiratory system whereby"… air-filled sacs of the lung responsible for absorbing oxygen become inflamed and flooded with fluid". The pathogen involved could be bacteria, viruses, fungi, or parasites. "The bacterial pathogen *Streptococcus pneumoniae* (also known as pneumococcus) is the world's leading cause of severe pneumonia among children across the developing world. This type of pneumonia is known as pneumococcal pneumonia." [4].

At 17%, diarrheal diseases are the third major cause of childhood deaths in Ethiopia [Fig. 7.3]. Acute diarrhea becomes the leading cause of death during famine. It is to be noted that up to 14 million people were said to need food aid during the 2003/2004 drought [5]. A recent study estimated the number of childhood deaths attributable to diarrhea in Ethiopia at 95,000 [6]. Moreover, "the percentage of children with diarrhea who receive ORT in Ethiopia is one of the lowest in the world" and "for all of Sub-Saharan Africa "lack of safe water, basic sanitation and hygiene may account for as much as 88% of the disease burden due to diarrhea" [6].

At the base of all risk factors in childhood morbidity and mortality issues is, without doubt, malnutrition.

> About half of all children under five are stunted (about six million children total), and about one-quarter are severely stunted. Eleven percent are wasted and 1% (a small proportion, but representing about 125,000 children) are severely wasted. As expected, rural children fare much

worse than urban children (for severe stunting, 27% versus 19%) as do children of uneducated versus well-educated mothers (28% versus 11%). [7]

Adult Mortality

The Ethiopian Demographic and Health Survey of (2000 and 2005) collected data on sibling mortality to arrive at an indirect mortality estimate of adult Ethiopians between the ages of 15 and 50 [8]. The survey reported an overall improvement in mortality with a modest reduction of 3% for adult females, and a suspicious figure of 26% reduction for males. The authors did not question the validity of such a massive decline in male mortality in just five years, but a figure of 26% is clearly inexplicable. Moreover, the erratic nature of the reported age specific rates point to inherent data errors leading to a lighter mortality at a higher age than at lower ages. For example, the rate for females aged 45 – 49, (year 2000) is lower than that of females aged 30 to 34. The reported age specific death rates (ASDR) are given in Table 7.4.

Table 7.4 Adult Age Specific Death Rate - ASDR (per thousand), 2000 and 2005.

Age Group	ASDR Female, 2000	ASDR Female, 2005	ASDR Male, 2000	ASDR Male, 2005
15 to 19	4.89	3.89	4.89	3.96
20 to 24	6.83	5.33	6.03	4.61
25 to 29	6.15	6.46	6.15	5.58
30 to 34	8.18	8.03	8.18	7.1
35 to 39	8.46	8.15	8.46	6.9
40 to 44	8.26	7.54	8.26	8.01
45 to 49	8.05	9.52	8.05	10.07

Source: DHS 2000, 2005

General

Death is a principal vital event. The three censuses and various sample surveys in Ethiopia have attempted to gather information about this event. There are also a few experimental vital registration systems in place to register the event at the time of occurrence, as opposed to the practice in censuses and surveys where death is reported up to a year after it has happened. Death statistics are needed for a number of reasons, including the need to know who dies, from what causes, in what numbers, etc. It also allows the understanding the correlates and determinants of the levels and trends of mortality in a country. Therefore, the collection, analysis, and publication of information on death is one of the fundamental responsibilities of any government, and a crucial starting point for any institution seeking to improve public health. Without statistics revealing current levels and past trends in death rates, it is impossible to make population projections.

The definitions, methodologies, and concepts presented below are modeled after those in one of the most comprehensive books on demographic techniques ever written, "*The Methods and Materials of Demography*", by Shryock and Seigel [9] and *Demography* by Preston et. al. [10]. The definition of death does not include deaths taking place before live birth has occurred. These are called ***fetal deaths***, and include ***stillbirths*** or deaths prior to the complete expulsion of the product of conception. The term ***miscarriage*** refers to accidental terminations of fetal life taking place early in the life of the fetus whereas the term stillbirth is often used as a synonym for fetal deaths occurring late in the pregnancy. The term ***abortion*****,** on the other hand, is used to refer to induced early fetal death [9].

Death statistics derived from censuses and surveys in Ethiopia suffer from a number of shortcomings including incomplete coverage of populations or geographic areas of the country or a region of a country. Places experiencing civil unrest and conflicts are often excluded, and excess mortality numbers in these areas due to violence and dislocation remain undocumented. Moreover, available financial resources and trained man-power has not been sufficient to achieve full canvassing of the entire country. Besides, Ethiopia is home to a number of nomadic groups who are perpetually on the move making it difficult, and at times impossible, for census takers or survey personnel to reach them. Moreover, a substantial portion of the population reached by censuses and surveys often fail to report a death event out of negligence, or because they do not fully appreciate the value of such information. Even those who make genuine efforts to report death might make errors on dates or place of death, and may not know the true cause of death.

It can be said that the close association between ***age*** and the probability of dying is the single most important determinant of the likely mortality experiences of any population. The gender (***sex***) of the deceased comes second in importance, followed by a number of other variables, including place of residence, marital status, socio-economic status, disability status, and the general characteristics of the community in which the person lived, together with the physical environment surrounding the community.

BASIC MORTALITY MEASURES

Newell [11] argues that "perhaps because death is a precise and easily definable event which occurs just once to each individual, the techniques for analyzing mortality have a longer history and are more developed than those for analyzing fertility". There are a number of measures we can use, some basic and others very complicated. Our goal here would be to focus on simple temporal and geographic measures of levels and variations in death among the various population groups in Ethiopia, as well as how this might be linked to changes over time, or spatial differences in socio-economic variables.

