The impact of a new disease: COVID-19 from 2020, 2021 and into 2022

1

The impact of a new disease: COVID-19 from 2020, 2021 and into 2022

Key findings

This article examines the direct impacts of Coronavirus disease 2019 (COVID-19) on the Australian population since the start of the pandemic in 2020 through to the first few months of 2022. The timeline of the pandemic is documented, presenting data on cumulative cases, hospitalisations and deaths. Updated burden of disease estimates are presented for 2020 plus preliminary estimates for 2021. Patterns of morbidity and mortality are explored for population groups, including Aboriginal and Torres Strait Islander people, people with disability, aged care facility residents, and people living in rural and remote areas.

The article is a point in time assessment which has been compiled predominantly from data available in the public domain; it should be considered preliminary and may change with future articles.

Key findings are described below:

- Compared with many other countries, the number of COVID-19 cases was very low in Australia until early 2022, when case numbers rose after the Omicron variant was introduced in December 2021. The cumulative incidence by 30 April 2022 was 231,000 cases per million people.
- Hospitalisations and deaths due to COVID-19 in Australia followed trends in cases. The number of people in hospital relative to the number of cases has, to date, been much lower during the Omicron wave than during earlier waves. The case fatality rate of COVID-19 related deaths fell from a peak of 3.3% in October 2020 to 0.1% in April 2022.
- Rapid vaccination rates in the second half of 2021 resulted in Australians now having one of the highest levels of COVID-19 vaccination in the world. However, inequalities in vaccination coverage exist: it is lower among Indigenous Australians, residents of the Northern Territory and participants in the National Disability Insurance Scheme (NDIS) than among the rest of Australians.

(continued)

- The incidence of COVID-19 is highest in people aged 20–39, although deaths in this age range are rare. The cumulative incidence is higher for females in all age groups between 10 and 59, after which it is higher for males. Among people aged 80 and over, the incidence of COVID-19 is lowest but mortality rates from COVID-19 are highest.
- By 30 April 2022, 5,335 deaths from COVID-19 had been registered in Australia, with 3,107 occurring in 2022. In 2021, 0.8% of deaths were from COVID-19, rising to 9.6% of deaths during January and February 2022. Since the largest number of deaths from COVID-19 during the pandemic, to date, has occurred in 2022, the impact on excess mortality in 2022 is likely to be greater than seen for 2020 and 2021.
- COVID-19 accounted for 23,000 disability-adjusted life years (DALY) in 2021. The largest proportion was due to fatal burden, 89% of DALYs for males and 84% for females. Total fatal burden equated to 15 years of life lost per person who died from COVID-19, based the Global Burden of Disease ideal life expectancy.
- The case fatality rate of COVID-19 related deaths in aged care facility residents is 6.3%. In 2020, 75% of all COVID-19 related deaths occurred in aged-care facility residents and fell to 17% in 2021. The cumulative mortality rate for aged care facility residents is 1.0%, which is lower than that observed for several other countries.
- COVID-19 incidence and mortality rates were higher in *Major cities* than in regional or remote areas. For deaths registered by 31 March 2022, people from lower socioeconomic groups and those born overseas, particularly in North Africa and the Middle East, had higher COVID-19 mortality rates than for other Australians.

Introduction

This chapter covers data and information available from the start of the pandemic until the end of April 2022. The data are the most recent available and were accurate when this article was written. However, given the dynamic and ongoing nature of the pandemic, the underlying data and/or information may be updated, changed or revised as more is learnt about the disease and its impact on the population.

COVID-19 emerged as a new disease in late 2019 and the World Health Organization (WHO) declared it a pandemic in March 2020. By 30 April 2022, more than 500 million cases had been confirmed worldwide and more than 6 million COVID-19 related deaths (Ritchie et al. 2022). However, the true numbers are likely to be much higher than these as many cases and deaths from COVID-19 may go undetected and unreported (COVID-19 Excess Mortality Collaborators 2022; Giattino 2020; Lau et al. 2021).

This article presents summary information for Australia on the acute effects of COVID-19, including the number of cases, hospitalisations and deaths from the start of the pandemic until 30 April 2022. Burden of disease estimates for 2020 that were previously published (AIHW 2021b) have been revised and updated to include data for 2021. Information on the COVID-19 vaccination roll-out and the impacts of COVID-19 on high-risk population groups are outlined briefly.

COVID-19 is a highly infectious disease with a wide spectrum of severity. Many people experience mild to moderate disease, but some develop very serious illnesses. Studies based on data from 2020 – early in the pandemic and before vaccines had been developed – showed that COVID-19 led to more severe respiratory illness (requiring hospitalisation) and mortality than influenza (Iacobucci 2021; Piroth et al. 2021). It is spread by both relatively large sized 'droplets' and smaller 'aerosol' particles that can linger in the air (Wang et al. 2021).

COVID-19 became a worldwide crisis due to its severity, its high transmission rates and because, initially, there was no population immunity or vaccine for it. It is also changing over time. By the start of December 2021, 5 variants of concern had been detected in Australia: Alpha, Beta, Gamma, Delta and Omicron – some of which are associated with increased transmission rates (COVID-19 NIRST 2021e). While the most recent variant (Omicron) is still being studied there is growing evidence that it can evade the immune system and spread rapidly (WHO 2022b). New variants, sub-variants and lineages are likely to continue to emerge, such as the BA.2 Omicron sub-variant for which there is increasing evidence of greater transmissibility than seen with BA.1 (Chen and Wei 2022; Cheng et al. 2022; Lyngse et al. 2022).

As well as the acute effects of COVID-19, it can take many months for some individuals to recover from the disease, with a post-COVID-19 condition (which includes the disorder often termed 'long COVID') being recognised, however the prevalence of persistent symptoms is currently unclear. There is also emerging evidence that people with mild illness can be at higher risk of long-term mental health and cardiovascular outcomes (Xie, Xu, and Al-Aly 2022; Xie, Xu, Bowe, et al. 2022). For more information on 'long COVID', see the section of this article titled 'Long COVID and Post-COVID-19 Syndrome'.

While Australia has not been spared from COVID-19, there has been less of an impact on morbidity and mortality than for many other countries (AIHW 2021b; OECD 2021b). The first case in Australia was identified on 24 January 2020 in a 58-year-old man who arrived from Wuhan, China on 19 January 2020 (Caly et al. 2020). Up until early October 2021, Australia had the second lowest total number of confirmed cases per head of population of all Organisation of Economic Co-operation and Development (OECD) countries (with only New Zealand lower) and the third lowest death rate (with South Korea and New Zealand lower) (OECD 2021b). In early 2022, all 38 OECD countries experienced increases due to Omicron outbreaks and by early March 2022 Australia had dropped to eighth lowest total rate of confirmed cases and the fifth lowest death rate (Ritchie et al. 2022).

Several non-OECD countries in the Asia–Pacific region have also had low numbers. For example, case and death rates in Taiwan and many Pacific Island nations have been very low by world standards; China, Singapore and Thailand also had low rates – though some of these countries experienced increases in early 2022 due to Omicron outbreaks (Ritchie et al. 2022). Many low-income and lower-middle income countries have had lower than expected numbers of COVID-19 cases and deaths due to poor disease surveillance capacity and low death registration rates (WHO 2020). During 2020 and 2021, 15 million excess deaths (the difference between the number of observed and expected deaths in a defined time period) from COVID-19 were estimated globally, 3 times more than the 5 million officially reported (Grimly et al. 2022; WHO 2022c). The largest proportion of excess deaths occurred in lower-middle income countries such as India, Egypt, and Indonesia, and are unreliable for 41 of 54 countries in Africa due to little data on deaths from the region.

A range of public health protection measures have been used in Australia to manage the spread of COVID-19 and protect the healthcare system. These include:

- measures to reduce movement of the population, such as border closures
- measures to promote physical distancing
- quarantine and isolation rules
- mask mandates (COVID-19 NIRST 2021b).

These interventions have had numerous indirect effects on the health of the population and are described in more detail in Chapter 2 'Changes in the health of Australians during the COVID-19 period'. For a discussion of public health protection measures implemented in Australia see 'Health promotion and health protection' at https://www.aihw.gov.au/reports/australias-health/health-promotion.

Vaccination has also been an important tool to protect the population from illness and death. As soon as the genomic sequence of the virus was published in early January 2020 scientists began developing vaccines to protect the population against severe illness. Several different vaccines were shown to be safe and effective and began to be administered in countries across the world in early 2021. Despite challenges with the rollout of the vaccines due to initial supply issues, Australia then had one of the highest vaccination rates in the world with 83% of the total population receiving 2 doses by 30 April 2022 (OWID 2022). Globally, there have been large disparities in the ability of individual nations to vaccinate their populations against COVID-19, with the United Arab Emirates having the highest rate of 97% and low-income countries, particularly those in the African region, having rates below 20% for 2 doses (OWID 2022). For more information on COVID-19 vaccination in Australia see the section titled 'COVID-19 vaccination' later in this article.

Several treatments have been developed to minimise illness and death following COVID-19 infection. The first oral treatments were provisionally approved for use in Australia by the Therapeutic Goods Administration (TGA) on 18 January 2022 (Department of Health 2022k). Lagevrio® (molnupirovar) and Paxlovid® (nirmatrelavir + ritonavir) are effective in treating mild to moderate COVID-19 in adults aged 18 and older, who do not require supplemental oxygen, and who are at increased risk of being hospitalised. These treatments have been added to the National Medical Stockpile for distribution throughout the country, with high-risk groups prioritised for treatment, including people living in residential aged care facilities and in rural and remote communities, Indigenous Australians and people with disability (especially in a supported living setting).

Sources of information used in this article

Data for this section are predominantly compiled from several publicly available sources. For international comparisons of the COVID-19 pandemic over time the "Our World in Data" online resource was used (Ritchie et al. 2022).

To enable specific and more detailed analyses of Australian data, information was obtained from the Department of Health website (Department of Health 2022d, 2022e), the *COVID Live* website (COVID Live 2022), state and territory COVID-19 websites, and the Australian Bureau of Statistics (ABS). *COVID Live* data which are collected from media releases and verified against Australian and state and territory health departments were the main source used in this article to analyse COVID-19 cases, hospitalisations and COVID-19 related deaths in Australia. For more detailed information, see the section titled 'Data notes' later in this article.

Detection of COVID-19 cases

Clinical testing for COVID-19 has been an important part of the public health response in Australia since the start of the pandemic. There are 2 main types of test used to detect COVID-19:

- nucleic acid amplification tests (NAATs), such as polymerase chain reaction (PCR) tests, which detect SARS-CoV-2 genetic material
- rapid antigen tests (RATs) that detect the presence of specific proteins of the virus (Therapeutic Goods Administration 2022b).

NAATs are the 'gold standard' for diagnosing COVID-19 as they are better at detecting the presence of the SARS-CoV-2 virus than RATs, and have been used since the start of the pandemic (PHLN 2022). RATs are most accurate when used in the early stages of symptomatic infection, and a follow-up PCR test is recommended in areas of low community transmission. RATs were approved for use at home without supervision by the TGA from 1 November 2021 and can be used on nasal swabs or saliva in accordance with manufacturer instructions for use (Therapeutic Goods Administration 2022a).

Case definitions for COVID-19 are summarised in Box 1.1. Under the Testing Framework for COVID-19 in Australia, RATs may be used in addition to NAATs when transmission exceeds response capacity without requirement to verify the result by PCR (Department of Health 2022l) and is currently in place in Australia. This means that data presented on confirmed cases currently includes people diagnosed using PCR or RATs, unless they are specifically referred to as PCR-confirmed cases.

Box 1.1 Case definitions for COVID-19

COVID-19 is a notifiable disease. Confirmed cases must be reported to the Department of Health via the National Interoperable Notifiable Diseases Surveillance System (NINDSS). Jurisdictions can determine reporting requirements for probable cases.

Confirmed case

A confirmed case requires laboratory definitive evidence.

Laboratory definitive evidence:

1. Detection of SARS-CoV-2 by nucleic acid amplification testing (NAAT)

OR

2. Isolation of SARS-CoV-2 in cell culture, with confirmation using a NAAT

OR

3. SARS-CoV-2 IgG seroconversion or a 4-fold greater increase in SARS-CoV-2 antibodies of any immunoglobulin subclass including 'total' assays in acute and convalescent sera, in the absence of vaccination.

Probable case

A probable case includes individuals who have laboratory suggestive evidence.

