Mortality

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The scientific study of demography began with the investigation of mortality. Graunt's (1662/1975) classic study, *Natural and Political Observations Mentioned in a Following Index and Made upon the Bills of Mortality*, first published in 1662, is usually considered the starting point of the statistical study of deaths and demography. The Bills of Mortality for London originated early in the 16th century and provided weekly statistics of total burials for each church parish, the number of deaths attributed to plague, and the total number of births registered by baptisms in church records. The interest in compiling these statistics seems to have been a desire to monitor the geographical incidence of deaths from plague.

Graunt's study was followed by other isolated and fragmented studies of mortality based on church records in various parts of Europe until the 19th century. In 1837 civil registration of births, deaths, and marriages was established in England and Wales. William Farr, the newly appointed Registrar General, recognised the need for a uniform classification of causes of death to identify patterns of mortality and trends over time. He set about formalising the collection and tabulation of annual mortality statistics. Farr 's proposed system of classifying deaths was accepted by the International Statistical Congress in 1855 and has survived as the basis of the classification of causes of death in the International Classification of Diseases, with the 11th revision (ICD-11) adopted in 2019 (WHO 2020a). Appendix A to this chapter provides more information on ICD-11, including a list of chapters.

Mortality has declined consistently since Graunt's and Farr's times, and continues to decline despite major increases in non-communicable diseases and associated health risk factors such as smoking and obesity. As will be discussed below, decreases in infant and child mortality, and reduction in infectious disease mortality through antibiotics and vaccination, as well as reductions in non-communicable disease mortality through advance medical technology and public health, are the main contributors to this decline.

A significant consequence of declining mortality is that life expectancy increases, which results in ageing of the population. As ageing is associated with the accumulation of chronic disease, population ageing coupled with increasing

[1] This chapter draws on Diamond, Ian and McDonald, Peter, 1994. 'Mortality', in D. Lucas and P. Meyer (eds), *Beginning Population Studies*, National Centre for Development Studies Centre, Australian National University, Canberra:29-43.

multimorbidity presents major public health challenges worldwide. With medical advances and greater access to health care, mortality is being compressed into older ages.

SOURCES OF MORTALITY DATA

Mortality statistics underpin evidence used for population change and population health, and policy development and service planning. The reasons demographers study mortality today are similar to those in Graunt's original study:

- to identify levels and trends of mortality and measure progress
- to compare mortality between different populations
- to identify patterns and trends for causes of death by demographic characteristics
- to better understand the differential impact of societal, economic, behavioural and environmental factors.

The ‘gold standard’ for mortality statistics is a complete civil registration and vital statistics system (CRVS), as discussed in the Population Data chapter. While these systems are ideal, they are expensive to implement and maintain. Consequently, there are huge gaps in the availability and quality of civil registration and vital statistics data. Recent evaluations of the strengths of CRVS are presented by Lopez and Setel (2015), Mikkelson et al. (2015) and Rao (2019).

A CRVS system can provide a foundation for reliable and comprehensive progress towards key development indicators such as the Sustainable Development Goals (SDGs), and planning and monitoring of public health policy and services, if integrated with a functioning health information system and other sources such as censuses and population registers.

Worldwide, around two-thirds of deaths occur in the community, outside of a hospital setting. About half of these are never registered and community death registration, when it occurs, is usually of poor quality, largely due to lack of medical certification and knowledge of the cause of death. Consequently, much information about deaths and their causes is missing (Adair et al. 2020). This can result in bias, for example, undercounting deaths due to non-communicable diseases in poorer areas, and more recently, due to COVID-19.

In China, mortality and causes of death are estimated using nationally representative samples selected across multiple disease surveillance points (DSPs). While the DSPs cover around 1% of the Chinese population, there is sufficient confidence in the use of these deaths data for broad disease groupings, for example monitoring tobacco-related deaths (Yang et al. 2005).

Similarly, mortality statistics for India are derived from sample registration covering around 14 million people. Known as the ‘Million Death Study’ it is used to monitor the underlying cause of premature child and adult deaths as well as associated behavioural, physical and environmental risk factors. The resulting

data have been used to monitor progress towards SDGs for India as well as for policy translation to improve public health programs (Gomes et al. 2017).

Recognising the need to strengthen national CRVS and related systems around the world, the Global CRVS Group—a collaboration of international agencies—was formed in 2014 to enable countries to plan, develop and implement reliable and accurate administrative systems for monitoring population health (United Nations 2014). The proportion of deaths registered worldwide increased from 36.2% in the early 1980s to 38.6% by the mid-2000s (Mikkelsen et al. 2015). India increased death registrations from 52 to 67% during the first decade of this century, despite having a weaker registration system. Rao (2019) reported that 82 out of 195 (41%) of countries had almost no mortality data suitable for measuring mortality and burden of disease. Not all CRVS systems are fully functional or complete. For example, less than 20% of African countries have complete deaths data coverage with CRVS (UN Statistics Division 2016, see also WHO 2020b).

MEASURING MORTALITY

There are many approaches to measuring mortality and tabulating causes of death for comparisons between populations and over time. The choice of an appropriate index for making comparisons requires great care, especially when interpreting differences between different populations and changes over time. This section describes commonly used mortality indicators, with a focus on three important measures: crude and age-specific death rates, infant mortality rate and life expectancy.

Crude and age-specific rates

The crude death rate (CDR) measures the number of deaths per population (usually per 1,000 or 100,000 population) during a given year. While this measure is straightforward, it has limitations.

The CDR for selected countries with different levels of economic development, population size and geographic location is shown in Table 1. This measure varies between countries and over time. For example, in 2010-2015 Sweden experienced 9.5 deaths per 1,000 population whereas this rate was much lower for Costa Rica (4.7), Egypt (6.1) and Indonesia (6.5). This gives the impression that mortality is greater in Sweden, a high-income country with a coordinated and accessible health system, compared to these low-income countries. The reason underlying this misconception relates to the age structures of the population. The Swedish population is much older with 25.3% of its population aged over 60, compared to 10.1% in Costa Rica, 8.6% in Egypt and 7.9% in Indonesia.

Disease and death are positively related to age, thus mortality rates depend on the age structure of the population. Mortality also varies between sexes, with

males usually being at higher risk of dying than females. CDRs provide a useful measure of the overall incidence of death in a population, but cannot be used to compare populations that have different underlying age structures. To make sense of CDRs, additional steps are required to account for the effects of age and sex.