Crude Death Rate

First, we would like to point out the difference between ***reported rates*** computed directly from actual data, and ***adjusted rates*** in which modifications are made to reported numbers and rates; modifications involving the use of various assumptions and techniques. The simplest and most common mortality measure often presented in statistical reports by countries or international agencies is the crude death rate (CDR). The CDR measures the number of deaths in a population in a given year by relating the total number of reported or adjusted deaths to the total number of person-years lived by the population in which the deaths took place. This can be defined as follows [10]:

$$\textbf{\textit{CDR}}\ [0,T] = \frac{\textit{Number of death in a population between time } 0 \textit{ and } T}{\textit{Person-years lived in the population between times } 0 \textit{ ad } T} \times 1000$$

Table 7.2 Calculations of Crude Death Rates for Selected Countries in Africa, 2000.

Country	Population	No. Deaths	CDR	CDR per thousand
1	**2**	**3**	**4** **Col. 3 ÷ Col. 2**	**5** **Col. 4 x 1000**
Western Sahara	300,000	5,400	0.018	18
Niger	10,100,000	242,400	0.024	24
Ethiopia*	64,100,000	1,346,100	0.021	21*
Zimbabwe	11,300,000	226,000	0.020	20
Libya	5,100,000	15,300	0.003	3
Egypt	68,300,000	409,800	0.006	6
Nigeria	123,300,000	1,602,900	0.013	13
Reunion	700,000	3,500	0.005	5

Source: [12]

**** A lower estimate of 15 per thousand is given for the year 2005*** [2]

In Table 7.2 a diverse group of African countries have been chosen to demonstrate the calculation of CDR. Simple calculations shown in the table reveal that a given country (***A)***, with a larger population than another country (***B)***, does not necessary experience deaths in the same proportion as the proportional difference in populations. For example, Libya's population size is seven times as large as that of Western Sahara, but the number of people dying in Libya annually is only three times as high. Ethiopia's population size is only slightly larger than that of Egypt, but the number of annual deaths is three times as large. Nigeria has almost twice the population size of Ethiopia, but the annual number of people dying there is only 19 percent higher. This means that even basic mortality measures like the CDR can bring out spatial differences in mortality rates in various parts of Africa and within Ethiopia. Countries with high CDR such as Niger, Ethiopia, and Zimbabwe, have been selected together with low mortality countries – Libya, Egypt, and the island state of Reunion – to show the CDR measure's ability to effectively show spatial variations in the force of mortality.

Table 7.3 Reported Crude Death Rates for African Countries in (year 2008)

Country	CDR	Country	CDR	Country	CDR
Niger	18	Western Sahara	18	Senegal	10
Zambia	21	Botswana	14	Lesotho	25
Swaziland	31	Chad	17	S. Africa	15
Malawi	16	Burundi	16	Cameroon	13
Ethiopia	15	Liberia	18	Sudan	12
Sierra Leone	23	Benin	12	Togo	10
Guinea Bissau	19	Cote d'Ivoire	14	Ghana	10
Rwanda	16	Mali	15	Comoros	8
Uganda	16	Djibouti	12	Cape V.	5
Namibia	15	Congo	13	Sao Tome	8
Zimbabwe	22	Chad	16	Seychelles	7
Gambia	11	D.R of Congo	13	Mauritius	7
Angola	21	Gabon	12	Tunisia	6
Mozambique	20	Kenya	12	Algeria	4
C.A. Republic	19	Madagascar	10	Egypt	6
Somalia	19	Tanzania	15	Morocco	6
Guinea	14	Eritrea	10	Reunion	5
Burkina Faso	15	Mauritania	9	Libya	4

Source: [12]

A crucial fact about the crude death rates above is their extreme sensitivity to reporting errors. For instance, a census or survey in which only half the deaths in a population have been reported results in a crude death, which is only 50 percent of what it should be. Underreporting in which half the deaths have been missed is not uncommon in Africa. If we were to assume that the rates in Table 7.3 are the true rates for all of Africa, or that departures from the true figure are uniform across the continent, we will note the lighter mortality experience of Africa north of the Sahara. Algeria, Egypt, Libya, Morocco, and Tunisia, have a single digit CDR, with Libya's CDR representing the lowest mortality in Africa, and one of the lowest in the world. Only Kuwait has a reported CDR less than Libya's (2 deaths per thousand per year) [12]. A true contrast is witnessed when one crosses the southern border of Libya into Niger. Here the CDR is 18 per thousand, one of the highest in Africa, and in the world. In other words, a community of 1000 people in Niger will bury, this year, more than four times as many members as a community in Libya with identical population size. One has to travel further south, to Zambia, Zimbabwe, Zimbabwe, Angola, and Mozambique to encounter a similar condition of very high mortality. In each of these countries, 20 or more people die each year per one thousand inhabitants. Swaziland has the highest CDR in Africa and in the world – 31 per thousand. A few bright spots, other than Northern Africa, include the island nations of Mauritius, Reunion, Cape Verde, Seychelles, as well as Sao Tome and Principe.