Laboratory suggestive evidence:

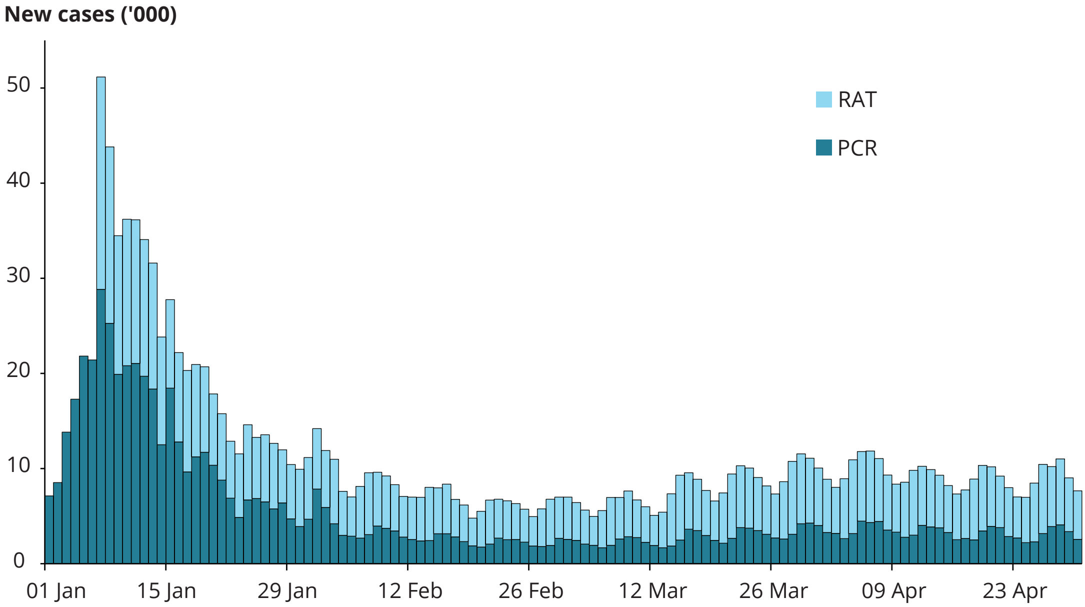
Detection of SARS-CoV-2 by rapid antigen testing (RAT).

Source: Coronavirus disease 2019 (COVID-19): Communicable Diseases Network Australia National Guidelines for Public Health Units, Version 6.7, 22 March 2022.

Since the emergence of the Omicron variant in December 2021, RATs have been increasingly used and have - since that point - accounted for more than half of the total cases reported each day (COVID Live 2022).

- The use of RATs compared to PCR tests also varies with level of geographic remoteness: over the 4 weeks prior to 23 April 2022, 72% of cases in rural areas of New South Wales were detected by RATs compared with 52% in metropolitan areas (NSW Health 2022b).
- Figure 1.1 displays the breakdown of cases according to the type of test used, showing the gradual integration of RATs in Victoria. On 30 April 2022, Victoria reported that 67% of its cases that day were from RATs. Similar patterns exist in other jurisdictions.

Figure 1.1 Rapid antigen self-test versus PCR confirmed cases, Victoria, 1 January to 30 April 2022



Source: State Government of Victoria 2022.

The incorporation of RATs was a response to the substantial pressures placed on the testing system due to the rapid rise in local transmission of the Omicron variant, pathology staff shortages and supply chain issues (Timms and Lloyd 2022). Access to testing was disrupted over the 2021 Christmas holiday season when testing centres and pathology services became overwhelmed with many already operating at reduced capacity over the holiday period (Lu 2021). At the time people required PCR tests for domestic and international travel as demand also rapidly increased for cases and close contacts during the growing Omicron wave. Waiting times were extensive with sites temporarily closing after reaching capacity (Daoud 2021; Vidler et al. 2021). Furthermore, the high temperatures typical of an Australian summer may have prevented people who were feeling particularly unwell from queuing at testing centres (Steger and Luff 2021).

The disruption and changes in laboratory testing experienced in 2022 are likely to result in an underestimate of COVID-19 cases. People with a positive RAT must register their result with their state or territory health department to be included in estimates of case numbers. As well, most jurisdictions experienced issues with the supply of RATs in January 2022, together with a delay between using them to diagnose COVID-19 and setting up reporting systems (Bannister 2022). From 24 January 2022, concession card holders could obtain up to 10 free RATs over a 3-month period to improve access to them for people at higher risk (Department of Health 2022m).

Testing for COVID-19 will continue to be an important tool in monitoring the pandemic going forward; it will also have a role in detecting outbreaks in conjunction with genomic surveillance, identifying new variants when they emerge (Hoang et al. 2022). Genomic sequencing has become a vital tool for detecting and responding to emerging SARS-Cov-2 variants in Australia and for contributing to global surveillance efforts (Andersson et al. 2021). Genomic surveillance can provide important information on genetic relatedness, thus aiding investigations of cluster and outbreak situations, community spread and the detection of new variants (PHLN 2022). In addition, other methodologies are being employed to gain a fuller picture of the pandemic, including seroprevalence studies and wastewater testing. See the section titled 'Novel approaches to understanding the pandemic' later in this article for more information on these methodologies.

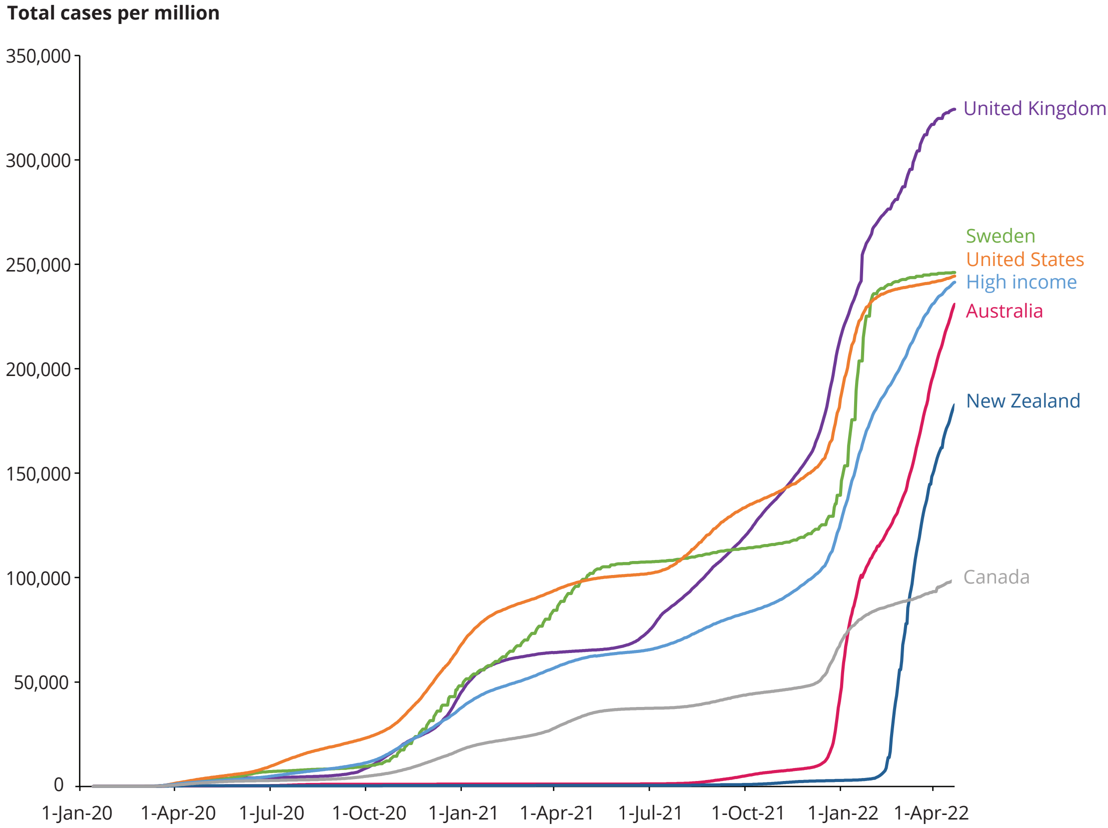
Summary of key patterns in Australia

Timeline of the pandemic

While Australia has fared better than many other countries in relation to the COVID-19 pandemic, the disease has still had a substantial health impact. By 30 April 2022, nearly 6 million cases had been confirmed in Australia since the start of the pandemic, and more than 7,000 COVID-19 related deaths (Department of Health 2022c). Compared with other countries, the number of cases in Australia was far below the average of all high-income countries until early 2022 when it rose rapidly, following the introduction of the Omicron variant and the easing of restrictions (Figure 1.2). By this time, however, vaccination levels were high, with more than 92% of Australians aged 16 and over being fully vaccinated with the initial 2-dose protocol by 2 January 2022, and booster doses were being rolled out (Department of Health 2022j).

During the first few months of 2022, the cumulative incidence of COVID-19 in Australia rose to 231,000 cases per million at 30 April 2022, similar to the average of 241,000 per million for all high-income countries combined, and 29% lower than that for the United Kingdom (Figure 1.2).

Figure 1.2: Country comparison of cumulative confirmed COVID-19 cases per million people, January 2020 to April 2022



Notes

1. Data are obtained from publicly reported daily numbers and should be considered preliminary data that may be subject to changes.
2. High income countries are all countries included in the 'World Bank's Income Groups Classification, 2016', of high income, which is determined by a country's gross national income per capita (in US$).

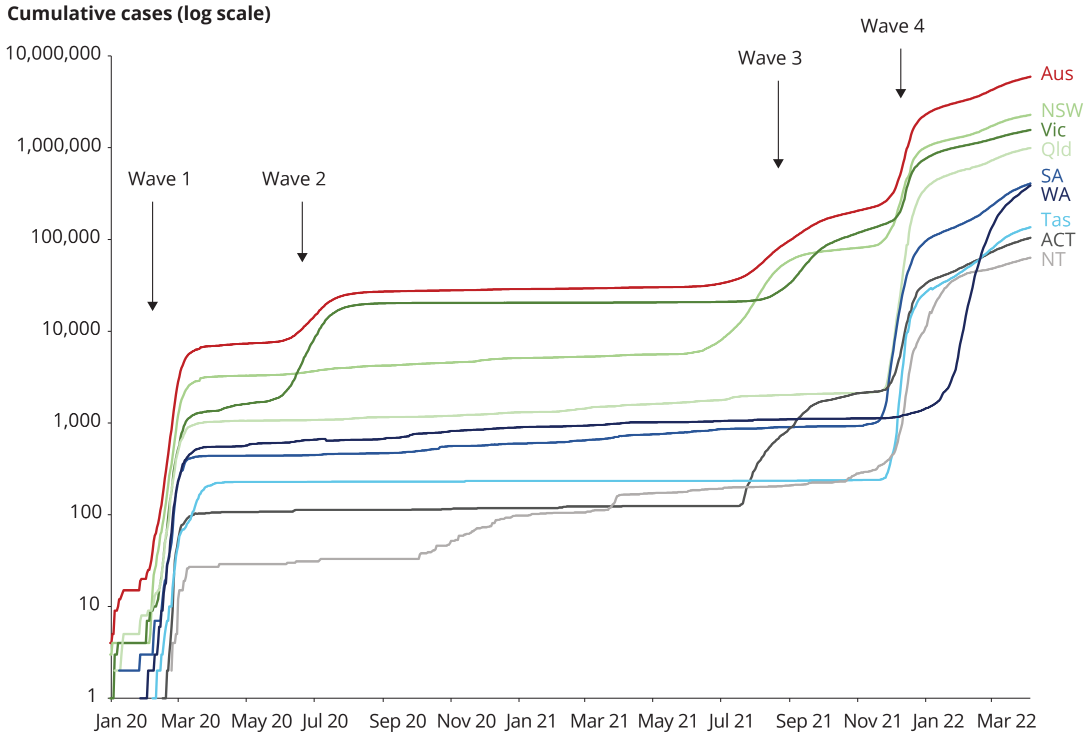
Source: Ritchie et al. 2022.

Figure 1.3 identifies the 4 waves of COVID-19 in Australia and shows the cumulative caseload for each state and territory since the start of the pandemic.

- The first wave occurred from March to April 2020 at the start of the pandemic, with cases in all states and territories.
- The second wave began in the winter of 2020, with most cases in Victoria.
- The third wave started in the winter of 2021 and daily case numbers started to decline from the end of October 2021. While most cases in the third wave were in New South Wales and Victoria, there was also a major outbreak in the Australian Capital Territory.