TABLE 1: Crude death rates, under-five mortality rates and life expectancy at birth, selected countries

Country	Crude death rate			Under-five mortality rate			Life expectancy at birth		
	1960–1965	1985–1990	2010–2015	1960–1965	1985–1990	2010–2015	1960–1965	1985–1990	2010–2015
Afghanistan	30.8	16.5	7.5	342.0	191.3	81.0	33.7	48.6	62.3
Australia	8.7	7.2	6.5	23.5	10.4	4.3	70.9	76.2	82.4
Bangladesh	19.3	11.4	5.6	241.4	155.6	41.0	46.7	56.7	70.8
Brazil	12.6	7.3	6.1	154.2	66.6	18.4	55.4	65.4	74.3
Cambodia	21.5	14.1	6.3	199.6	118.4	35.0	41.4	52.0	67.6
Canada	7.7	7.0	7.3	30.2	9.0	5.3	71.3	76.8	81.8
Chile	10.9	5.6	5.8	132.1	21.5	8.5	58.3	72.7	79.3
China	20.7	6.7	7.0	210.0	53.5	14.3	44.6	68.9	75.1
Costa Rica	9.3	4.0	4.7	112.3	20.5	11.4	62.0	75.1	79.2
Denmark	9.8	11.5	9.5	23.6	9.7	4.1	72.4	74.7	80.1
Egypt	18.3	9.1	6.1	277.7	102.2	24.2	49.3	63.5	70.8
Ethiopia	23.5	19.0	7.6	269.8	212.3	67.9	40.1	46.2	63.7
Fiji	7.8	6.5	8.2	69.5	32.0	24.2	61.5	65.4	66.9
Finland	9.4	9.9	9.5	23.2	7.2	2.7	69.1	74.8	80.7
France	11.3	9.6	8.7	29.1	9.6	4.2	70.7	76.1	81.9
India	20.9	11.6	7.3	231.7	133.5	49.4	42.9	56.7	67.8
Indonesia	17.9	8.8	6.5	207.9	93.2	30.1	48.2	61.3	70.0
Japan	7.2	6.3	9.8	31.7	6.7	3.0	69.2	78.5	83.3
Laos	19.8	14.5	7.0	234.4	157.4	60.5	44.0	52.4	65.5
Mexico	11.5	5.7	5.5	134.3	48.4	17.5	58.5	69.8	74.9
Mozambique	23.6	20.5	11.6	272.7	246.6	90.0	40.5	44.4	54.2
Myanmar	20.7	11.5	8.5	232.7	114.0	56.6	43.7	56.0	64.7
Nepal	26.2	14.2	6.7	310.6	158.2	41.5	36.6	52.3	68.6
Netherlands	7.8	8.5	8.3	20.1	9.0	4.1	73.5	76.7	81.3
Peru	17.1	7.7	5.3	212.6	94.0	18.1	49.6	64.6	75.1
Philippines	9.0	6.8	5.8	96.2	66.0	30.2	62.0	65.2	70.2
Russia	8.1	11.1	13.4	47.9	28.2	10.2	67.9	69.1	70.3
Sierra Leone	31.7	24.6	13.7	379.1	265.2	136.6	32.5	39.7	51.4
Spain	8.8	8.2	8.5	48.5	10.1	3.5	69.9	76.9	82.5
Sri Lanka	10.7	6.5	6.2	94.9	32.0	10.1	60.3	68.9	75.9
Sweden	10.0	11.2	9.5	18.2	7.3	2.9	73.5	77.2	81.9
Thailand	12.3	5.6	7.3	132.7	41.5	11.7	56.0	69.8	75.2
United Kingdom	11.8	11.5	9.0	25.3	10.6	4.7	71.0	75.1	80.9
USA	9.4	9.0	8.2	29.1	12.3	7.0	70.1	74.9	78.9

Source: United Nations 2019

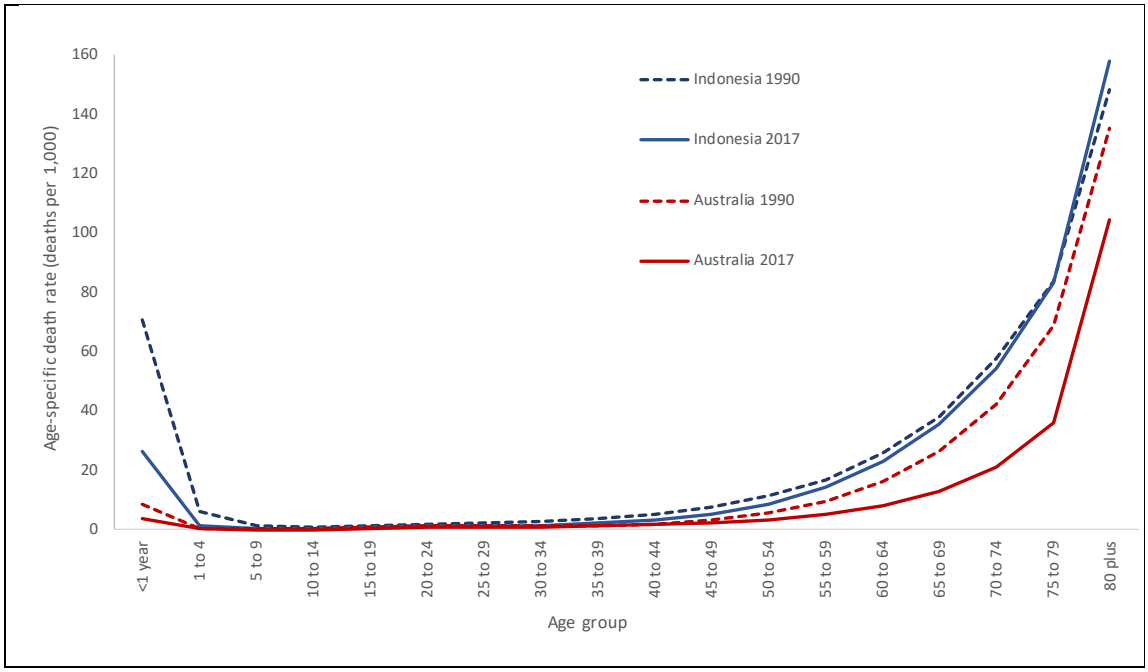
One method is to compare age-specific rates for each population. These rates are like the CDR but for each age group in the population. Age-specific mortality

rates provide a useful measure of mortality because the risk of death is different at different ages.