Age-specific death rate ASDR

In any population, the frequency of a demographic event such as death is highly dependent on age. The crude death rate provides only a general indication of the level of mortality in a population. For this reason, it is necessary to compute age specific rates which still depend on the "count of events in the numerator and person-years in the numerator. However, the age range within which the events and person-years are to be tallied is restricted" [10], usually, to single-age groups, or five-year age groups. The age specific death rate can be defined as:

$$_nM_x[0,T] = \frac{\text{Number of deaths in the age range } x \text{ to } x+n \text{ between time 0 and } T}{\text{Number of person-years lived in the age range } x \text{ to } x+n \text{ between time 0 and } T}$$

The subscript x in $_nM_x$ refers to the age at the beginning of an age interval, and the subscript n to the length of the interval. For example $_5M_{45}$ is the age specific death rate between age 45 and 50 (or between ages 45.0000 and 49.9999…., to be precise), calculated with the number of annual deaths in that age group as a numerator, and the person-years lived by members of the population in that group as a denominator. It is important to note, however, that death rates need not be based on yearly totals of deaths and person-years lived. It is possible to calculate quarterly or monthly rates as well. It is also important to recognize the relation of crude death rates to the underlying age-specific death rates. A crude rate may be viewed as "…the weighted average of a set of age-specific death rates, the weights being the proportion of the total population in each age [9]. Infant deaths are customarily tabulated separately to produce another measure commonly reported in most mortality studies – the infant mortality rate (IMR). The United Nations recommends that infant deaths be further broken up to include those taking place in the first 28 days of birth and those happening during the rest of the first year, and that classifications be made on the basis of gender, month of death, and cause of death [9]. Classification by gender is also mandated for deaths at age 1 and greater than 1 due to the dissimilar mortality experiences of male and female babies and children.

The distribution of age-specific death rates, typically shows a bimodal pattern (Fig. 7.4) with peaks at age under 1 and at ages 65+ after which the numbers of survivors falls off rapidly to the terminal ages of the human life-span. We have chosen to use data from Sweden, and not Ethiopian data to draw the graph, for three reasons:

1) It has been almost a decade and a half since a national data on mortality by age was collected in Ethiopia. Moreover, given the rampant HIV/AIDS epidemic in

Ethiopia over the same period, it won't make much sense to use the 1994 census data.

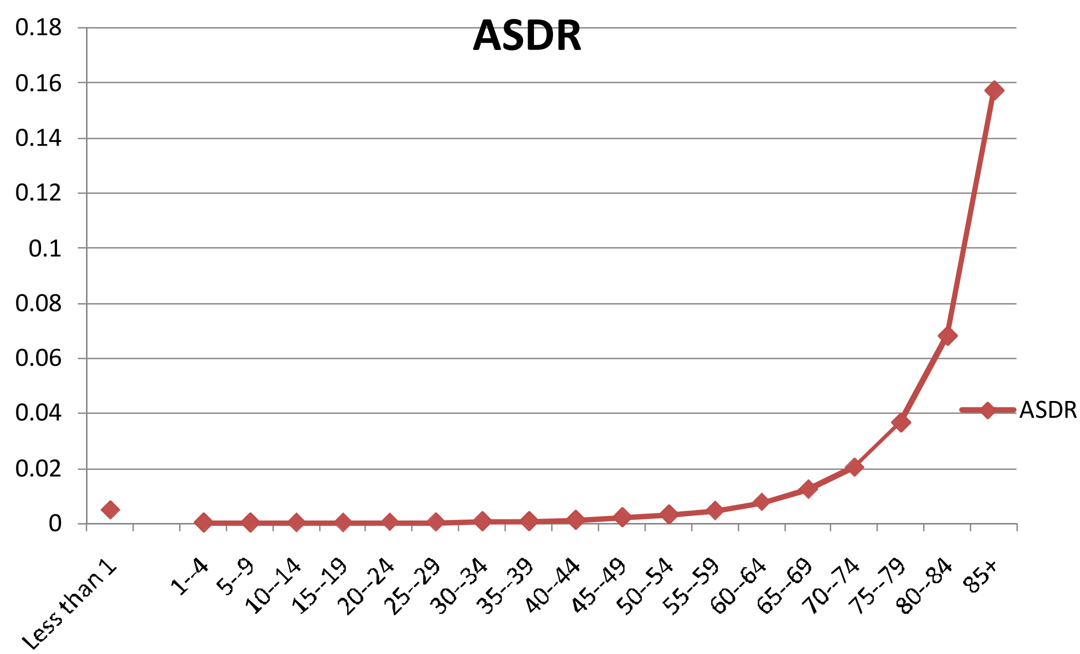
2) There is clear evidence of data errors with the 1994 census mortality data due to reporting problems, incompleteness of coverage, and other causes.
3) Sweden has achieved an almost "stable" population status (refer to Lesson 10 definition) with little yearly changes and shifts in age specific birth and death rates. In other words the age specific numbers in column 4 of Table 7.4 are most likely to apply today in their entirety.

Table 7.4 Calculation of Age Specific Mortality Rate and Crude Death Rate (Sweden, Females 1992)

Age Group	Mid-year population	No. Deaths	Death Rate
Less than 1	59,727	279	0.00467
1--4	229,775	42	0.00018
5--9	245172	31	0.00013
10--14	240110	33	0.00014
15--19	264957	61	0.00023
20--24	287176	87	0.00030
25--29	311111	98	0.00032
30--34	280991	140	0.00050
35--39	286899	197	0.00069
40--44	308238	362	0.00117
45--49	320172	643	0.00201
50--54	242230	738	0.00305
55--59	210785	972	0.00461
60--64	216058	1640	0.00759
65--69	224479	2752	0.01226
70--74	222578	4509	0.02026
75--79	184102	6745	0.03664
80--84	140667	9587	0.06815
85+	110242	17340	0.15729
All	4,385,469	46256	0.01055
CDR			10.54756

Source: Based on [10]

Fig 7.4 Graph of Age Specific Death Rate (Sweden, Females 1992)



Source: Based on [10]