- The fourth wave started in December 2021 after the introduction of Omicron BA.1. It affected all jurisdictions. International and domestic border restrictions – and a suite of public health restrictions that continued into 2022 – resulted in a delayed but rapid progression of COVID-19 cases during March 2022 in Western Australia. The Omicron wave for Australia flattened from the end of January 2022 but increased again at the end of March 2022 when BA.2 became the dominant sub-variant.

Figure 1.3: Time series of cumulative confirmed COVID-19 cases for Australia and each jurisdiction, 25 January 2020 to 30 April 2022



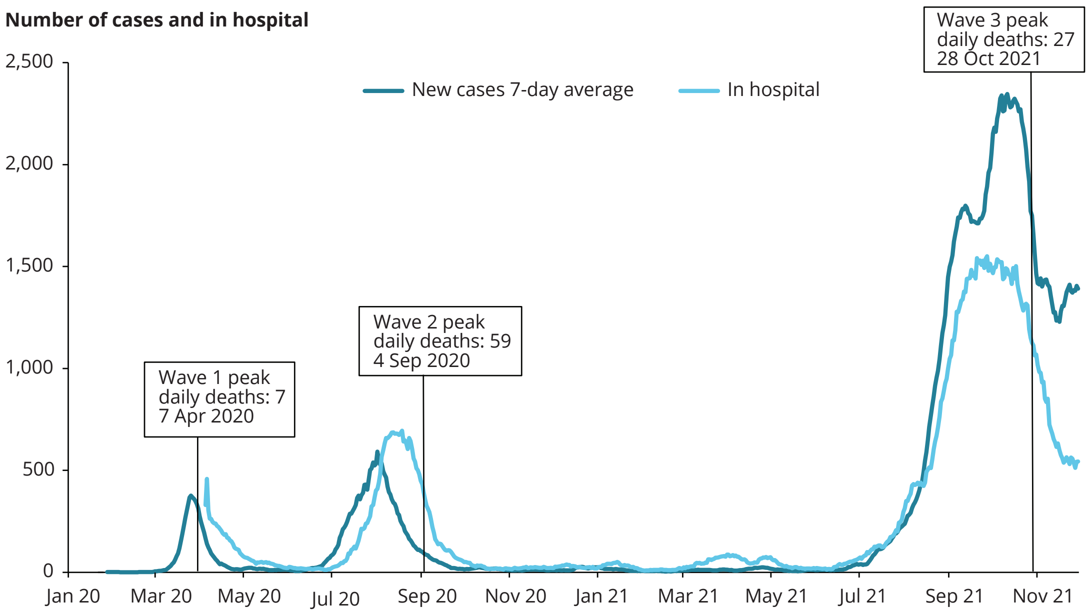
Note: Data are obtained from publicly reported daily numbers and should be considered preliminary data that may be subject to changes.

Source: COVID Live 2022.

Figures 1.4 and 1.5 show the number of new daily confirmed cases, along with counts of people in hospital each day. The peak daily number of deaths are noted for each wave. The number of people in hospital largely follows trends of cases; the peak was around 2 weeks later in the second wave while hospitalisations tracked closer to cases in waves 3 and 4. The number of people in hospital relative to the number of cases is much lower in wave 4 than in earlier waves. For example, on 4 September 2020, when peak deaths were recorded in wave 2, 16% of active cases (357 out of 2,252) were admitted to hospital compared with 1.3% (5,021 out of 373,226) on 28 January 2022 (the date of peak deaths in wave 4) (COVID Live 2022).

The number of deaths also follow the time trends for cases, again with a lag between the peak in cases and the peak in deaths (about 4 weeks in the first 3 waves and 2 weeks in the fourth wave). These observations are consistent with global data analysed up to July 2021 – namely, that a surge in deaths occurred between 6 to 20 days after a surge in cases (Jin 2021).

Figure 1.4: Waves 1-3 daily confirmed cases, hospitalisations and peak deaths.

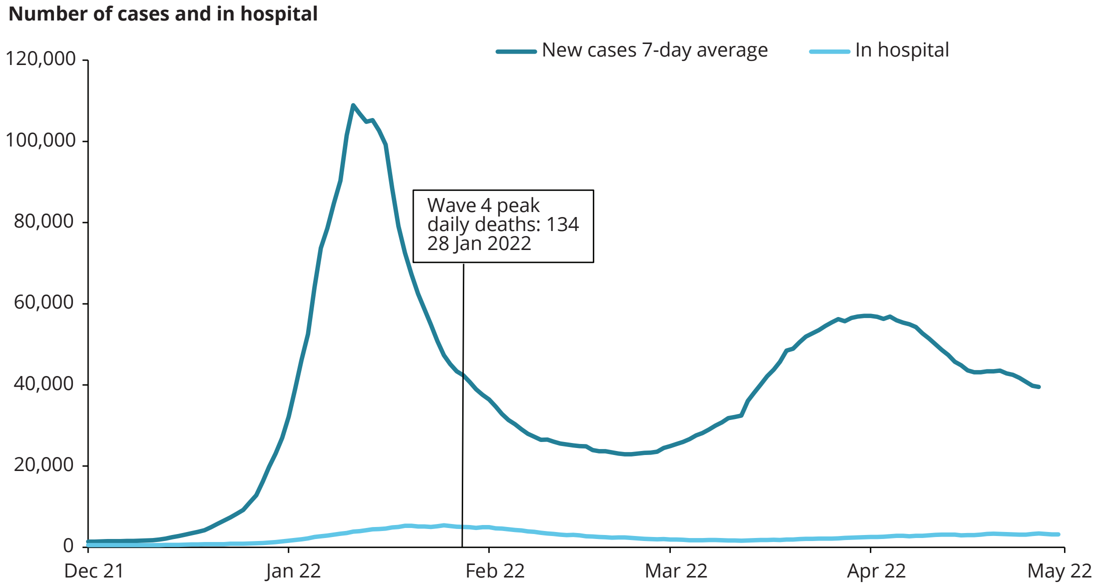


Notes

1. Data are obtained from publicly reported daily numbers and should be considered preliminary data that may be subject to changes.
2. The data presented in the figure is the number of people in hospital on a given day rather than the number of new admissions each day. This measure also reflects severity of the illness as more severe surviving cases generally stay in hospital longer.
3. Counts of deaths are those reported by surveillance systems and comprise deaths due to COVID-19 plus deaths from other causes in COVID-19 patients.

Source: COVID Live 2022.

Figure 1.5: Wave 4 daily confirmed cases, hospitalisations and peak deaths



Notes

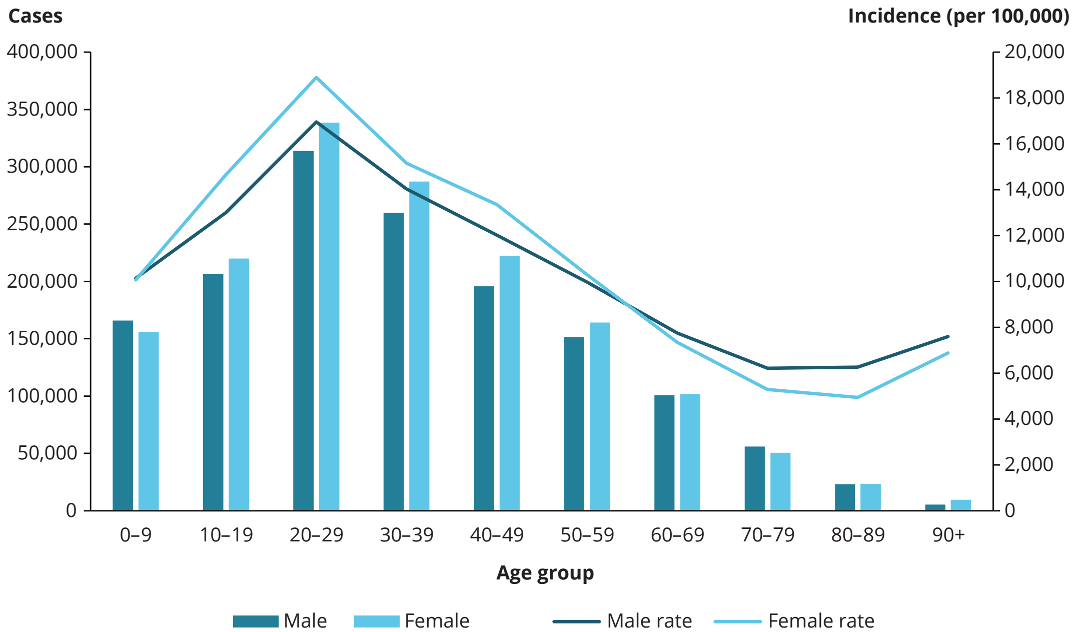
1. Data are obtained from publicly reported daily numbers and should be considered preliminary data that may be subject to changes.
2. The data presented in this figure are the number of people in hospital on a given day rather than the number of new admissions each day. This measure also reflects severity of the illness as more severe surviving cases generally stay in hospital longer.
3. Counts of deaths are those reported by surveillance systems and comprise deaths due to COVID-19 plus deaths from other causes in COVID-19 patients.
4. A total of 331 historical COVID-19 related deaths that occurred between January and March 2022 in NSW were reported on 1 April 2022 following cross-checking of death certificates by NSW Health (NSW Health 2022e).

Source: COVID Live 2022.

Cases by age and sex

The total number of confirmed COVID-19 cases and cumulative incidence varies with age (Figure 1.6). People aged 20–29 had the highest number of cases and incidence followed by people aged 30–39. Overall, the incidence was higher for females (12,200 per 100,000) than for males (11,600), although this varied with age. The incidence was higher for females in all age groups between ages 10 and 59, after which it was higher for males. The age distribution of COVID-19 has changed since 2020, when the cumulative incidence was highest in people aged 80 and over (AIHW 2021b).

Figure 1.6: Total number and cumulative incidence of COVID-19 cases since the start of the pandemic, by age group and sex, as at 1 May 2022.



Notes

1. Data are the total number of confirmed cases reported to the National Notifiable Diseases Surveillance System since the first case was reported.
2. Rates are calculated using the estimated resident population as at 30 March 2020.

Source: Department of Health 2022e.