While multiple comparisons of age-specific mortality rates can quickly become unwieldy, comparisons can be readily visualised using a mortality curve. The curve in Figure 1 shows the age-specific probability of dying for males in Indonesia and Australia in 1990 and in 2017. The shape of a mortality curve is typically like a 'J' with higher mortality rates among infants followed by a decline in death rates during the childhood years, then slow increases through adulthood and accelerated increases in older ages.

The rates shown here for Indonesia are typical of a country with high mortality. Note that infant mortality (under 1 year) and child mortality (1-4 years) in Indonesia were much higher in 1990 compared with 2017. At all ages for both years, mortality rates are higher in Indonesia compared with Australia, a country of low mortality overall.

FIGURE 1: Age patterns of mortality for males, Australia and Indonesia, 1990 and 2017



Source: Institute for Health Metrics and Evaluation 2018.

While the Indonesian curve seems to approach that of the Australian curve over time, the acceleration of mortality rates occurs at earlier ages in Indonesia compared to Australia. Looking at the differences over time in Australia, the pattern is typical of an ageing population: a delay in mortality until the oldest ages, indicated by the start of a rapid incline in mortality at age 75-79 years. In this

figure, mortality rates in Australia in 2017 at ages 75-79 years were around 36 deaths per 1,000 while in Indonesia this rate was reached by ages 65-69 years.

To make meaningful comparisons between populations, it is essential to account for differences in the age composition of each population of interest. This is done using a technique called *standardisation* (Palmore and Gardner 1983; Carmichael 2016). This process adjusts the age-specific rates in each population to a specified standard structure. As a result, the age-standardised rate is independent of age and can be used to compare mortality between population groups and at different times. Any population can be used as the standard, provided the same standard population is used to calculate all rates being compared. In Australia, mortality rates are usually standardised to the Estimated Resident Population for 2001, but other standard populations, such as from the World Health Organization (WHO) or the Organisation for Economic Co-operation and Development (OECD) could be used.

While age-standardised rates provide a useful summary index for comparing populations, they can overlook important age-specific patterns in mortality. A *life table* (see below), defined as the detailed description of the mortality of a population, includes the age-specific-probability of dying at a given age, as well as other age-specific statistics (Pressat 1985).

Child mortality

Another important measure of mortality is child mortality or under-5 mortality (U5MR), defined as the ratio of the number of deaths of children aged less than 5 years during the year to the number of live births occurring during the same year. Strictly speaking, the U5MR is a measure of the probability that a child born in a particular year will die before reaching their 5^{th} birthday. It is a key global indicator of child health and is usually derived from a life table where mortality rates are constructed from CVRS, censuses or surveys.

The WHO and United Nations routinely collect information from countries for infant and child mortality. These data are used to evaluate progress in countries' development (e.g. SDGS) and to indicate the vulnerability of populations.

In the selected countries shown in Table 1, Afghanistan, Nepal and Sierra Leone had the highest U5MRs in 1960–1965. The U5MR declined successively over the periods for all countries shown in Table 3.1. Considering change between 1985-1990 and 2010-2015, the most spectacular reductions in U5MR were for Peru (from 94 to 18 deaths per 1,000 live births), Egypt (102 to 24), Nepal (158 to 41) and Bangladesh (156 to 41).

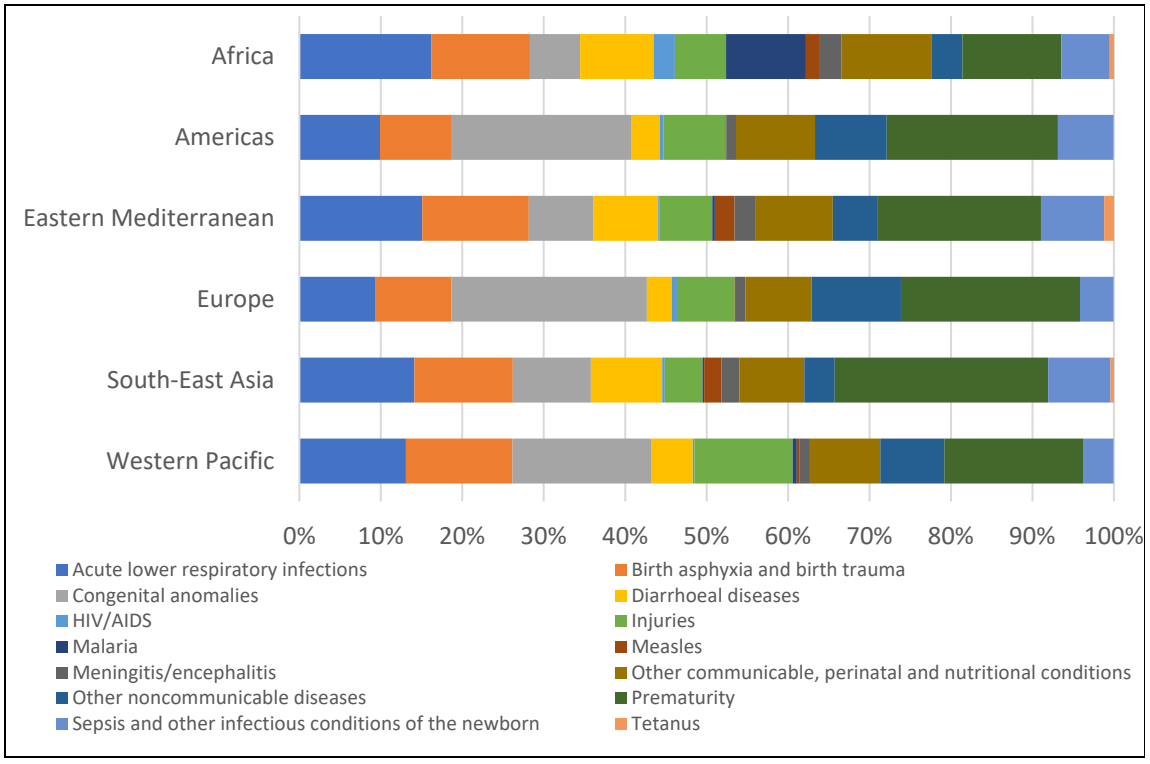
High income countries typically have the lowest U5MRs; as shown in Table 1, the rates for Sweden, Iceland and Finland are all less than 3 deaths per 1,000 live births. While there have been substantial declines for child mortality, regional

disparities remain. Sub-Saharan Africa remains the region with the highest probability of death among children less than five years.