It is useful to note that the crude death rate is determined by two important factors – the set of age specific death rates ${}_nM_x$ discussed above, and the proportions of populations in the various age groups. If the crude death rate depended on age specific death rates alone, the United States would have a much lower crude death rate than Egypt. In reality, however, the US crude death rate – 9 per thousand – is 33 percent higher than Egypt's. The lower CDR for Egypt reflects the effects of the second factor – differences in the proportionate age distribution of the two populations. Egypt has a "young" population, and the US has an "old" and "aging" population. In other words, a very large proportion of Egypt's population is concentrated in the younger age groups where mortality is very low, whereas the US population is heavily represented at the higher ages where mortality is high. It is also worth noting that the age distribution of a given population is itself shaped, among other things, by past levels of age specific death rates. It is possible to separate out the difference between Egypt and US's CDR that is due to differences in levels of mortality, and differences between the two attributable to age structure. The method often employed to achieve this is known as standardization. This involves re-calculating the CDR for one of the two countries by "borrowing" the age structure of the other. The difference between actual CDR and the CDR obtained in this way represents the portion of the mortality difference that is solely an artifact of differences in age structure. There are two types of standardization, *direct standardization,* and *indirect* *standardization*. Direct standardization is simpler and more straightforward. A demonstration is presented in Table 7.5 for Ethiopia (Oromiya females) and Sweden.

Table 7.5 Calculation of Age Standardized Crude Death Rate (Direct method)

Age	Ethiopia (Oromia F 1994)		Sweden, Population		Sweden Deaths	
Group	Population	Proportion	Actual	Expected	Actual	Expected
	1	2	3	4	5	6
0	259,446	0.0281	52,727 1	23,2322	79	567
1 – 4	1,162,628	0.1259	229,775	552,130	42	99
5 – 9	1,505,140	0.1630	245,172	714,832	31	93
10 – 14	1,304,803	0.1413	240,110	619,667	33	87
15 – 19	1,014,714	0.1099	264,957	481,945	61	145
20 – 24	732,536	0.0793	287,176	347,923	87	104
25 – 29	668,193	0.0724	311,111	317,363	98	102
30 – 34	534,411	0.0578	280,991	253,822	140	127
35 – 39	500,521	0.0542	286,899	237,726	197	164
40 – 44	399,230	0.0432	308238	189,613	362	222
45 – 49	256,814	0.0278	320,172	121,975	643	245
50 – 54	280,113	0.0303	242,230	133,041	738	406
55 – 59	136,644	0.0148	210,785	64,900	972	299
60 – 64	196,458	0.0212	216,058	93,309	1,640	708
65 – 69	81,931	0.0089	224,479	38,913	2,752	477
70 – 74	96,120	0.0100	222,578	45,653	4,509	925
75 – 79	34,575	0.0037	184,102	16,422	6,745	602
80 – 84	44,297	0.0048	140,667	21,039	9,587	1,434
85+	24,838	0.0027	110,242	11,797	17,340	1,856
Total	9,233,412	1.0000	4,385,469	4,385,469	46,256	8,662

Sources: [10, 13]

Columns 1 and 2 of Table 7.5 show the population sizes, by age, of Oromyia females and their proportionate distribution (col. 2) out of the total shown at the bottom. Columns 3 and 4 show the actual population distribution by age for Sweden, and the population numbers by age that would be observed in Sweden (col. 4) if it had the proportionate distribution by age of Oromo females of Ethiopia shown in column 2. Columns 5 and 6 show the actual numbers of deaths by age for Sweden, and the numbers that would be observed if Sweden had the same age structure as the Oromo females of Ethiopia respectively. The totals at the bottom for columns 5 and 6 also show the overall number of people dead in the actual count, and the number of deaths that would be observed in Sweden if it had the same age structure as female Oromos in Ethiopia respectively. The difference between the two is enormous, as is the implied difference in the CDRs. If

Sweden had the age structure of Oromo females of Ethiopia its crude death rate would drop from 10.5 per thousand to only 2 per thousand matching Kuwait's CDR which is the lowest CDR observed for any country in the world. The exercise, actually, helped us solve the mystery behind Kuwait's status as the country with the lowest CDR. It, simply, has the best of both worlds – the best health care system money can buy, financed by billions of dollars of petroleum export revenues, and a very favorable age structure composed of a young population. The best evidence for the latter comes from the fact that seventeen percent of Swedes are 65 years or older. Only one percent of Kuwaitis are in that category.

Infant Mortality Rate

The infant mortality rate (IMR) measures mortality levels at infancy. If is defined as the total number of infant deaths (D) in a given time period, usually a year, per 1000 births (B) during that period. Neonatal mortality refers to the death of infants during the first month of life. The constant (k) of 1000 is now universally adopted even though other numbers like 100 could be used. Thus:

$$IMR = {}_1M_0 = (D_0 \div B) \times 1000$$

$$\text{Neonatal mortality rate} = \frac{D_{0\text{-}3\ weeks} \times 1{,}000}{B} \quad \text{or}$$

$$\text{Neonatal mortality rate} = \frac{D_{<1month} \quad X \quad 1{,}0000}{B}$$

The infant mortality rate is a very useful measure of mortality, and a powerful indicator of the overall well being of the population it relates to. It is being increasingly adopted as an indispensable yardstick in the rating of countries on the socio-economic scale of descent living, with Canada often taking the number one spot. Generally, infant mortality is high in low-income countries such as those in Sub-Saharan Africa, and low in high income countries such as those in North America and Europe. In other words, there is a strong negative correlation between infant mortality and development. Hence, socio-economic development is the number one determinant of infant mortality variations in space and over time. However, the countries with low infant mortality mentioned above did not always have such low rates. For instance, mortality in United Kingdom was much higher at the start of the industrial revolution than it is today. As late as the 1930s several localities in the UK had infant mortality rates exceeding 85 deaths per thousand births per year [14]. The rate for the year 2007 in the UK is 10 infant deaths per 1000 births per year [15].