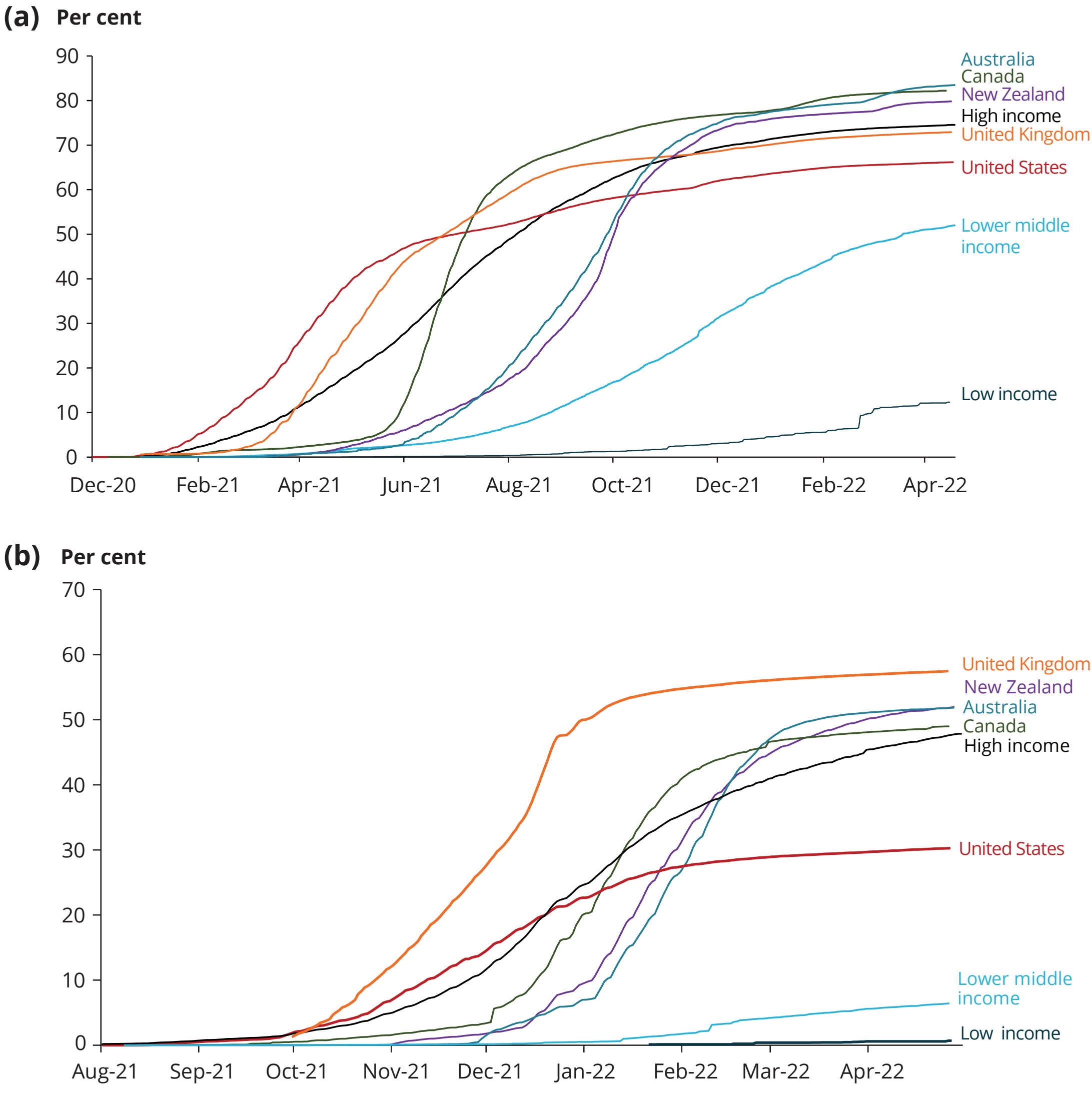
COVID-19 vaccination

COVID-19 vaccinations began in Australia on 22 February 2021, consisting of a primary 2-dose protocol (Department of Health 2021c). The roll-out strategy took a phased approach – commencing with priority populations, followed by adult populations, and then 12–16-year-olds (Hanly et al. 2022). Vaccinating children aged 5 to 11 years began on 10 January 2022 (Department of Health 2021a). A third 'booster' dose has been available since 8 November 2021 for people aged 16 and over.

An additional 'winter' boost is recommended for specific population groups: people aged 65 and older, residents of an aged care or disability care facility, people who are severely immunocompromised, and Indigenous Australians aged 50 and older (Department of Health 2022a). For more information on COVID-19 vaccines see 'Immunisation and vaccination' and 'Health promotion and health protection' at https://www.aihw.gov.au/australias-health/summaries.

The vaccine roll-out in Australia started later than in other high-income countries, but rapid vaccination rates in the second half of 2021 have resulted in Australia now having one of the highest levels of vaccination in the world (Figure 1.7).

Figure 1.7: International comparison of vaccination levels of people who (a) completed the initial vaccination protocol (2) doses between 1 December 2020 and 30 April 2022 and (b) received a booster (3rd dose) vaccination between 1 August 2021 and 30 April 2022



Source: Ritchie et al. 2022.

By 30 April 2022, more than 95% of the population aged 16 and over were fully vaccinated against COVID-19 under the primary 2-dose protocol (Table 1.1). All jurisdictions except the Northern Territory have more than 90% of their people aged 16 and over fully vaccinated, with Western Australia having the highest booster vaccination coverage (85%). The Australian Capital Territory has the highest percentage of children aged 5–11 fully vaccinated (65%). To date 346,000 people have received a fourth/winter dose (Department of Health 2022i).

Table 1.1: Percentage of people who were fully vaccinated (2 doses) and who have received a booster dose for COVID-19 in Australia, as at 30 April 2022.

	Fully vaccinated (2-doses)			Booster (3rd dose)
Jurisdiction	16 and over	12–15	5–11	Eligible population[(a)]
NSW	94.8	79.5	35.3	66.3
Vic	93.9	85.6	39.8	71.3
Qld	92.1	71.9	29.7	62.6
WA	97.4	80.8	38.2	84.4
SA	93.2	78.4	40.1	72.5
Tas	98.8	83.1	50.2	72.0
ACT	>99.0	>99.0	65.4	77.2
NT	88.8	75.0	32.2	75.8
Australia	**95.5**	**80.4**	**36.9**	**69.3**

(a) Eligible population consists of people aged 16 and over who completed a primary course of vaccination at least 3 months ago (data correct as at 30 April 2022).

Source: Department of Health 2022i.

Progress in vaccination of children in Australia is among the highest in the world, with 53% of children aged 5–11 having received one dose and with 37% being fully vaccinated by 30 April 2022 (Department of Health 2022i).

- In Canada, 57% of 5–11-year-olds had received at least one dose and 41% had received 2 doses by 24 April 2022 (Government of Canada 2022).
- Similarly, Iceland, Portugal and Spain have all vaccinated more than 50% of children aged 5–9 with at least one dose (OWID 2022).
- In the United States, 28% of 5–11-year-olds and 58% of 12–17-year-olds had received 2 doses by 27 April 2022 (AAP 2022).
- Several European countries, including Switzerland, have vaccinated less than 10% of children with their first dose (OWID 2022).

However, COVID-19 vaccination status varies by population groups in Australia. Coverage is high for aged care residents where 97% of residents have received 3 or more doses; however, only 74% of NDIS participants and 53% of Indigenous Australians over the age of 16 had received 3 or more doses by 30 April 2022 (Department of Health 2022i). Only 60% of Indigenous children aged 12–15 are fully vaccinated with 2 doses compared with 80% for all 12–15-year-olds (Department of Health 2022i).

COVID-19 deaths and disease severity

Information on COVID-19 deaths in Australia is available from two sources: the NINDSS which receives data on COVID-19 related deaths from states and territories, and the ABS which compiles death registrations processed by state and territory Registries of Births, Deaths and Marriages.

Defining a COVID-19 related death

The COVID-19 Communicable Diseases Network Australia National Guidelines for public health units define a COVID-19 death as: "a death in a probable or confirmed COVID-19 case, unless there is a clear alternative cause of death that cannot be related to COVID-19 (for example, trauma). There should be no period of complete recovery from COVID-19 between illness and death" (Department of Health 2022f).

There are two considerations:

- First, under this definition COVID-19 deaths reported in surveillance data will include people who died from COVID-19 as well as people who died with COVID-19, where COVID-19 was not necessarily the cause of death.
- Second, the Registries of Births, Deaths and Marriages include additional information on underlying causes of death and other associated causes sourced from the Medical Certificate of Cause of Death (death certificate) (which is certified by a medical practitioner or coroner).

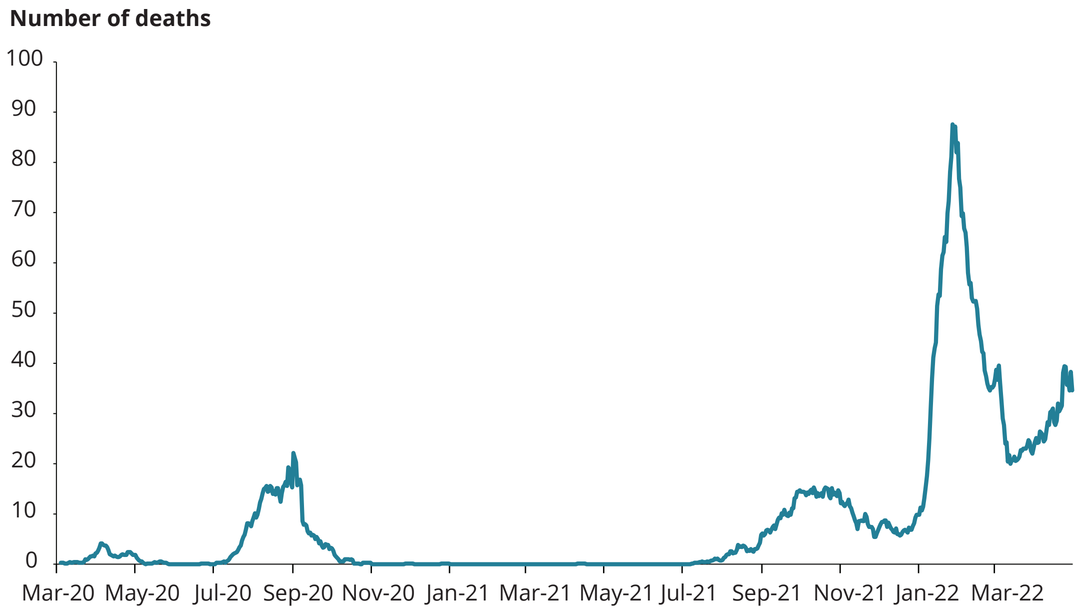
There is a lag between when deaths occur and when they are registered, with around 93% of doctor and coroner certified deaths registered within 2 months of occurrence (ABS 2022c). While death registrations are the official source for reporting on COVID-19 deaths, surveillance data provide rapid information to monitor trends used to inform the public health response and health system preparedness. In this article, surveillance data are used to describe trends in COVID-19 mortality over time and for international comparisons. Death registration data are used to explore demographic differences in mortality due to COVID-19 and report on associated causes of death and comorbidities.

COVID-19 deaths and severity reported by disease surveillance systems

Compared with many other countries, Australia has a relatively low overall COVID-19 related mortality rate. By 30 April 2022, the cumulative mortality rate since the start of the pandemic was 281 per million people, compared with 2,985 for the United States, 2,567 for the United Kingdom, and 1,033 per million for Canada (Ritchie et al. 2022).

Figure 1.8 presents the daily deaths in Australia corresponding to the 4 waves, with the greatest number of deaths occurring in the 4th wave (Omicron).

Figure 1.8 Number of confirmed daily deaths (7-day rolling average) 1 March 2020 to 30 April 2022, Australia



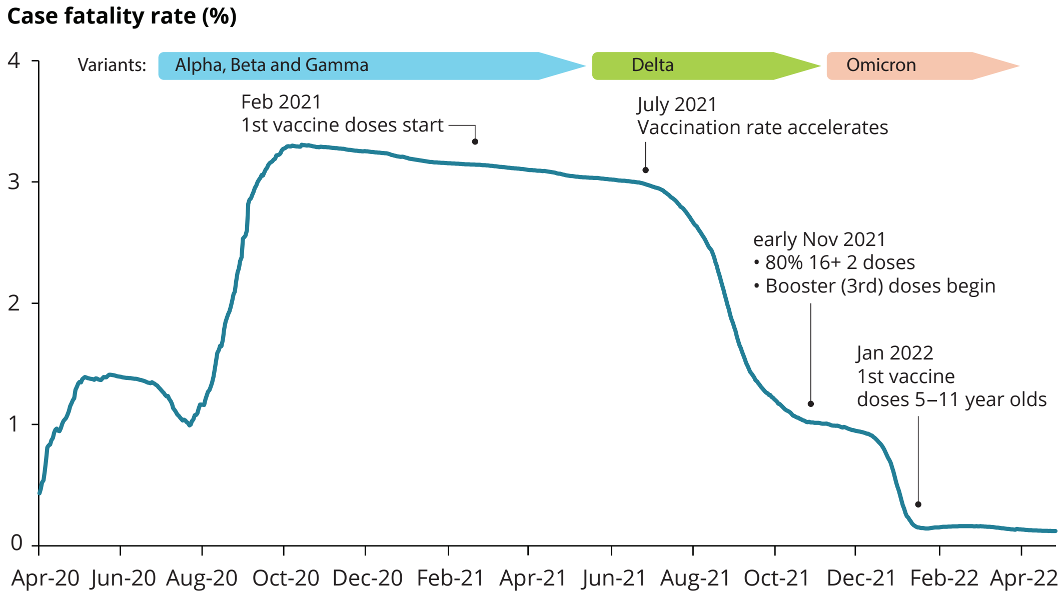
Note: NSW reported 331 additional COVID-19 deaths on 1st April 2022 that are not included in this figure: 270 that occurred between 1 January and 23 March 2022, 58 in 2021 and 3 in 2020 (NSW Health 2022e).

Source: AIHW analysis of COVID Live 2022.

The case fatality rate (CFR) defined as the proportion of cases that result in death is often used as a measure of disease severity. It is important to note that the true total number of cases is likely to be unknown as not everyone with COVID-19 is tested and the CFR will overestimate the true risk of death. Since the start of the pandemic, the CFR in Australia has fluctuated; it peaked at 3.3% in October 2020 and has rapidly declined since July 2021 to 0.1% by 30 April 2022, corresponding to the roll-out of the vaccination program (Figure 1.9). For more detail on vaccination, see the section titled "COVID-19 vaccination" earlier in this article.