As well as being an indicator of child health, the U5MR is a sound gauge of the overall health and well-being of the population. It is an SDG indicator measuring the progress of countries towards reducing U5MR to fewer than 25 deaths per 1,000 live births. By 2017, 118 countries had already achieved this goal. However, around 5.4 million children still die each year before reaching their 5th birthday; about half of these deaths occur in sub-Saharan Africa and almost one-third in Southern Asia (United Nations IGME 2020).

Most deaths in childhood occur within one year from birth and are characteristically different from deaths that occur at older ages. Deaths in the first weeks of life are usually due to those occurring in the womb, such as congenital malformations, restricted fetal growth or a medical condition in the mother, whereas those later in the first year are largely the result of the environment, such as infectious diseases and diarrhoea. Most child deaths are preventable or amenable to treatment.

FIGURE 2: Distribution of causes of death, children under five, by WHO region, 2017



Source: WHO 2020c

The risk of dying from different causes varies by region. Figure 2 shows the distribution of causes of child deaths in different regions. Malaria caused nearly

10% of child deaths in Africa, but less than 1% in all other regions. HIV/AIDS resulted in around 3% of child deaths in Africa but fewer than 1% in other regions. The Western Pacific region had the highest percentage of child mortality from injuries (12%) while it was less than 8% in all other regions. The proportion of children dying of congenital anomalies was highest in Europe (24%) and the Americas (22%), compared to Africa (6%). This does not mean that children in Europe and the Americas are more likely to have congenital anomalies, but rather that of all the children who die under 5 years of age, a higher proportion are dying from congenital abnormalities than say, communicable diseases.

Globally, it is predicted that 52 million children under five years of age will die between 2019 and 2030 with half of these deaths being of newborns. While many interventions improve infant survival, many newborn deaths can be prevented by attaining a high coverage of quality antenatal care, skilled care at birth, postnatal care for mother and baby and care of sick newborns. Other interventions that have been shown to improve infant and child survival include oral rehydration salts to treat diarrhoea, promotion of breastfeeding and extensive immunisation programs. In addition, major improvements in public health and sanitation are important for reducing disease and consequently infant and child mortality.

Life expectancy

The last measure of mortality considered here is life expectancy, which can be expressed as life expectancy at birth, or life expectancy at other ages. Life expectancy at birth is a summary index obtained from a life table and indicates the average number of years that people can expect to live from the time of birth if they experience the prevailing age-specific death rates throughout their lives. Life expectancy at birth for selected countries is shown in Table 1 and again illustrates the differences between developed and less developed nations. It is independent of the age composition of a population because the expectation of life is based on application of age-specific mortality rates to a hypothetical population, and thus provides a more reliable basis for international comparisons of mortality than the CDR. Life expectancy at birth is heavily influenced by infant and early childhood mortality, because these deaths mean the loss of a whole lifetime with a potential length of 70 to 80 years. As such, countries with high infant mortality have low life expectancy at birth.

The life table is a basic tool of the demographer and permits the calculation of the average number of years that persons can expect to live from their current age. Table 2 shows life expectancy at different ages for Australian males and females. It shows that at all ages, female life expectancy is longer than male life expectancy, and life expectancy has increased at each age in each time period. An Australian male aged 45 years in 1975-1977 expected to live 28.3 more years (that is to age 73.3). However, if he survived 20 more years to age 65 (around 1995-1997, by which time mortality rates had fallen) he could expect to live a further 16.1 years (to age 81.1 years).

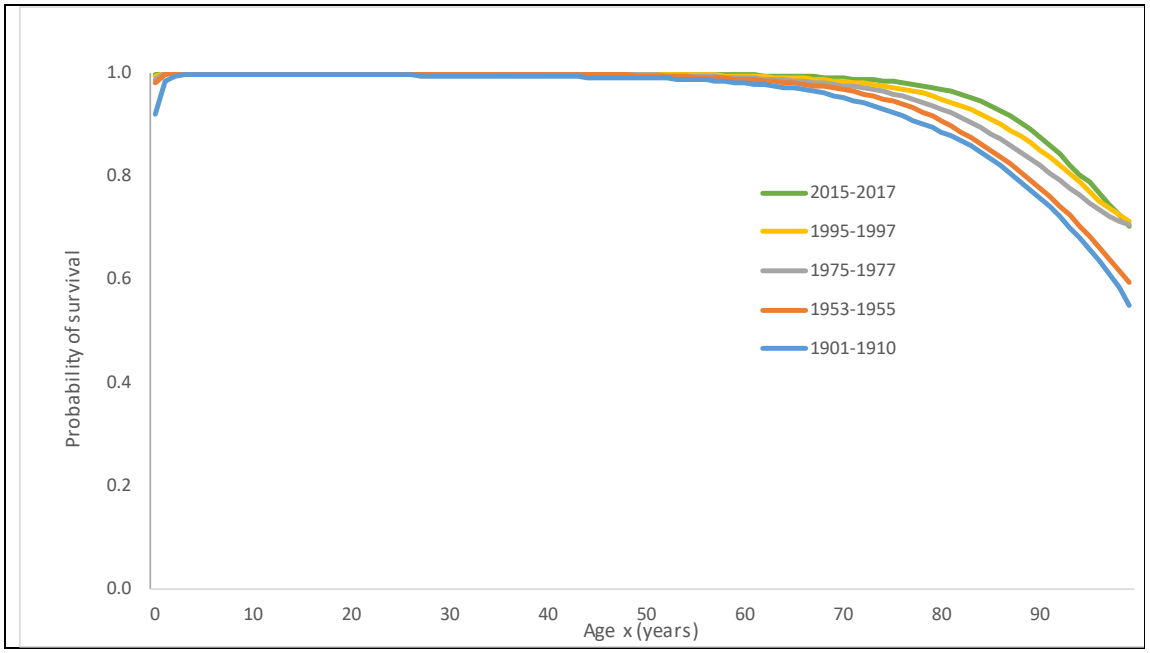
TABLE 2: Life expectancy (years) at ages 0, 25, 45, 65 and 85 years for Australian males and females, each decade 1965-1967 to 2015-2017