Similarly, the rates, in all Sub-Saharan countries have changed over time with most countries registering gains in the numbers and proportions of infants making it to their first birthday. It is, difficult however, to say with total certainty, or to accurately quantify the magnitude of reductions in IMR in various regions of Africa. A major impediment is the lack of reliable data on both the numbers of infants dying in the first 51 weeks of life, and accurate data on the numbers of births in a population. Very commonly, both the numbers of infant deaths (the numerator), and the births in a given year (denominator) are under reported. This would not cause a great deal of problems if the underreporting of the numerator and denominator took place in the same magnitude everywhere because the errors will, simply, cancel each other out. In reality, however, the proportions are different, and rarely, accurately known.

For the world, in general, infant mortality varies from a low of 2.6, 3.2 and 3.5 in Iceland, Singapore and Japan/Sweden, to 157 per thousand per year in Sierra Leone (the highest in the world). Western Sahara has the second highest infant mortality rate in the world. Half of the Sub-Saharan African countries are reporting triple digit infant mortality rates. Iraq with its crippling economic embargo, Haiti, and the war-torn countries of Afghanistan, Laos, and East-Timor, are the only nations outside of Sub-Saharan Africa with triple digit infant mortality rates. In other words, twenty two of the 27 countries with infant mortality in excess of 100 per thousand births per year, are in Sub-Saharan Africa (Table 7.6).

Table 7.6 Countries of Africa in Descending Order of Infant Mortality Rates per 1000 Births/Year (Year 2008)

Country	IMR	Country	IMR	Country	IMR
Sierra Leone	158	Zambia	100	Nigeria	100
W. Sahara	53	Eq. Guinea	91	Cape Verde	28
Liberia	113	Swaziland	85	Burundi	107
Mozambique	108	Burkina Faso	89	Kenya	77
Gambia	93	Tanzania	77	Sudan	81
Guinea Bissau	117	Guinea	113	Namibia	47
Malawi	80	Central Af. R.	102	Senegal	61
Somalia	117	Madagascar	75	Botswana	44
Angola	132	Benin	98	Ghana	71
Mali	96	Mauritania	77	Egypt	33
Niger	81	Gabon	58	Sao T & P.	77
Rwanda	86	Lesotho	91	South Africa	45
Ethiopia	77	Eritrea	59	Algeria	27
Djibouti	67	Uganda	76	Morocco	43
Cote d'Ivoire	100	Zimbabwe	60	Tunisia	19
Chad	106	Togo	91	Libya	21
Congo	75	Cameroon	74	Mauritius	15
D.R. Congo	92	Comoros	69	Reunion	8
				Seychelles	11

Source: [12]

The island states Reunion is the only independent country in Africa with a single digit infant mortality rate. Four Arab states north of the Sahara – Egypt, Algeria, Libya, and Tunisia - also have a relatively low infant mortality of less than 40 per thousand. With an infant mortality rate of 100 per thousand, the population giant – Nigeria – is facing the mortality of more infants in the general population than any other country in the world. The total populations figure shows that even though there were nearly two and a half times as many Americans as Nigerians, in just one year - year 2000 - Nigerians buried five times as many dead infants - close to a million - as Americans who only lost 192,500 babies. What is even more striking is the fact that Sierra Leone's population of only 5.2 million, (but with the highest infant mortality rate in the world), will produce 816,400 infant deaths this year. This is 4.2 times the number in the United States where the population size for the year 2000 was 275,600,000.

THE LIFE TABLE

The life table provides a statistical summary of the mortality experiences of a given cohort, usually a birth cohort. In its simplest form, the life table is derived from a set of age-specific mortality rates to measure mortality, survivorship, and life expectancy. Life tables allow, among other things, the combination of age specific mortality rates (and many other rates) into a single statistical model. Moreover, as can be observed from the forthcoming discussions, the effects of differences in the age structure of populations do not distort life table values. Life tables are commonly used in mortality analysis by demographers and other students of population as well as:

> "… public health workers, demographers, actuaries, and many others in the study of longevity, fertility, migration, and population growth, as well as in making projections of population size, and characteristics, and in studies of widowhood, orphanhood, length of married life, length of working life, and length of disability free life." [9]

There are two types of life tables. The first type combines the mortality experience of the population in a particular short period of time to give a cross-sectional view - a snapshot - of current mortality. This is known as ***period*** life table (also occasionally referred to as *current* life table). The second type known as, ***cohort*** life table or ***generation*** life table is based on real mortality experiences of a real cohort, e.g. all persons born in 1920 [9]. In this approach, the mortality experiences of all members of the cohort would be observed until the last person dies. The major shortcoming associated with latter method is that, it requires data gathering over a period of time lasting several decades just to complete a single table.