The CFR varies with age. Data from New South Wales reported the CFR between 26 November 2021 and 12 February 2022 to be 7.9% in people aged 90 or more, 3.6% for 80–89-year-olds, below 1% for people aged 60–79, and less than 0.1% for all other age groups (NSW Health 2022c).

Figure 1.9: Case fatality rate, 1 April 2020 to 30 April 2022, Australia

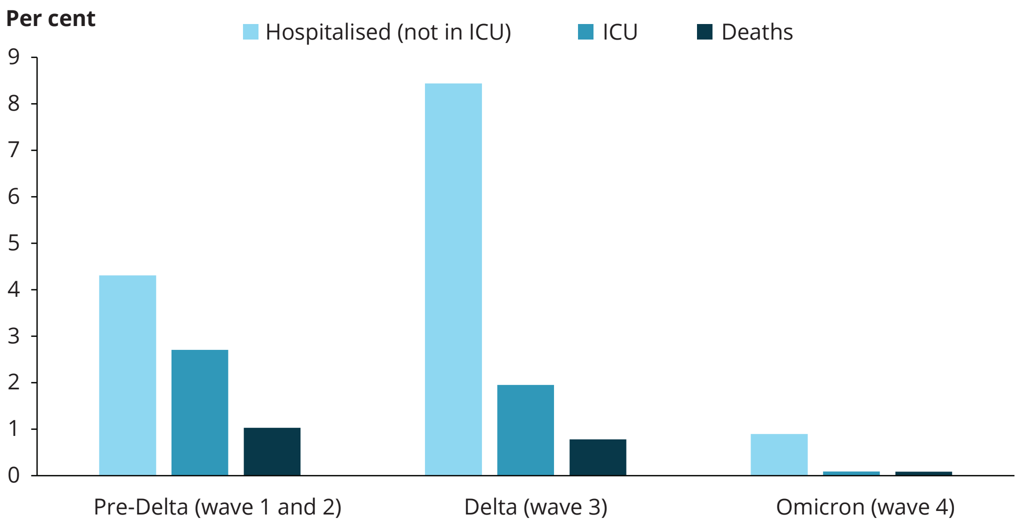


Source: AIHW analysis of COVID Live 2022.

For national reporting purposes, severe cases of COVID-19 are defined as the number of people (cases) admitted to an ICU or who died. The proportion of people with severe COVID-19 per week increased from 0.4 to a peak of 3.7 per 100,000 population nationally between December 2021 and mid-January 2022 in line with the increase in cases over this period (COVID-19 NIRST 2022a, 2022b). This peak was 3 times that of the Delta outbreak, when the proportion reached 1.2 per 100,000 people in the first week of September 2021.

Figure 1.10 compares hospitalisations, ICU admissions and deaths among cases diagnosed with COVID-19 for the Omicron and previous waves in New South Wales. It shows that the proportion of cases experiencing a severe outcome was considerably lower for Omicron than for Delta and earlier waves.

Figure 1.10: Proportion of COVID-19 cases resulting in severe disease (hospitalisation, ICU or death) for Omicron compared with previous waves (NSW), from 1 January 2020 to 23 April 2022



Notes

1. The pre-Delta wave includes cases diagnosed from 1 January 2020 to 15 June 2021. The Delta wave includes cases diagnosed from 16 June 2021 to 25 November 2021. The Omicron wave includes cases diagnosed from 26 November 2021 to 23 April 2022.
2. Categories are not mutually exclusive. Deaths may occur with or without ICU admission.

Source: AIHW analysis of NSW Health 2022a.

Experience in Australia to date reflects growing international evidence that, while Omicron spreads more easily than previous variants, the risk of it causing severe disease resulting in hospitalisation or death is lower than for previous variants (CDC 2022c). The severe case rate nationally depends on the severity of individual cases and the number of cases. The case severity will be determined by several factors including age distribution, vaccination status, and the intrinsic pathogenicity of circulating variants.

When there is a large number of cases associated with a highly transmissible variant such as Omicron, even a small proportion of individuals needing care for severe illness could overwhelm the healthcare system. For example, on 30 April 2022, 3,157 of 329,664 active cases (1.0%) were in hospital, with 144 (4.6%) of these cases in an ICU (Department of Health 2022c).

COVID-19 deaths by vaccination status

Comprehensive analysis of data in Australia on death rates from COVID-19 by vaccination status is forthcoming. South Australia recently reported a death rate of 159.7 per 100,000 COVID-19 cases who were unvaccinated compared with 50 per 100,000 cases who were fully vaccinated and had received a booster (ABC News 2022). Evidence from other countries shows a clear protective effect provided by COVID-19 vaccination (Table 1.2).

Table 1.2 Age-standardised COVID-19 death rates by vaccination status for selected countries

		COVID-19 death rate per 100,000 people		
Country	% of population fully vaccinated	Unvaccinated	Fully vaccinated, no booster	Fully vaccinated plus booster
Switzerland[(a)]	68.8	0.41	0.16	0.11
United States[(b)]	66.5	3.37	0.42	0.20
Chile[(c)]	91.0	1.96	1.23	0.36

(a) As at 1 May 2022.

(b) As at 26 February 2022.

(c) As at 17 April 2022. 'Not fully vaccinated' is included in unvaccinated category.

Notes

1. Fully vaccinated refers to a 2-dose primary protocol.
2. Denominator used to calculate death rate is number of people in each group
3. The main vaccines Switzerland and USA used were Pfizer and Moderna; the main vaccine Chile used was Sinovac.

Source: Mathieu and Roser 2021.

COVID-19 deaths from death registrations

Cause of death data recorded on the death certificate are coded to the WHO International Classification of Diseases and Related Health Problems, 10th Revision (ICD-10). In responding to the pandemic, the WHO issued new codes to be used for coding cause of death for statistical purposes (Box 1.2). Data from the death registration system also provide additional information on comorbidities and consequences of the disease (see section titled 'Associated causes of death and comorbidities' later in this article).

Box 1.2 WHO ICD-10 codes used for classifying COVID-19 deaths from the Medical Certificate of Cause of Death

- U07.1 – COVID-19 virus identified: used when COVID-19 is confirmed by laboratory testing
- U07.2 – COVID-19 virus not identified: used for suspected or clinical diagnosis of COVID-19 where testing is not completed or inconclusive
- U08 – personal history of COVID-19: used when a person has recovered from COVID-19 and no long-term effects have been certified as contributing to an individual's death. These deaths are not included in COVID-19 mortality statistics
- U09 – post-COVID condition: used to link long-term conditions that are a result of the virus, such as chronic lung conditions. These deaths are included in COVID-19 mortality statistics
- U10 – multi-system inflammatory syndrome associated with COVID-19: used to identify people who have died from COVID-19 where the virus has led to a multi-inflammatory response syndrome. These deaths are included in COVID-19 mortality statistics.

By 30 April 2022, there were 5,940 registered deaths where people died either with or from COVID-19 (ABS 2022a). For 5,335 (90%) of these, COVID-19 was determined to be the underlying cause of death; 605 (10%) people died with COVID-19, but it was not the underlying cause of death.

Of the 5,335 deaths due to COVID-19:

- 5,269 were confirmed COVID-19 deaths (99%) with laboratory identification of the virus (ICD-10 code U07.1)
- 19 were suspected COVID-19 deaths (0.4%) with the virus not confirmed in a laboratory at the time of certification (ICD-10 code U07.2)
- 47 were deaths (0.9%) due to long-term effects of COVID-19 (ICD-10 code U09)
- none were due to multi-system inflammatory syndrome.

The following figures and tables in this section report on deaths considered to be due to COVID-19.

From the start of the pandemic to 30 April 2022, most deaths (3,107) from COVID-19 occurred in 2022 (1,323 in 2021, 905 in 2020). Table 1.3 compares the number of deaths for the 10 leading causes of death in 2019 with the number of deaths (including from COVID-19) in 2020, 2021 and 2022 (to 28 February 2022).

- Between 2019 and 2021, dementia and coronary heart disease were the leading causes of death, each accounting for around 10% of deaths each year.
- In 2021, only 0.8% of deaths were from COVID-19.
- This proportion of deaths from COVID-19 rose to 9.6% of deaths during the first 2 months of 2022 compared with 8.4% of deaths from coronary heart disease.

The median age of people who have died from COVID-19 to date is 83.9 compared with 84.1 for coronary heart disease and 89.1 for dementia in 2020 (ABS 2021, 2022a).

It should be noted that the death rate will change depending on the course of the pandemic in 2022, and the relative contribution of COVID-19 as a cause of death is likely to change.

Table 1.3: Number of deaths in 2019 - 2021 and 2022 year to date for top 10 causes of death in 2019 compared with COVID-19 deaths

	2019		2020		2021		January – February 2022	
Cause	Number	%	Number	%	Number	%	Number	%
Dementia including Alzheimer's disease (F01, F03, G30)	14,604	10.1	14,561	10.2	15,473	10.3	2,662	10.1
Coronary heart disease (I20–I25)	14,028	9.7	13,610	9.6	13,921	9.3	2,201	8.4
Cerebrovascular disease (I60–I69)	9,142	6.3	9,046	6.4	9,150	6.1	1,413	5.4
Lung cancer (C33, C34)	8,499	5.9	8,390	5.9	8,562	5.7	1,432	5.4
Chronic obstructive pulmonary disease (COPD) (J40–J44)	7,045	4.9	6,033	4.2	6,537	4.4	946	3.6
Colorectal cancer (C18–C20, C26.0)	5,091	3.5	5,339	3.8	5,230	3.5	825	3.1
Diabetes (E10–E14)	4,524	3.1	4,934	3.5	4,984	3.3	859	3.3
Influenza and pneumonia (J09–J18)	3,806	2.6	2,148	1.5	2,134	1.4	319	1.2
Prostate cancer (C61)	3,493	2.4	3,587	2.5	3,576	2.4	590	2.2
Heart failure and complications and ill-defined heart disease (I50–I51)	3,261	2.3	3,048	2.1	3,501	2.3	489	1.9
COVID-19 (U07.1, U07.2)	0	0.0	854	0.6	1,212	0.8	2,521	9.6
All causes	**144,323**	**100**	**142,345**	**100**	**149,939**	**100**	**26,305**	**100**

Notes

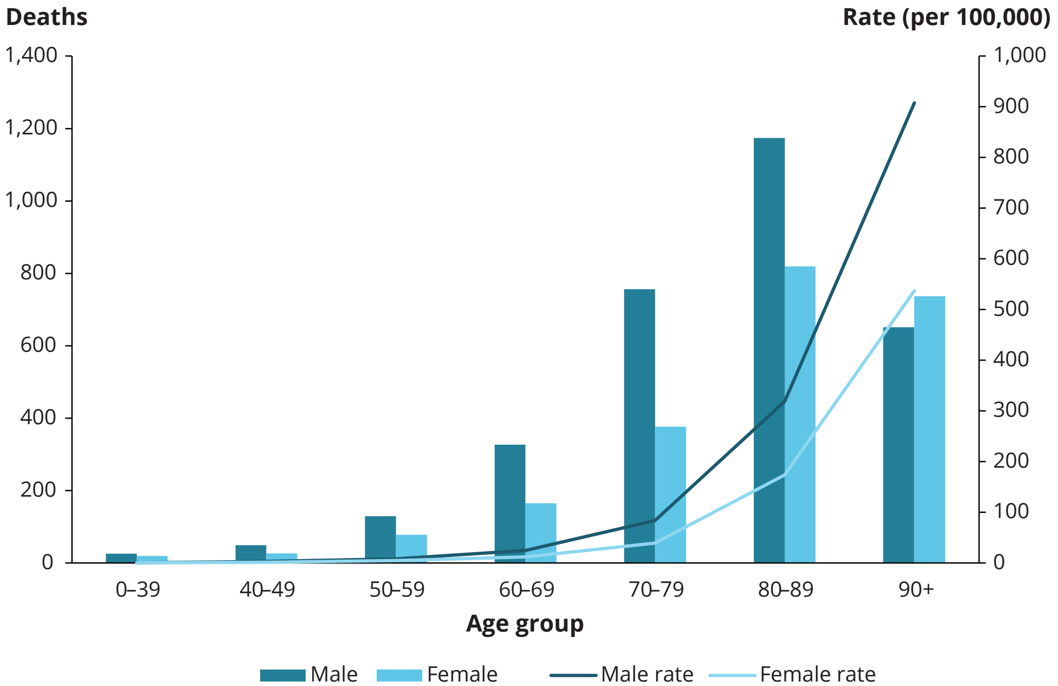
1. Data are doctor certified deaths compiled by the date on which the death occurred. Data are provisional and subject to change as additional data are received.
2. Data for 2022 include deaths occurring until 28 February and registered by 30 April 2022.
3. Data in this table are not comparable to numbers of deaths published in ABS reports 3302.0 Deaths, Australia and 3303.0 Causes of Death, Australia. For scope differences, please refer to the methodology section of Provisional Mortality Statistics, Australia.