	Males					Females				
	0	25	45	65	85	0	25	45	65	85
1965-1967	67.6	45.4	27.0	12.2	4.1	74.2	51.2	32.3	15.7	4.9
1975-1977	69.6	46.9	28.3	13.1	4.5	76.6	53.1	34.0	17.1	5.5
1985-1987	72.7	49.5	30.8	14.6	4.9	79.2	55.4	36.1	18.6	6.1
1995-1997	75.6	51.8	33.1	16.1	5.3	81.3	57.1	37.7	19.8	6.4
2005-2007	79.0	55.0	36.0	18.5	6.0	83.7	59.4	39.9	21.6	7.1
2015-2017	80.5	56.2	37.2	19.7	6.3	84.6	60.1	40.7	22.3	7.3

Source: ABS 2019

Increasing life expectancy over time can also be illustrated using a survival curve. Figure 3 shows the probability of survival to each successive age for Australian females at different times throughout history. Over time with increasing life expectancy, females have become increasingly more likely to survive to older ages represented by the 'rectangularisation' of the curve.

FIGURE 3: Probability of survival by age, selected periods, Australia



Source: Analysis of ABS 2019

A somewhat related measure of expectation of life is *years of life lost* (YLL) which describes the amount of time lost due to dying prematurely from all or specific causes of death. YLLs or *fatal burden* are a central measure in burden of

disease studies where 'premature death' is prescribed by a specific or aspirational life table (Murray and Lopez 1996).

Life expectancy as described above refers to *period life expectancy*. This measure assumes that the life course mortality experience of the population is static and equal to the prevailing mortality rates. A *cohort life expectancy* on the other hand, applies the observed mortality experience of cohorts over time. It offers a less biased estimate taking into consideration actual experiences in mortality over time. However, it also requires data over a long enough time period to calculate or make projections for some age cohorts.

Guillot and Payne (2019) used historical data from the Human Mortality Database and measured life expectancy, incorporating actual population mortality, for four low mortality countries: Japan, Sweden, France and USA. They demonstrated the impact of past histories of mortality experience. For example, life expectancy at birth in 2014 for Japanese females—using the period method—was highest of the four countries, followed by France then Sweden (see Table 3.3). Considering country- and cohort-specific mortality history, using a Lagged Cohort Life Expectancy (LCLE) method, the life expectancy ranking for Japanese females was reversed; instead led by Sweden. The period life expectancy estimate indicates that Japanese women could expect 2.7 more years than Swedish women, while the LCLE method estimates that Swedish women actually lived, on average, 5.5 years longer than Japanese women. In addition, the LCLE method estimates shorter life expectancy than the period life expectancy; for Japanese women the difference is around 13 years and for Swedish women, less than 6 years.

TABLE 3: Life expectancy and difference estimates using the period method and the lagged cohort method, 2014

	Males			Females		
Country	Period life expectancy	Lagged cohort life expectancy	Difference	Period life expectancy	Lagged cohort life expectancy	Difference
Japan	80.5	68.5	-12.0	86.7	72.9	-13.8
France	79.3	68.8	-10.5	85.4	77.0	-8.4
Sweden	80.4	74.0	-6.4	84.0	78.4	-5.6
USA	76.7	71.6	-5.1	81.4	76.1	-5.3

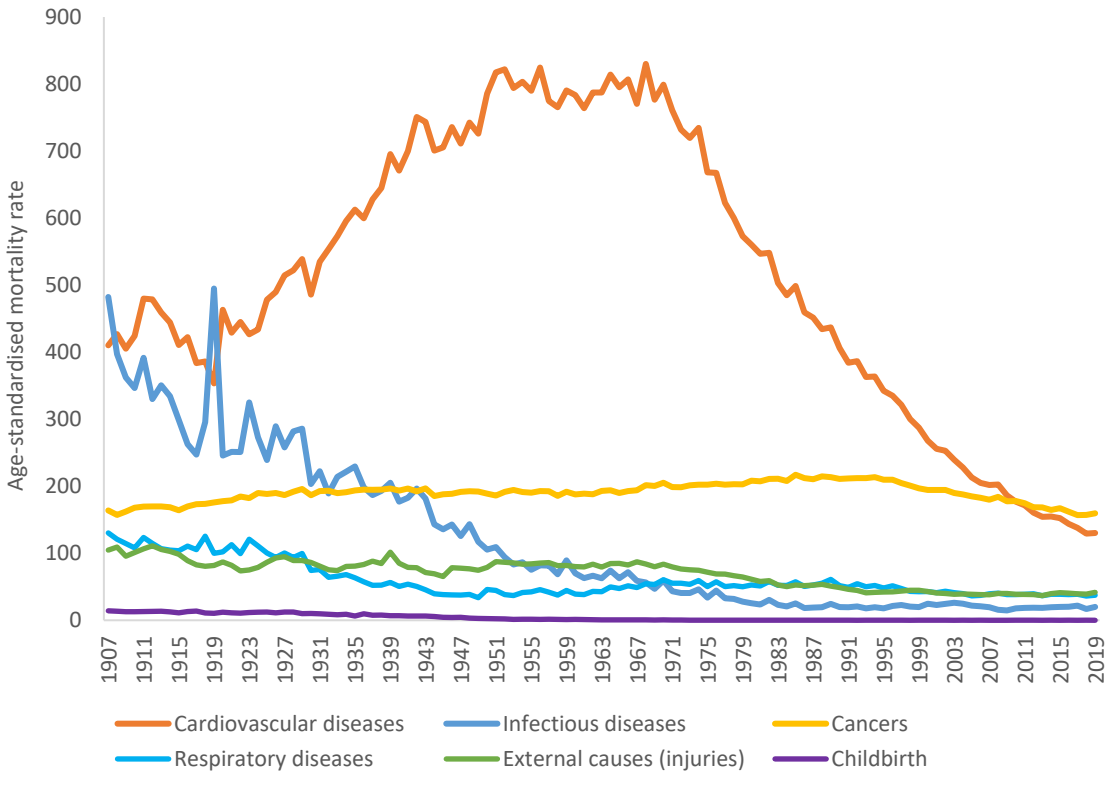
Source: Guillot and Payne 2019

Cohort life expectancy measures such as the LCLE method can be used to estimate life expectancy taking into account historical experiences and fluctuations in mortality, especially those related to infant and child mortality and to war.