Life tables are also classified into two as ***abridged*** and ***unabridged*** (or complete). An unabridged life table contains data by single year of age, whereas an abridged life table presents data by intervals of 5 or 10-year age groups. According to Woods [14] the life table represents

"… a formalized departure from the concept of age specific mortality rates $_nM_x$. Instead of expressing the number of deaths to a mid-year estimate, the probability that a person aged x will die before reaching age x+n (symbolized by convention as $q_{x,x+n}$ or $_nq_x$) is considered. Thus q_0 is the probability that a newly born child will die during the first year of life; $_5q_{20}$, the probability that a person aged exactly 20 will die before reaching 25…"

The difference between the age specific death rates (ASDR) or ${}_nM_x$ and ${}_nq_x$ is, simply, that with ${}_nM_x$ the denominator is the population at the *middle* of the year, whereas in ${}_nq_x$ the population at the *start* of the year is used as a denominator. Generally, ${}_nM_x$ and ${}_nq_x$ will be very similar in value with ${}_nq_x$ slightly smaller in a population that is growing, and slightly higher in a declining population. Therefore, in the construction of life tables we have to adjust ${}_nM_x$s slightly to produce ${}_nq_x$s. The process of conversion is explained as follows by Newell (1988: p68, 69):

Let D_x be the number of deaths in the year of persons aged x.

Let N_X be the population age x at the start of the year.

Let P_X be the population aged x at mid-year.

Then: $q_x = \frac{D_x}{N_x}$

and $M_x = \frac{D_x}{P_x}$

In other words, N_x is just P_x plus persons dying between the beginning and the middle of the year. For most populations and most age groups the proportion of persons dying between the start of the year and the middle of the year is half ***(0.5D)*** of the total deaths for the whole year, because, given normal conditions, deaths will occur fairly evenly throughout the year.

Thus: $N_x = P_x + 0.5D_x.$

Placing D_x over both sides of the equation we get:

$$\frac{D_x}{N_x} = \frac{D_x}{P_x + 0.5_x}$$

$$= q_x = \frac{D_x}{P_x + 0.5_x}$$

Dividing top and bottom by P_x gives,

$$qx = \frac{D_x/P_x}{P_x/P_x + 0.5(D_x/P_x)}$$

$$= \frac{M_x}{1 + 0.5M_x}$$

If the ASDRs $({}_nM_x s)$ are expressed per 1,000, rather than 1, the equation becomes:

$$qx = \frac{M_x}{1{,}000 + 0.5M_x}$$

It is possible to obtain estimates of q_xs from a schedule of ASDRs $({}_nM_x s)$. "However, it is only an approximation and its accuracy depends on the extent to which reality differs from the assumption that those who died in the year lived, on average, half of a year during that year" [14]. A serious problem will arise, however, when trying to apply this method to the very young. At very young ages, mortality is highly concentrated in the early part of the year, and an assumption of an even mortality for the entire year will produce erroneous results. The fraction of the year lived by the very young is often denoted by a_x. Thus, from the equations above the formula for the probability of dying at very young ages would be:

$$q_x = \frac{M_x}{1 + (1 - a_x)\ M_x}$$

For five-year age groups (abridged life tables) the formula would be:

$$ {}_nq_x = \frac{n \, . \, M_x}{1 + (1 - {}_na_x) \, x \, {}_nM_x} $$

The a_0, a_1,... values vary from one country to another depending on overall levels of mortality and levels of childhood mortality. "For developing countries, where mortality is high, values of 0.3 for a_0, 0.4 for a_1 and 0.5 for all others are normally used. Where mortality is low, 0.1 is a better figure for a_0. In general, the values chosen are not critical, except for a_0" [14]. For high mortality populations an a_0 of 0.3, indicated that 70 percent (1.0 - 0.3 = 0.7) percent of infant deaths take place in the first half of the first year of life. An a_0 of 0.1 for low mortality countries suggests that 90 percent of infant deaths happen in the first half of the first year of life. These, often, represent deaths from congenital causes that medical science has not been able to prevent. Fortunately, the life table probability of infant deaths q_0 can be directly calculated without using the formula above as follows:

$$ q_0 = \frac{D0}{\text{Births in a year}} $$

$$ {}_nq_x = \frac{n \, . \, M_x}{1 + (1 - {}_na_x) \, x \, {}_nM_x} $$

As noted above, the difference between age specific death rates $({}_nM_x)$, and the probability of dying $({}_nq_x)$ is that the former is calculated with the mid-year population as a denominator, whereas in ${}_nq_x$ calculations the dead are "resurrected" (added back to the denominator) to reflect the probability of dying as of the beginning of the year. The ${}_nq_x$ values for ages greater than 5 are calculated by simply entering the ${}_nM_x$s for those ages, and then substituting the a_x value of 0.4 in the above example by 0.5. In this way, the ${}_nq_x$ column (the most important column in life table calculations) can be entered for all ages.

Computing the ${}_nq_x$ column is the most important exercise in the construction of abridged or unabridged tables. The quality of data used is also very crucial. Since this depends on the quality of the ASDRs, the overall reporting of the numbers of people alive and dead in a given age group becomes very critical. Erroneous data will distort all entries of the life table columns, and as shown in Table 7.6, the table has many columns.

Customarily, the first column (Table 7.6) is used to show the age interval chosen (single year, or 5 years, or 10 years). The second and third columns relate to the midyear population in that age group, and the number of people dead, respectively. The fourth and fifth columns, usually, relate to ASDRs and probabilities of dying $({}_nq_x)$ respectively. The sixth column ${}_np_x$ is simply the complement of values in the fifth column (i.e. ${}_np_x = 1 - {}_nq_x$). The seventh column l_x, is different from the functions entered in columns discussed so far in that it refers to an exact age, and not to age intervals. It is defined as the number still remaining alive at an exact age x out of the original cohort denoted by l_0 [9]. The size of an original cohort (l_0) is determined arbitrarily, the most commonly used number being 100,000. Others numbers such as 1000 or 1 could also be used. The observed mortality rates in a population are applied to this hypothetical cohort, known as the *radix*, with individual members being given a measured “mortality dose” until the last surviving member dies. The “dose” often depends on the overall mortality levels in the population which, in turn, determines the mortality at a given age. Catastrophes such as war, or a fatal childhood disease, which selectively affect given age groups could lead to a significant disconnect between overall mortality in the population and the age specific rates for the affected age groups. In sum, the construction of a life table combines the use of real observed numbers and rates, as well as a hypothetical cohort to be subjected to the force of mortality represented by those numbers.