Source: ABS customised report.

Deaths by age and sex

The number of deaths and mortality rate increased with age, with the highest rates in the older age groups (Figure 1.11). Overall, the mortality rate from COVID-19 was 1.4 times as high for males (24 per 100,000) as for females (17 per 100,000). However, this varied with age and mortality was significantly higher in males than females from 50 years of age.

Figure 1.11: Number and rates of registered COVID-19 deaths by age and sex, as at 30 April 2022



Notes

1. Data are deaths due to COVID-19 that occurred and were registered by 30 April 2022.
2. Deaths due to COVID-19 have an underlying cause of either ICD-10 code U07.1 COVID-19, virus identified or U07.2 COVID-19, virus not identified.
3. Data are provisional and subject to change as additional data is received.
4. Rates are calculated using the estimated resident population as at 30 March 2020.

Source: AIHW analysis of ABS 2022a.

Deaths by jurisdiction

The overall COVID-19 mortality rate in Australia as at 30 April 2022 was 208 per million population. More than 80% of all deaths occurred in New South Wales and Victoria (Table 1.4). The mortality rate was highest for Victoria, followed by New South Wales, and was lowest in Western Australia.

Table 1.4: Number and mortality rate of COVID-19 deaths, by state or territory of registration, as at 30 April 2022

State/territory	Number	Proportion of total COVID-19 deaths (%)	Deaths per million
NSW	2,026	38.0	248
Vic	2,438	45.7	364
Qld	563	10.6	109
WA	39	0.7	15
SA	168	3.1	95
Tas	39	0.7	72
ACT	52	1.0	121
NT	10	0.2	41
Australia	**5,335**	**100.0**	**208**

Notes

1. Data are deaths due to COVID-19 that occurred and were registered by 30 April 2022.
2. Deaths due to COVID-19 have an underlying cause of either ICD-10 code U07.1 COVID-19, virus identified or U07.2 COVID-19, virus not identified.
3. Data are provisional and subject to change as additional data is received.
4. Rates are calculated using the estimated resident population as at 30 March 2020.

Source: AIHW analysis of ABS 2022a.

Associated causes of death and comorbidities

Most deaths due to COVID-19 (94%) had other associated causes of death listed on the death certificate (ABS 2022a). Associated causes include manifestations of COVID-19 infection such as viral pneumonia and secondary infection (conditions in the causal sequence) and pre-existing chronic conditions that place people at greater risk of developing severe illness from COVID-19.

Of these deaths, 52% had both a condition listed in the causal sequence and a pre-existing chronic condition, 20% had a condition in the causal sequence only, and 22% had a pre-existing chronic condition only. The most common condition in the causal sequence was pneumonia, associated with 69% of COVID-19 deaths (Table 1.5).

Table 1.5: Most commonly certified associated causes of COVID-19 deaths: conditions in the causal sequence as at 30 April 2022

Acute conditions	%
Pneumonia	68.5
Respiratory failure	13.8
Other infections	10.0
Acute renal complications	9.8
Acute cardiac complications	8.4
Other organ failure	8.0
Delirium	3.6
Acute Respiratory Distress Syndrome	3.4

Notes

1. Data are deaths due to COVID-19 that occurred and were registered by 30 April 2022.
2. Deaths due to COVID-19 have an underlying cause of either ICD-10 code U07.1 COVID-19, virus identified or U07.2 COVID-19, virus not identified.
3. Data are provisional and subject to change as additional data is received.
4. Total percentage will exceed 100% as more than one condition can be listed.

Source: ABS 2022a.

Chronic cardiac conditions were the most common comorbidities, recorded in 37% of COVID-19 deaths, followed by dementia which was recorded for 31% of deaths (Table 1.6). The comorbidities present in COVID-19 deaths in Australia are consistent with those reported internationally.

Table 1.6 Most commonly certified associated causes of COVID-19 deaths: pre-existing conditions as at 30 April 2022

Chronic condition	%
Chronic cardiac conditions	37.4
Dementia	31.1
Diabetes	19.1
Chronic respiratory conditions	17.5
Cancer	16.5
Chronic kidney diseases	13.5
Hypertension	13.1
Musculoskeletal disorders	5.3
Chronic cerebrovascular diseases	4.1
Parkinsons disease	3.6

Notes

1. Data are deaths due to COVID-19 that occurred and were registered by 30 April 2022.
2. Deaths due to COVID-19 have an underlying cause of either ICD-10 code U07.1 COVID-19, virus identified or U07.2 COVID-19, virus not identified.
3. Data are provisional and subject to change as additional data is received.
4. Total percentage will exceed 100% as more than one condition can be listed.

Source: ABS 2022a.

Excess mortality

The burden of mortality that can be attributed either directly or indirectly to the COVID-19 pandemic is measured by estimating excess deaths. Excess mortality is the difference between the observed number of deaths in a defined period and the expected number of deaths during that same period. Excess mortality in Australia has been analysed using methodology that forecasts expected mortality based on the previous 5 years of data (ABS 2022b). Results for registered deaths in Australia during 2020 and 2021 that occurred up until 31 December 2021 are summarised in Table 1.7. Key points are:

- During 2020, there were around 1,700 fewer deaths than expected in Australia in total. Most were within expected thresholds, with only 209 during the winter months exceeding the lower threshold.
- During 2020, there were significantly fewer deaths than expected in New South Wales (-2.6%) and Queensland (-2.6%). Victoria had significantly higher deaths than expected (1.1%).
- During 2021, there were around 5,000 more deaths than expected in Australia in total. Most were within expected thresholds, only 108 across a 5-week period exceeded the upper threshold.
- During 2021, there were significantly more deaths than expected in Victoria (8.3%) and South Australia (8.4%).

Table 1.7: Excess deaths in Australia, 2020–2021

	2020		2021	
State/territory	Number	%	Number	%
NSW	–1,292*	-2.6	13	0.0
Vic	382*	1.1	2,782*	8.3
Qld	–786*	-2.6	853	2.8
WA	-63	-0.5	804	6.5
SA	102	0.9	891*	8.4
Tas	–68	-1.8	366	9.8
ACT	24	1.2	102	5.2
NT	18	2.1	–96	-11.0
Australia	–1,734	-1.2	5,090	3.5

* Denotes periods of statistically significant excess mortality or lower than expected mortality (2 weeks or more above or below thresholds). Thresholds are the upper and lower limits of the expected number of deaths in the absence of an influenza epidemic.

Note: Data are doctor certified deaths that had occurred by 31 December 2021 and were registered by 28 February 2022 for which jurisdictional data were available. Updated national-level excess mortality estimates for deaths registered until 30 April 2022 (for which jurisdictional figures are not available) are presented in Chapter 2.

Source: AIHW analysis of ABS 2022b.

In terms of specific causes of death, lower than expected deaths have been observed during the pandemic from 2020 to 2021 for some conditions, including pneumonia and influenza, and diabetes (ABS 2022b). Higher than expected deaths were observed for cancer and chronic lower respiratory conditions in 2021. Since the largest number of deaths from COVID-19 during the pandemic has occurred in 2022, the impact on excess mortality in 2022 is likely to be greater than seen for 2020 and 2021. For more information on excess mortality see Chapter 2 'Changes in the health of Australians during the COVID-19 period'.

Burden of disease

Burden of disease analysis quantifies the gap between a population's actual health and an ideal level of health – that is, every individual living without disease or injury to the theoretical maximum life expectancy – in a given year. Burden of disease is measured using the summary measure disability-adjusted life years (DALYs). One DALY is one year of 'healthy life' lost due to illness and is comprised of 2 components:

- fatal burden estimated by the number of years of life lost (YLL)
- non-fatal burden estimated by the number of years lived with disability (YLD)

The more DALYs associated with a disease or injury, the greater the burden.

Burden of disease analysis compares the impact of different diseases using a common metric, including which diseases are doing the most harm. For information on the methods used for this analysis see *'The first year of COVID-19 in Australia: direct and indirect health effects'* (AIHW 2021b).

It is important to note that some of the data used for the 2021 estimates are preliminary and may change with future articles.

Total burden

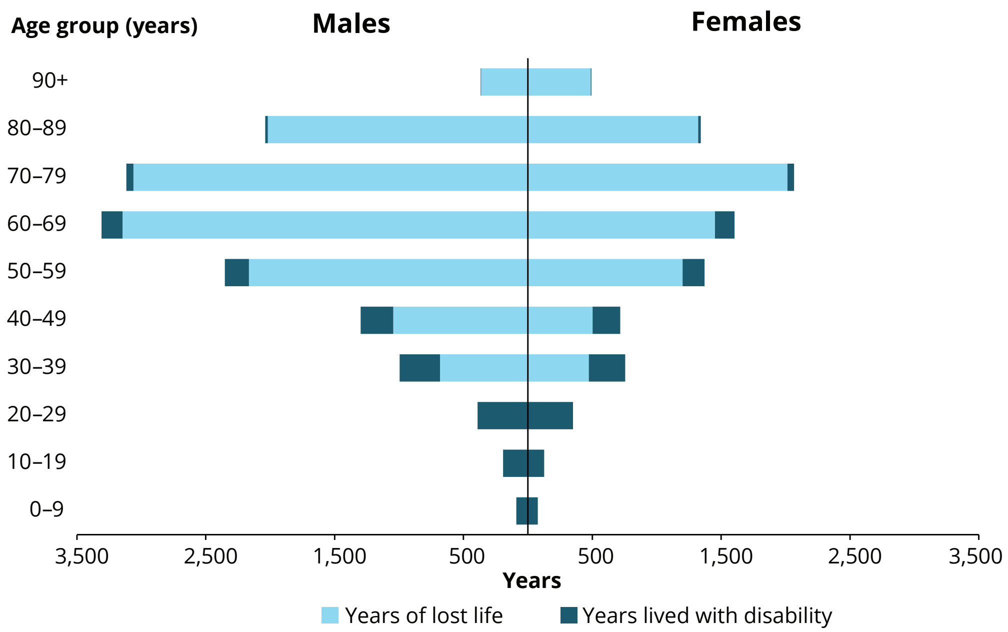
The total burden of disease from COVID-19 was slightly more than 14,100 DALYs for men and 8,900 for women, giving a total of 23,000 DALYs from COVID-19 in Australia in 2021, compared with 8,800 in 2020.

This estimate for Australia in 2021 is much lower than for the leading diseases. For example, coronary heart disease was the leading cause of burden in 2018 (the most recent estimates available) with around 312,000 DALYs (AIHW 2021a). Estimated COVID-19 DALY numbers in 2021 were also fewer than for lower respiratory infections including influenza and pneumonia, responsible for around 40,300 DALYs in 2018 (AIHW 2021a).

Based on 2018 burden of disease estimates, COVID-19 accounted for around 0.5% of the total burden in 2021. In comparison, cancer and other neoplasms accounted for 18% and cardiovascular diseases for 13% of the total burden (AIHW 2021a). The lower burden for COVID-19 in Australia compared with other diseases reflects the relative success Australia had in containing the virus in 2021. Analysis for Scotland using very similar methods to those used in this Australian analysis shows that COVID-19 would likely be the second leading cause of burden in that country in 2020, behind coronary heart disease (Wyper et al. 2022).

Most of the total burden for COVID-19 was due to fatal burden, which contributed 88% of DALYs for males and 84% for females (Figure 1.12).