CAUSES OF DEATH

Notwithstanding the COVID pandemic (see Box 1), over the past century, death rates have declined substantially in Australia: from 2,054 deaths per 100,000 population in 1907 to 528 in 2019, representing a 74% reduction. Over the same period, causes have contributed differently to overall mortality. Figure 4 shows age-standardised death rates for the Australian population from 1907 through to 2019. Substantial declines in death rates are evident for infectious diseases by 96% (from 482 deaths per 100,000 to 20) and respiratory diseases by 71% (from 130 to 37), as well as a steady decline for external causes by 60% (from 104 to 42). While death rates for cardiovascular diseases also declined in this period, rates were in excess of 800 deaths per 100,000 population in the 1950s and 1960s. Cancers on the other hand have declined only a little over this period, from 164 deaths per 100,000 to 157. Based on the broad groupings of causes of death, the contribution to overall mortality from cardiovascular diseases was surpassed by cancers in 2010.

FIGURE 4: Age-standardised death rates, selected causes, Australia, 1907–2019



Notes: Influenza and pneumonia deaths are included in Infectious diseases.
Deaths are age-standardised to the Australian Estimated Resident Population 2001

Sources: Analysis of AIHW, 2019a; ABS, 2020.

These changes over time largely align with patterns in high-income countries. Declines in cardiovascular mortality are mainly attributed to better treatment and management as well as reductions in the prevalence of risk factors such as tobacco use and hypertension. However, globally however, there is a rise in deaths from cardiovascular disease due to the combined impact of population growth and ageing and only small gains in reduction of risk factors such as tobacco use. While there have been dramatic declines in tobacco use in some high-income countries (for example, Australia, Japan, Canada and Italy), this change has not been observed in South Asian countries and population growth and ageing continue to contribute to the rise in cardiovascular deaths (GBD 2017 Collaborators, 2018).

Omran's (1971, 1982) theory of epidemiologic transition describes patterns of mortality associated with shifts in populations from high to low mortality (described in the chapter on World Population Growth). Three stages were identified:

The 1st stage refers to the *era of pestilence and famine* in which mortality rates are very high due to pestilence such as epidemic plagues and to famine. With such high levels of mortality, population growth is restrained and life expectancy is low (around 20 to 40 years). Any public health initiative or famine relief would lead to a reduction in mortality.

In the 2nd stage, pandemics recede and mortality levels become lower, so life expectancy increases (to around 30 to 50 years). While deaths are mostly due to infectious and parasitic diseases, with improved knowledge of disease and public health interventions, population growth can begin to be sustained. Stages of transition can be lengthy. For example, in England and Wales the transition to stage 2 took place over two centuries. In contrast, Japan transitioned from Stage 1 to 2 in decades.

The 3rd stage is the age of non-communicable diseases. Mortality rates decline and causes of death are largely due to chronic diseases, which usually impose some level of disability but are not immediately fatal. Life expectancy is around 70 years. This shift towards degenerative diseases reflects the control of diseases which affect younger people, leading to a relative increase in those which affect older people.

Rogers and Hackenberg (1988) have argued for a 4th stage which they call *the hubristic stage*, in which lifestyles play an important part in determining mortality levels. They posit that while medical advances can facilitate a reduction in mortality, patterns of age and causes of death are largely driven by lifestyle factors. These *behavioural* risk factors (for example, smoking, poor diet, and insufficient exercise) increase the risk of *biomedical* risk factors (such as hypertension and high cholesterol) and the risk of chronic diseases (such as cardiovascular diseases, cancer and diabetes).

BOX 1: Measuring the fatal impact of COVID-19

In March 2020, the WHO declared a global pandemic due to the virus now known as COVID-19. The pandemic has necessitated a rapid global response, including intense surveillance for identifying cases and deaths. Objective, accurate and timely information is crucial for governments to understand the spread of the disease, measure the impact across regions and time, and monitor the effectiveness of national responses (Leon et al. 2020; Setel 2020).

Early in the pandemic, numerous shortcomings such as differences in case definitions, testing protocols, and absence of a standard practice for certification of COVID deaths, hampered the ability to derive consistent measures of COVID-19 mortality (Kiang et al. 2020; Leon et al. 2020). Although the WHO released specifications for certifying COVID-19 deaths, attribution to COVID-19 has varied due to jurisdictional directives such as requiring a positive test, testing capacity and availability of data and resources for medical certification.

Newspaper headlines trumpet death numbers and convey the immediate impact, but a more objective measure is needed to fully understand the differential effects of COVID-19. One approach is to measure *excess mortality*, which refers to the amount of mortality in a particular time period that is over and above the amount expected. Specifically, the excess all-cause mortality can be attributed to events occurring in the period of interest that were not at play during the baseline period; in this case, deaths likely due to COVID-19.

For example, recent assessments of mortality during the COVID-19 period have shown:

- the highest excess mortality among 29 high-income OECD countries was in Lithuania, Poland and Spain, as well as Hungary and Italy for men, and Slovenia and Belgium for women (Islam 2021)
- in the US, all-cause mortality increased by 22.9% of which 72.4% was attributed to COVID-19, with racial disparities reflected by greater mortality experienced by the non-Hispanic Black population (Woolf et al. 2021).
- Rates of excess mortality in the UK varied by region and socioeconomic status, from 93 to 124 per 100,000 in the most to least affluent areas respectively (Kontopantelis et al. 2021)

Over a longer timeframe and with more detailed data, the broader impact of COVID-19, including from indirect effects, may become apparent. Researchers have noted that excess mortality could reflect undocumented COVID-19 (Woolf et al. 2021), or indirect impacts, such as reductions in cancer screening associated with service closure and behaviour change during periods of lockdown (AIHW 2020a; Rossen et al. 2020; Setel 2020).

Currently most of the world's population is encumbered by the impacts of chronic disease. Increases in life expectancy accompany declines in mortality, such that chronic diseases have a major impact on mortality in both developed and developing countries. Since the turn of this century, global life expectancy has increased by 6.3 years (GBD 2019 Demographic Collaborators 2020).