The first step in calculating l_x is to chose a suitable radix and then obtain the numbers of individual members of a cohort using the formula:

$$l_x = l_{x-n} \times {}_nP_{x-n}$$

For example, in Table 7.6 $\mathbf{l_{10} = l_5 \times {}_5P_5}$ = 82956 x 0.9824 = 81496. Preston [10] reminds us that “some functions (l_x, T_x, e_x) refer to a single (exact) age, while other functions $({}_nd_x, {}_np_x, {}_nq_x, {}_nm_x, {}_na_x)$ refer to age intervals that begin with exact age **x** and extend for exactly **n** years”.

Table 7.7 Life Table Values for Addis Ababa, Ethiopia (Females)

Age	$_nM_x$	$_nq_x$	$_nP$	l	$_nd_x$	$_nL_x$	T_x	e_x
0	0.1191[a]	0.1103	0.8897	100000	11030	92610	5071698	50.71
1 - 4	0.0177[b]	0.0676	0.9324	88970	6014	339954	4979088	55.96
5 - 9	0.0036	0.0176	0.9824	82956	1460	411128	4639134	55.92
10 – 14	0.0026	0.0129	0.9871	81496	1051	404848	4228006	51.88
15 – 19	0.0045	0.0222	0.9778	80444	1786	398062	3823156	47.53
20 – 24	0.0062	0.0304	0.9696	78658	2391	387462	3425094	43.54
25 – 29	0.0064	0.0316	0.9684	76267	2410	375327	3037632	39.83
30 – 34	0.0068	0.0334	0.9666	73857	2467	363180	2662305	36.05
35 – 39	0.0077	0.0380	0.9620	71390	2713	350303	2299125	32.21
40 – 44	0.0093	0.0454	0.9546	68678	3118	335810	1948822	28.38
45 – 49	0.0119	0.0577	0.9423	65560	3783	318680	1613012	24.60
50 – 54	0.0161	0.0774	0.9226	61777	4782	297389	1294332	20.95
55 – 59	0.2209	0.1049	0.8951	56995	5979	270645	996944	17.49
60 – 64	0.0329	0.1523	0.8477	51016	7770	236382	726299	14.24
65 – 69	0.0480	0.2150	0.7850	43247	9298	193657	489916	11.33
70 – 74	0.0751	0.3161	0.6839	33949	10731	142979	296259	8.73
75 – 79	0.1046	0.4139	0.5861	23217	9610	91850	153281	6.60
80 – 84	0.1921	0.6326	0.3674	13608	8608	44806	61430	4.51
85 – 89	0.2750	0.7640	0.0.236	4999	3820	13888	16624	3.33
90 – 94	0.4228	0.8898	0.1102	1180	1050	2483	2737	2.32
95 – 99	0							

Source: [16]

[a] $_1a_0 = 0.330$ [b] $_4a_1 = 1.352$

In table 7.6 $_n\mathbf{d}_x$ relates of the number of persons in the original cohort dying between ages x and ***x+n***. Thus, $_n\mathbf{d}_x = \mathbf{l}_x - \mathbf{l}_{x+n}$. In words, this means that the number of deaths between a given age x and ***x+n*** equals the difference between the number of persons in the original cohort surviving to age x and the number surviving to age ***x+n.*** The $_nd_x$ column can also be calculated using the formula: $_nd_x = lx \text{ x } {_nq_x}$. In words, this means that the number of life table deaths between ages ***x*** and ***x+n*** equals the number of persons in the original cohort of 100,000 surviving to age x, multiplied by the probability of dying between those ages. For example, in Table 7.6 $_5d_{50} = l_{50} - l_{55} = 61777 - 56995 = 4782$. The same answer is obtained when the second formula is used: $_5n_{50} = l50 \text{ x } {_5q_{50}} = 61777 \text{ x } 0.0774 = 4782$. The next column, $_nL_x$ is defined as the number of person-years lived between ages x and ***x+n***. It is calculated by adding the product of the mean number of person-years lived by those dying in the interval ***($_na_x$)*** and the number of members of the cohort dying in the interval ***($_nd_x$)*** to the number of person-years lived in the interval by the members of the cohort who survive the interval ***($n.l_{x+n}$).*** In other words ***$_nL_x = (n \times l_{x+n})\ (_na_x + {_nd_x})$.*** Using the example in Table, we can calculate $_5L_{10}$ (the person years-lived between ages 10 to 15) for Addis Ababa, Ethiopia as follows:

$_5L_{10}$ = (n x l_{15}) + ($_5a_{10}$ x $_5d_{10}$)
= (5x 80444) + (2.5 x 1051)
= 402220 + 2628
= 404848

Perhaps the easiest column to calculate is the ***T_x*** column. All it takes is summing the ***$_nL_x$*** values from the bottom of the table upwards. It is defined as the person-years lived by members of the life-table cohort above a given age x. For example, T_{75} in Table 7.6 is the sum of ***$_5L_{100}$, $_5L_{95}$, $_5L_{90}$, $_5L_{85}$, and $_5L_{80}$***. Thus, T_{75} = 16 + 238 + 2483 + 13888 + 44806 + 91850 = 153281. The column most commonly referred to in population studies, including geographical studies, is the last one ***(e_x).*** In fact, the values in all other columns are calculated to obtain this last column, which shows the expectation of life at a given age ***x***. "It refers to the average number of additional years that a survivor at age ***x*** will live beyond that age" [10]. It is easy to calculate using the formula ***$e_x = T_x/l_x$.*** For example the ***e_{35}*** for Addis Ababa equals 2299125 divided by 71390, which is equal to 32.2. In other words a 35 year old female in Addis Ababa, Ethiopia can expect to live 32.3 years longer.