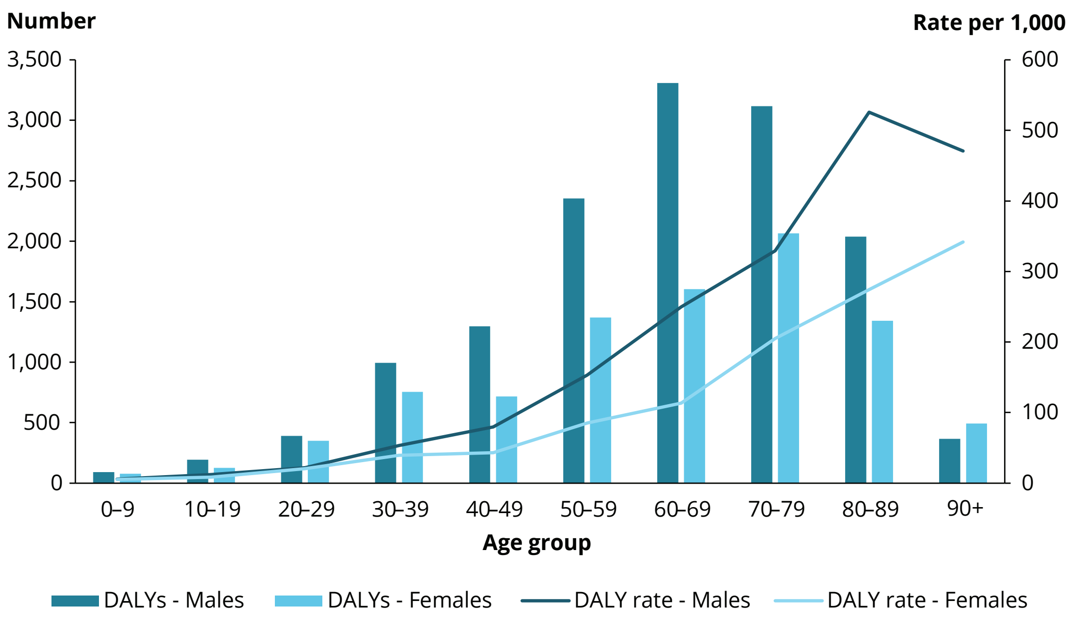
Figure 1.12: Total burden (DALYs) for COVID-19, disaggregated into fatal (YLL) and non-fatal (YLD) burden, by sex, 2021



Source: AIHW analyses as detailed in AIHW 2021b.

While numbers of DALYs were higher in the 60–69 and 70–79 age groups, DALY rates were highest for men aged 80 or more (Figure 1.13). Rates remained relatively low from the youngest to the 40–49 age group for males and females. For men, the rates then increased sharply into the older age groups and were higher than for women. For women, the sharper increases were apparent from the 60–69 age group.

Figure 1.13: Total burden (DALYs) for COVID-19: numbers and rates, 2021



Source: AIHW analyses as detailed in AIHW 2021b.

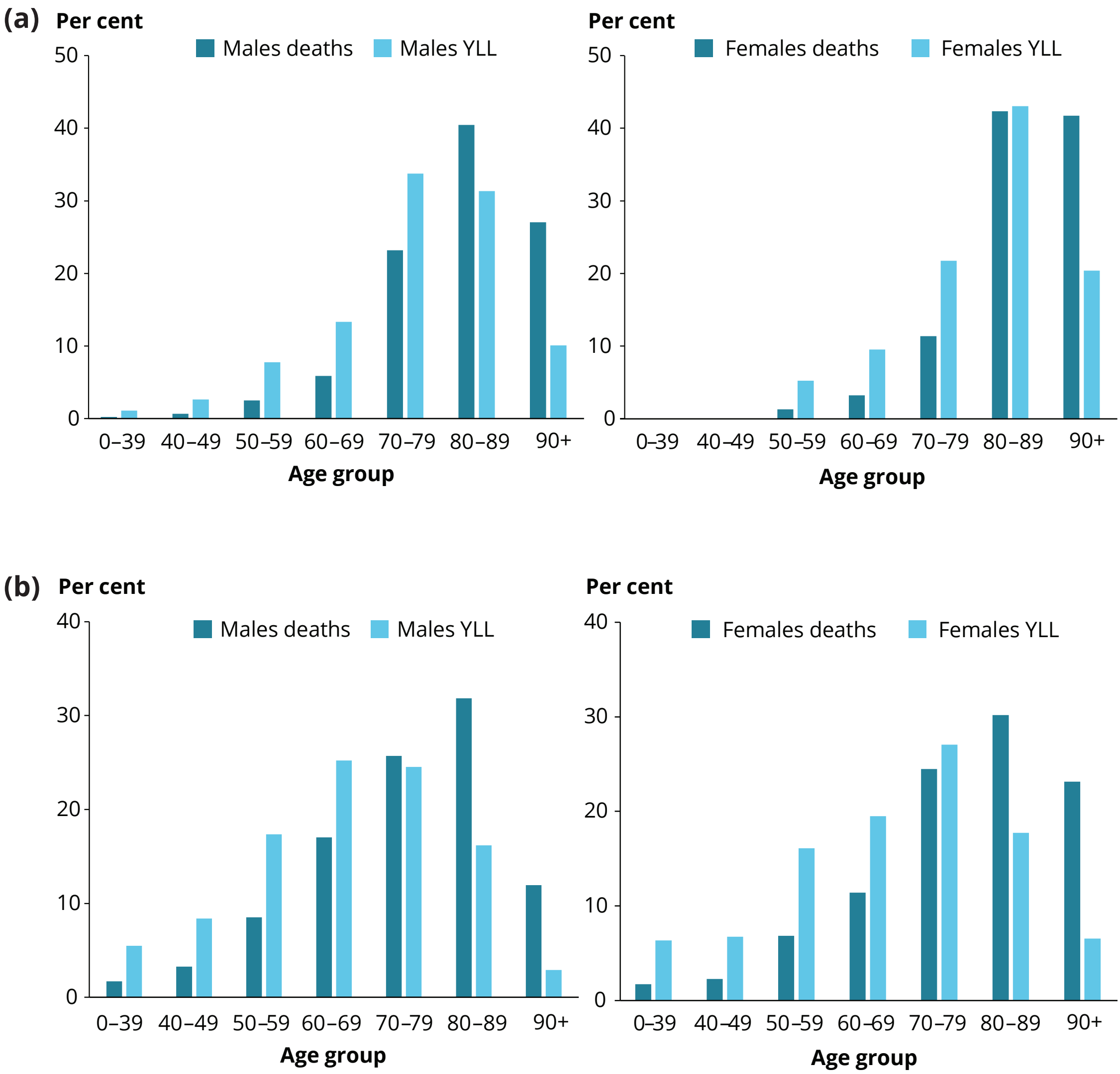
Fatal burden was also found to account for a large proportion (90% or more) of total DALYs in analyses undertaken in many countries, including India (Singh et al. 2022), Mexico (Salinas-Escudero et al. 2021), the Republic of Ireland (Moran et al. 2022), Malta (Cuschieri et al. 2021) and other European countries (Gianino et al. 2021).

The burden of COVID-19 in 2022 will be higher than in 2021 given the increase in the number of cases and deaths since the Omicron wave began in December 2021.

Years of life lost to COVID-19

The YLL per person dying of COVID-19 is estimated to be 15 years (16 and 14 for males and females, respectively) based on the ideal life expectancy used in the Australian Burden of Disease Study (Murray et al. 2012). The percentage of total YLL in people younger than 70 increased from 2020 to 2021 for both males and females (Figure 1.14). Men younger than 70 accounted for 31% of male deaths and 56% of YLLs in 2021 compared with 9.3% of deaths and 25% of YLLs in 2020 (Figure 1.14). The corresponding figures for females were 22% of deaths and 49% of YLLs in 2021 compared with 4.5% of deaths and 15% of YLLs in 2020.

Figure 1.14: Percentage of total COVID-19 deaths and YLL in each age group, by sex, (a) 2020 and (b) 2021



Source: AIHW analyses of ABS deaths data.

Long COVID and Post-COVID-19 Syndrome

Most people who get COVID-19 fully recover within 1–2 weeks. However, some patients experience a range of symptoms that continue for several months after initial infection or appear months after recovery – generally referred to as 'long COVID'. Symptoms that arise after acute infection often include fatigue, 'brain fog' and prolonged loss of taste and smell (Blomberg et al. 2021; Logue et al. 2021; Sudre et al. 2021). However, more severe symptoms – such as delirium, chest pain, heart palpitations and shortness of breath – have been observed in a smaller proportion of COVID-19 patients (Sudre et al. 2021). A recent scoping review indicated that long COVID may encompass a spectrum of more than 100 symptoms (Hayes et al. 2021).

The prevalence of persistent COVID-19 symptoms is unclear. Estimates from early studies varied due to the lack of a universally accepted definition as well as data collection differences, such as the duration of follow-up of patients, and different study populations (for example, hospitalised compared with community cases). One study found that up to 1 in 3 Australian COVID-19 patients experience symptoms up to 4 months after infection (Darley et al. 2021). A similar prevalence has been reported among patients in the United States six months after COVID-19 infection (Logue et al. 2021). In 2021, the WHO reported that around one-quarter of people who have had the virus experience symptoms that continue for at least a month but 1 in 10 are still unwell after 12 weeks (Rajan et al. 2021), while smaller studies in Italy have reported that nearly 9 in 10 patients discharged from hospital were still experiencing at least one symptom 60 days after the onset of COVID-19 (Carfì et al. 2020). A large survey in the United Kingdom found that 22% of people experienced at least one symptom 5 weeks after COVID-19 infection, with 9.8% experiencing symptoms after 12 weeks (Ayoubkhani et al. 2021).

Two clinical case definitions have now been developed that differentiate between ongoing symptomatic COVID-19 where symptoms continue for 4 to 12 weeks after initial infection, and Post-COVID-19 Syndrome where symptoms continue for more than 12 weeks (Box 1.3) (NICE 2021; WHO 2021a). Long COVID is an umbrella term that covers both ongoing symptomatic COVID-19 and Post-COVID-19 syndrome.

Box 1.3: Long COVID clinical case definitions

Long COVID clinical case definitions have been developed to differentiate between ongoing symptomatic COVID-19 symptoms and Post-COVID-19 Syndrome.

National Institute for Health and Care Excellence (NICE) (United Kingdom)

Acute COVID-19

Signs and symptoms of COVID-19 for up to 4 weeks.

Ongoing symptomatic COVID-19

Signs and symptoms of COVID-19 from 4 weeks up to 12 weeks.

Post-COVID-19 Syndrome

Signs and symptoms that develop during or after an infection consistent with COVID-19, continue for more than 12 weeks and are not explained by an alternative diagnosis. It usually presents with clusters of symptoms, often overlapping, which can fluctuate and change over time and can affect any system in the body. Post-COVID-19 Syndrome may be considered before 12 weeks while the possibility of an alternative underlying disease is also being assessed.

In addition to the clinical case definitions, the term 'long COVID' is commonly used to describe signs and symptoms that continue or develop after acute COVID-19. It includes both ongoing symptomatic COVID-19 (from 4 to 12 weeks) and post-COVID-19 Syndrome (12 weeks or more).

World Health Organisation

Post COVID-19 condition occurs in individuals with a history of probable or confirmed SARS-CoV-2 infection, usually 3 months from the onset of COVID-19 with symptoms and that last for at least 2 months and cannot be explained by an alternative diagnosis. Common symptoms include fatigue, shortness of breath, cognitive dysfunction but also others and generally have an impact on everyday functioning. Symptoms may be new onset, following initial recovery from an acute COVID-19 episode, or persist from the initial illness. Symptoms may also fluctuate or relapse over time. A separate definition may be applicable for children.

It is not yet clear why long COVID occurs in some patients and not others, though there is some early evidence to suggest that vaccinated people are less likely to experience long COVID than unvaccinated people (Antonelli et al. 2022; Ledford 2021). A study of nearly 300,000 COVID-19 survivors in the United States found that the risk of long COVID was higher in patients who had more severe COVID-19 infection (Taquet et al. 2021), but even mild COVID has been shown to have effects on brain structure and function (Douaud et al. 2022).

It is too early to tell whether Omicron will result in more cases of long COVID than previous variants. It is plausible that any long-term effects of infection will be less serious if Omicron causes less severe illness, however, the sheer volume of Omicron cases alone could translate into a substantial long COVID burden in a community (Downy Jr. 2022; Sakay 2022).

Up to 30 April 2022, 47 deaths in Australia have been attributed to Post Covid-19 condition (ABS 2022a). Ongoing research will be important for understanding the public health impact of long COVID and health system planning and management. The AIHW is developing a national linked COVID-19 data set for research into a broad range of health questions affecting all Australians who have had COVID-19, including prevalence and risk factors for long COVID, health system use, effectiveness of vaccines, and burden of disease.

Population groups

There is strong evidence that people from some population groups are at greater risk of contracting and dying from COVID-19 than the general population. The disparities in COVID-19 morbidity and mortality interact with and exacerbate existing health and social inequalities encountered by:

- minority ethnic groups
- people experiencing economic disadvantage or poverty
- marginalised population groups such as prisoners, people experiencing homelessness, and sex workers (Bambra et al. 2020).