With reference to the first stage, Ruzicka (1986:7) argued that national and international epidemics, which have a major impact on overall mortality, are now a matter of history and points to the 1918-19 influenza pandemic as being the last epidemic to have a major impact on mortality. However, at the time of writing (June 2021), the world is experiencing a global pandemic from COVID-19 (see Box 3.1) which to date has caused 180 million cases and 3.9 million deaths (WHO 2021). While this pandemic continues, it is crucial to be able to consistently measure the impact of COVID-19 across regions and time to objectively assess the effectiveness of national responses.

MORTALITY DIFFERENTIALS

The previous sections showed differences in mortality between countries and how mortality has changed over time. Factors that influence mortality are multifaceted, dynamic and complex. They can be proximal (that is, having a direct influence on the health and mortality outcomes of individuals, for example, through exposure to infectious diseases or other hazards) or distal (for example, the social, cultural, environmental and economic conditions that underlie proximal impacts on the health of populations). Mortality differentials refers to the disparities in mortality between groups, defined for example on the basis of sex, occupation, level of education, income, marital status, where people are born, where people live, their level of access to health care, and exposure to biomedical and behavioural risk factors.

Differentials by sex

A commonly observed differential is the disparity in mortality rates between men and women. In most countries, life expectancy is higher for women than men. This is somewhat of a paradox given that, in general, women suffer higher levels of disease burden (see for example GBD Cardiovascular Collaborators, 2018). The life expectancy differential between sexes has persisted over time with few exceptions, such as in Ireland in the 1920s and selected developing countries (Bangladesh, Bhutan, Nepal and Vanuatu) (Diamond and McDonald 1994).

In Australia, the gap in life expectancy between men and women has changed over time. At the turn of the 20th century, life expectancy at birth for women was 3.6 years longer than for men. By the mid-1970s and through to 1982, the gap peaked at 7.0 years and subsequently declined to 4.1 years in 2015-2017 (ABS 2019).

While there is no definitive explanation of this discrepancy between male and female mortality, presumed drivers include biological, genetic, societal, environmental and behavioural factors and the complex interplay between them. Specific diseases and health outcomes impact males and females differently, and males and females differ in patterns of risky behaviours that are known to be associated with the development of disease and injury. Examples highlighting the breadth of potential explanations for these differences include:

- the greater impact on male mortality due to work-related injuries and respiratory diseases from their tendency to work in more hazardous environments than women. The fatal burden from occupational risks in Australia was 7 times higher among males compared with females (AIHW 2019b)
- the largest differences in male-female life expectancy in Europe between 1985 and 2005 being attributed to high levels of alcohol consumption and smoking among men (Clark and Peck 2012)
- the potentially protective effect of the female hormone oestrogen against the onset of cardiovascular disease in pre-menopausal women (AIHW 2019b).

After coronary heart disease, the leading causes of fatal burden of disease among men comprise more highly fatal conditions such as suicide and lung cancer, while for women long-lasting chronic diseases cause substantial burden (AIHW 2019b).

Other mortality differentials

Numerous demographic and epidemiological works show mortality differentials between populations defined by socioeconomic and demographic factors. Some examples of factors that influence levels of mortality include occupation, level of education, employment, marital status, socioeconomic position, area of residence, migrant status, and ethnicity. These are largely distal factors, but can act through more direct factors such as biomedical and behavioural exposures. Assessment of inequalities in mortality highlights opportunities to improve population health through policy and planning.

On the relationship between socioeconomic characteristics and mortality: higher levels of education, higher income and access to health care are associated with reduced mortality. While there are many examples of this mortality differential, just a few are described below.

Katikreddi et al. (2017) noted employment as a long-established determinant of health and found that in the United Kingdom in 1991-2011, the occupations with the highest mortality had more than three times the rate of the occupations with the lowest mortality. While for most occupational groups mortality had

improved over time, excess mortality persisted among low-skilled workers in Scotland.

There are substantial mortality differentials by education. For example, mortality rates in the Netherlands among those with only primary education were twice as high as for those with tertiary education, resulting in a life expectancy gap of 3.4 years for males and 2.4 years for females (Kulhanova et al. 1997). Educational inequalities in Australia were found to be largest for deaths due to injury, such as transport accidents among men aged 25-44 years and for chronic diseases such as lung cancer among those age 45-64 years (Welsh et al. 2020).

Widespread disadvantage and health inequality have long been experienced by Indigenous Australians. Indigenous children are twice as likely to die before their 5th birthday than non-indigenous children. 'Closing the gap' targets, which were set by the Council of Australian Governments in 2008, aim to reduce the gap in life expectancy between Indigenous and non-indigenous Australians by 2031. According to the latest report on Australia's health, progress is not on track to meet this target; the life expectancy gap is 8.6 years for males and 7.8 years for females (AIHW 2020b).