Table 7.8 Life Expectancy at Birth (e_0) for African Countries (Year 2008)

Country	e_0	Country	e_0	Country	e_0
Libya	73	Nigeria	47	Namibia	47
Reunion	76	Senegal	62	Somalia	48
Mauritius	72	Gabon	57	Ethiopia	49
Seychelles	76	Madagascar	58	Guinea	54
Algeria	72	Sudan	58	Guinea Bissau	45
Morocco	70	Liberia	46	Sierra Leone	48
Tunisia	74	Benin	56	Gambia	58
Cape Verde	71	Equatrl. Guinea	59	Congo Dem. Rep	53
Egypt	72	Togo	58	Botswana	43
Sao Tome & P.	64	Kenya	53	Uganda	48
Comoros	64	D. Rep. Congo	49	Niger	57
Ghana	59	Djibouti	54	Mozambique	43
South Africa	50	Chad	47	Zimbabwe	40
Eritrea	57	Congo	53	Malawi	46
Central Af.R.	43	W. Sahara	47	Rwanda	47
Mauritania	60	Burkina Faso	51	Swaziland	33
Lesotho	36	Cote d'Ivoire	52	Zambia	38
Tanzania	51	Burundi	49	Cameroon	52
Mali	56	Angola	43		

Source: [12]

The e_0 values in Table 7.8 show great variations in the life expectancy at birth for the countries of Africa, but many of these values cannot be taken at face value since their validity depends greatly on the quality of data they have been derived from. For example, it is difficult to justify the 17 percent higher life expectancy reported for Eritrea than for Burkina Faso and Cote d'Ivoire. Reunion, with a life expectancy of 76 years and Swaziland with less than half of that, represent the extremes upper and lower limits for Africa. The low rate for the latter can be blamed on HIV/AIDS and economic stagnation. The reasons behind the high rate in Reunion are less straightforward. Overall, the rankings based on infant mortality rates (Table 7.6) and those in Table 7.8 reveal the expected negative relationship between infant mortality rates and life expectancy at birth. That is to say, generally speaking, countries with high infant mortality rates, have low life expectancy at birth, and vice versa. This can be easily understood from the way life expectancies are computed in Table 7.7. High infant and childhood mortality rates result in high ${}_nd_x$s and low l_xs at early ages. This in turn results in lower ${}_nL_x$s and, ultimately lower T_xs, which result in lower e_0 values. This does not mean, however, that e_0 values are only affected by mortality in the early years of life. The precipitous drops in life expectancies in Southern and Eastern African countries following the devastating effects of HIV/AIDS is testimony to the sensitivity of e_0 to changes in adult mortality rates also. This will be discussed in more details in the chapter on HIV/AIDS.

THE STABLE POPULATION AND STATIONARY POPULATION

The ${}_nL_x$ column in Table 7.7 can be thought of as a stationary population with a constant size and age structure. There are two reasons for this: "First, its size is T_0. Secondly, there are l_0 babies being born each year, and, since the population size is unchanging, exactly the same number of persons are dying " [14]. Any population can be thought of a stationary population by making the following three assumptions:

a) Constant age specific death rates over time (but usually not for the age groups),
b) Constant birth rates in which the same number of births are added to the population per unit of time regardless of the unit of time used.
c) Zero Net migration at all ages (in effect, the population is assumed to be closed). Thus:

A stationary population will result from the indefinite continuation of a constant number of births (constant per day, month, and year), a constant life table, and zero migration at all ages. Such a population will have a constant age structure and certain simplified relationships among demographic parameters. For example, the birth rate of a stationary population is the reciprocal of life expectancy at birth. In a stationary population short-cut methods of demographic accounting can often be employed [10]

The assumptions above allow researchers to compute differences between what is observed in a real population as compared to an imaginary life table (stationary) population. Moreover, since stationary populations do not grow or shrink (hence, the word stationary) observed growth or decline in a given population represents the extent of departures from a stationary setting. A small departure represents a population approaching a stationary status, while greater departures indicate a situation far removed from conditions of constant fertility mortality and migration. Some populations around the world are beginning to become stationary, with insignificant changes in fertility or mortality. Only net migrations are keeping them from becoming truly stationary. None of the countries of Africa can be placed in this category, however. Widening gaps between birth rates and death rates during the past decades has resulted in substantial population increase in almost all of the countries of Africa. Stationary populations do not grow, they remain stable. In other words, all stationary populations are also stable populations. All stable populations are not stationary, however.

A population could be stable but growing or shrinking. "Unlike the life table population, which is stationary, as well as stable …[a stable population] may increase or decrease in absolute numbers" [9]. For example, a population could remain stable with constant mortality and migration, but increasing birth rates, provided the latter are growing at a constant annualized growth rate.

The stable population model is used by demographers to demonstrate the long-term implications of maintaining short-term demographic patterns and also to identify the effects of changes in one parameter on the value of others. It is the device that demographers use most frequently to study how the different components of population structure and processes are connected to one another. It has also been used to estimate the trajectories of demographic elements in populations that can be assumed to be stable. [10]

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