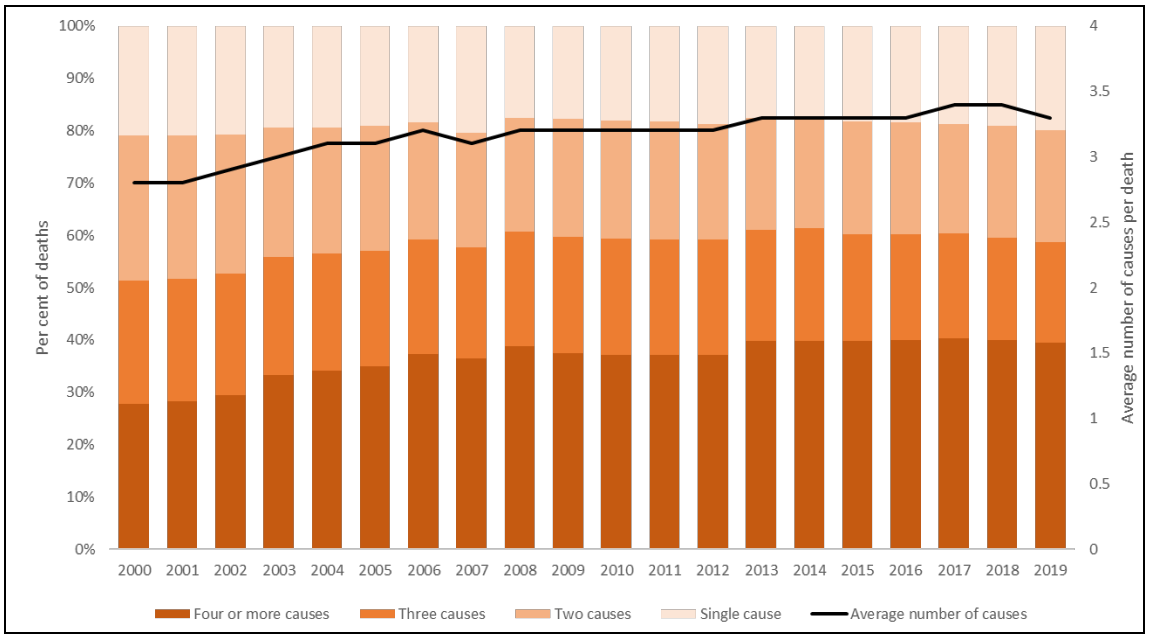
MULTIPLE CAUSES OF DEATH

The *Medical certificate of cause of death* (MCCD) is the recommended international format for documenting the conditions that caused death (WHO 2020a) and is widely used in many countries. The format allows a medical practitioner to document the initiating or underlying cause, plus all other causes and comorbid conditions that contributed to the death. A standard set of coding rules are applied to the documented causes to identify a single *underlying* cause of death*,* with other causes designated as *contributing* causes of death.

Typically, only the underlying cause is used to portray mortality patterns and to identify the leading causes of death in populations. While this is necessary, it is increasingly difficult to identify a single condition as the underlying cause of death, with an increasing proportion of deaths involving multiple chronic conditions. To better understand the impact of other causes, multiple causes of death (MCoD) analysis is used to assess all conditions involved in causing the death.

Figure 3.5 shows the annual percentage of deaths in Australia that have one, two, three or four or more causes reported on the death certificate and the average number of causes per death certificate for deaths registered in 2000 to 2019. The proportion of deaths having a single cause declined over this time from 21.0% in 2000 to 19.9% in 2019, while the proportion having four or more causes increased from 27.7% to 40.0%.

FIGURE 5: Relative frequency of number of causes per death, average number of causes per death, Australia, 2000–2018



Source: Analysis of ABS 2020

People with multimorbid chronic disease have higher mortality rates (Fabbri et al. 2015), and shorter life expectancy (DuGoff et al. 2014) compared to people with none or just one long-term condition. Ageing is a major risk factor associated with the development of multiple chronic diseases and there is greater likelihood of misreporting the underlying cause of death with increasing prevalence of multimorbidity (Desesquelles et al. 2010). As such, evidence on mortality from multimorbid chronic disease is important for developing strategies to help prevent the accumulation of chronic conditions and reduce the associated health burden on people as they age.

MORTALITY-RELATED POLICES

The United Nations claimed that '… in a sense, since all governments have a health policy and this is related to mortality, all countries have some form of "national population policy" (UN 1979:14). The reality is, of course, more nuanced than that.

The SDGs were developed by the United Nations as a universal, international call to action for governments and business alike to combat the urgent health, environmental, political and economic challenges for the benefit of all humanity. SDG 3 is entitled *Good Health and Well-Being*. It specifically aims to 'ensure healthy lives and promote well-being for all at all ages' (United Nations no date) and comprises targets related to mortality. These include:

- reducing the global maternal mortality ratio to less than 70 per 100,000 live births
- reducing premature mortality from non-communicable diseases by one-third
- halving the number of global deaths from road traffic accidents.

Also developed by the United Nations, the Human Development Index is a composite indicator integrating life expectancy, average years of schooling and gross national income to provide an objective measure for comparing countries' levels of development.

Mortality statistics are used globally to monitor population health and provide evidence for governments to develop policies and strategies to improve health in respective nations. However, a major public health challenge for many governments is tackling the ill-health and mortality due to non-communicable diseases, especially those associated with risk factors such as smoking and obesity. Worldwide, 8 million deaths per year are attributable to tobacco use with more than 1 in 8 of these deaths arising from second-hand smoke rather than direct use (WHO 2020d).

The Australian Government is a signatory to the WHO Framework Convention on Tobacco Control and has been at the forefront of tackling tobacco use and its harms. Policy and legislation have enabled the prohibition of advertising of tobacco products (since 1992), mandating plain packaging by obscuring brand names and logos (since 2011), the addition of health warnings to packages, the banning of smoking in public places, and over a long period, continued increasing taxes on tobacco products (Department of Health 2020).

Australia has one of the lowest tobacco smoking rates among the OECD, largely attributed to the success of these innovative strategies (OECD 2019), currently at an all-time low of 11.0% among people aged 14 years or more and down from 24% in 1991 (AIHW 2020c). Nevertheless, 1 in every 8 deaths in Australia is attributed to tobacco use (AIHW 2019b). In 2019, the government announced its intention to set a new national target to reduce smoking rates to less than 10% by 2025 (Department of Health 2019).

However, Australia has been less successful in the battle against the obesity epidemic. Adult obesity has risen from 57% in 1995 to 66% in 2017-18 making it the 6th highest of OECD countries. More than one-quarter of Australia's children are overweight or obese (AIHW 2020d). Various studies show the negative impact on mortality associated with excess body weight (Vidra et al. 2019; Peeters et al. 2003), and a negative impact on life expectancy, especially among young adults (Fontaine et al. 2003; Lung et al. 2018). In Australia, strategies such as the Healthy Food Partnership are designed to bring together governments, the public health sector and the food industry to improve the diet of Australians and reduce diet-related diseases, overweight and obesity (Department of Health 2021).

CONCLUSION

Mortality is a key driver of population change with multifaceted determinants that vary over time and across population groups. It is one of the longest measured aspects of population health, and statistics provide crucial evidence underpinning policy, research and planning.

While mortality data are largely obtained from health information systems, the accuracy and timeliness of these data have real-world consequences. Maintaining high standards and global consistency is central for reporting against international indicators for monitoring progress. With many different ways to measures mortality, care is required to select the method most appropriate for the purpose.

Many countries have experienced the epidemiological transition with increasing prevalence of non-communicable diseases and the detrimental impacts of smoking, obesity and other health risk factors. While these pose immediate public health challenges, the need for accurate and timely mortality surveillance has been intensified by the more urgent and compelling task of tackling COVID-19, which to date, has caused very high levels of mortality amongst the most vulnerable members of society.

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