Socioeconomic area

Table 1.8 presents data on registered deaths from COVID-19 from the start of the pandemic until 30 April 2022 across 5 socioeconomic areas. There is a clear gradient across these areas, with higher numbers and mortality rates for people living in the lowest socioeconomic areas for both males and females. The age-standardised mortality rate was nearly 3 times as high for people living in the lowest socioeconomic area as for people living in the highest socioeconomic area, and this difference was similar for males and females. However, for each socioeconomic area (or quintile), the mortality rate was higher for males than females.

Table 1.8: People who died from COVID-19 in Australia, by socioeconomic area, as at 30 April 2022

IRSD quintile	Deaths	Rate (per million)	95% CI	Age-standardised rate (per million)	95% CI
Males					
1 (lowest)	1080	462	434–489	143	130–156
2	676	274	254–295	93	83–104
3	538	211	193–229	80	70–91
4	465	174	158–190	73	63–83
5 (highest)	328	126	112–140	53	44–62
Females					
1 (lowest)	790	331	308–354	77	68–85
2	482	191	174–208	50	43–57
3	420	161	146–177	48	40–55
4	320	117	105–130	39	33–46
5 (highest)	199	75	64–85	26	20–31
Persons					
1 (lowest)	1870	396	378–413	105	98–113
2	1158	232	219–246	69	63–75
3	958	186	174–197	62	56–68
4	785	145	135–155	55	49–60
5 (highest)	527	100	92–109	38	33–43

IRSD = Index of Relative Socio-economic disadvantage; CI = confidence interval.

Notes

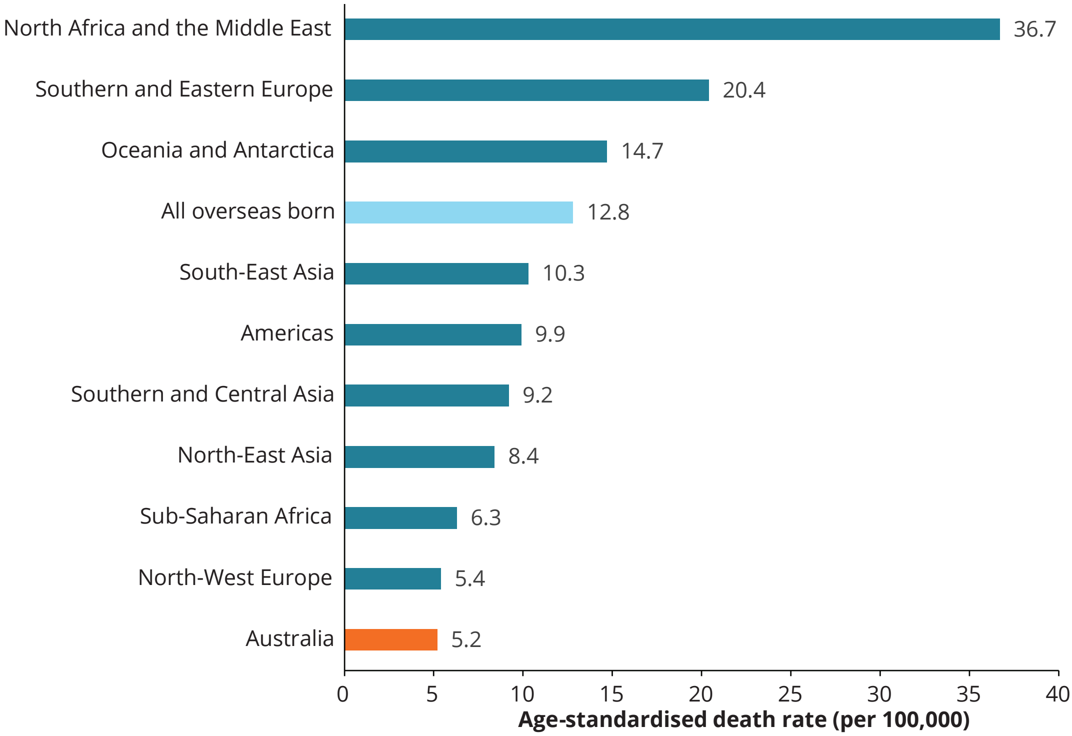
1. This table includes information on doctor or coroner certified deaths registered by 30 April 2022 and numbers will differ from those reported by disease surveillance systems.
2. Deaths due to COVID-19 in this table have an underlying cause of either ICD-10 code U07.1 - COVID-19, virus identified or U07.2 - COVID-19, virus not identified.
3. The analysis uses IRSD, which ranks areas in Australia according to relative socioeconomic disadvantage. Socioeconomic group 1 represents people living in the lowest socioeconomic areas (most disadvantaged) and group 5 represents people living in the highest socio-economic areas (least disadvantaged)
4. The 95% CI is the range of values that are likely to contain the true estimate with 95% confidence.
5. Data are provisional and will change as additional data are received.

Source: ABS customised report.

Region of birth

The age-standardised death rate in the Australian population was 2.5 times as high for people born overseas (12.8 deaths per 100,000) as for people born in Australia (5.2) for COVID-19 deaths registered by 30 April 2022 (Figure 1.15). Of people born overseas, the rate was highest for people born in North Africa and the Middle East (36.7 per 100,000) and lowest for people born in North-West Europe (5.4).

Figure 1.15: Age-standardised COVID-19 death rate in Australia, by region of birth, as at 30 April 2022



Notes

1. Data for Oceania and Antarctica exclude Australia.
2. Data are deaths due to COVID-19 that occurred and were registered by 30 April 2022.
3. Deaths due to COVID-19 have an underlying cause of either ICD-10 code U07.1-COVID-19, virus identified or U07.2-COVID-19, virus not identified.
4. Data are provisional and subject to change as additional data is received.

Source: ABS 2022a.

Rural and remote areas

Large cities with extensive global connections experienced COVID-19 earlier than smaller cities and rural areas (OECD 2021a). For example, in the United States, the cumulative rate of COVID-19 cases in non-metropolitan areas has largely tracked that seen for metropolitan areas; however, since December 2020, the cumulative death rate in non-metropolitan areas has exceeded that of metropolitan areas (CDC 2022a). Factors thought to contribute to the increased mortality risk include lower vaccination coverage and strain on local health systems including hospital closures and staff shortages (Weber 2021).

COVID-19 cases in rural and remote areas of Australia

The spread of cases from urban to rural areas of Australia was of acute concern in August 2021 when cases were confirmed in rural areas of New South Wales despite several weeks of lockdown in Sydney (Malone 2021). There is little information available on COVID-19 cases in rural areas of Australia nationally.

Using New South Wales data reported for individual local government areas (LGAs), cases and rates are calculated for levels of remoteness (Table 1.9). The largest proportion of cases occurred in *Major cities* (81%) and decreased with increasing remoteness in line with Australia's population distribution. The incidence was also highest in *Major cities* (265 per 1,000) and was higher in *Very remote* (183) than in *Remote* areas (157).

Table 1.9: Cumulative number of total COVID-19 cases (confirmed and probable), by remoteness area, New South Wales, as at 26 April 2022

Remoteness Area	Number of cases	Proportion of all cases (%)	Incidence (per 1,000)	95% CI
Major cities	1,652,597	81.2	265	265–266
Inner regional	3,21,968	15.8	204	204–205
Outer regional	57,505	2.8	184	182–185
Remote	3,468	0.2	157	152–162
Very remote	796	0.0	183	172–195

CI = confidence interval.

Notes

1. This table includes cases confirmed with PCR and probable cases identified from RAT results.
2. LGAs were classified into remoteness areas using the Australian Statistical Geographic Standard LGA 2016 to Remoteness Area 2016 correspondences.
3. Rates were calculated using estimated resident population as at 30 June 2020.
4. LGA information was available for a total of 2,036,334 NSW cases that had been reported by 26 April 2022. A further 2,614 were diagnosed in correctional facilities, and 63 in hotel quarantine.
5. The 95% CI is the range of values that are likely to contain the true estimate with 95% confidence.

Source: AIHW analysis of NSW Health 2022d.

COVID-19 deaths in rural and remote areas

The largest proportion of all deaths from COVID-19 registered by 30 April 2022 occurred in *Major cities* (87%). The age-standardised mortality rate was 3 times as high in *Major cities* as in *Inner regional* areas (Table 1.10).

Table 1.10: Number of COVID-19 deaths and mortality rate (per 100,000) by remoteness area to 30 April 2022

Remoteness area	Number of deaths	Rate (per million)	95% CI	Age-standardised rate (per million)	95% CI
Major Cities	4,604	248	241–255	84.9	81.1–88.7
Inner Regional	476	104	95–114	28.2	24.3–32.1
Outer Regional	169	82	70–94	23.7	18.2–29.1
Remote and very remote	14	28	n.a.	n.a.	n.a.

CI = confidence interval

n.a. = not available – due to the small number of deaths in these categories, the 95% CI is not calculated.

Notes

1. This table includes information on doctor or coroner certified deaths registered by 30 April 2022 and numbers will differ from those reported by disease surveillance systems.
2. Deaths due to COVID-19 in this table have an underlying cause of either ICD-10 code U07.1 - COVID-19, virus identified or U07.2 - COVID-19, virus not identified.
3. The 95% CI is the range of values that are likely to contain the true estimate with 95% confidence.
4. Data are provisional and will change as additional data are received.

Source: ABS customised report.

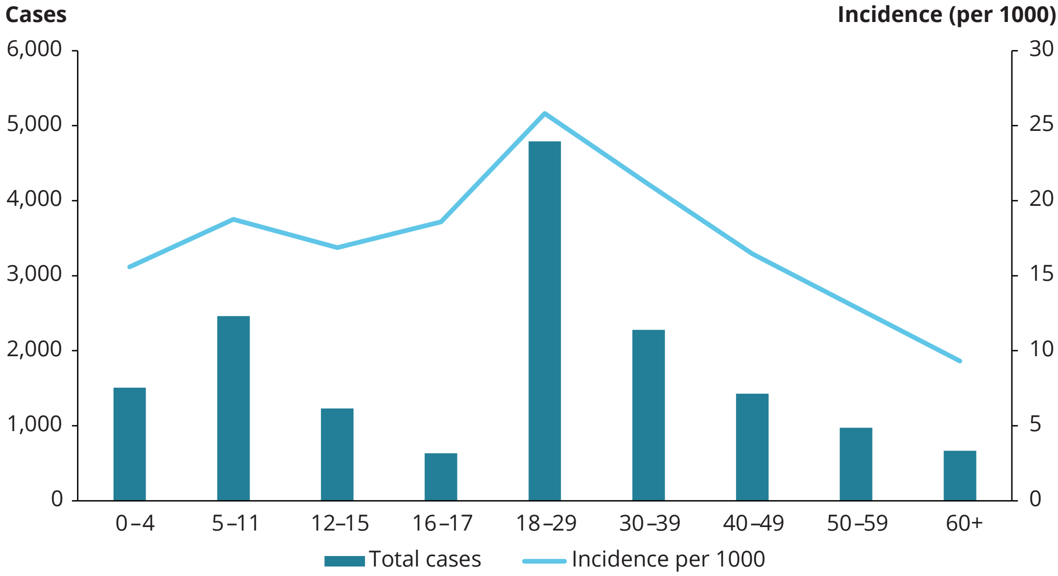
Aboriginal and Torres Strait Islander people

Since the start of the pandemic and, up until 22 May 2022, there have been 175,000 COVID-19 cases among Indigenous Australians (114,000 confirmed by PCR) representing 2.5% of all cases in Australia; most cases (166,000) have occurred since December 2021 during the Omicron wave (NINDSS 2022). The number of COVID-19 cases is likely to be an underestimate as Indigenous status is unknown for 20% of confirmed cases, particularly in 2022 where the rapid increase in cases had an impact on the collection of detailed epidemiological data (COVID-19 NIRST 2022c). For more information on the course of the pandemic among Indigenous people see Chapter 3 'Changes in Aboriginal and Torres Strait Islander people's use of health services in the early part of the COVID-19 pandemic'.

The New South Wales outbreak (which started in late July/early August 2021) showed how quickly COVID-19 can spread through Indigenous communities. As at 31 January 2021, there were 151 confirmed cases of COVID-19, and no deaths reported among Indigenous Australians, representing around 0.5% of all confirmed cases throughout the pandemic (COVID-19 NIRST 2021a). By 24 October 2021, the cases among Indigenous Australians had increased to 6,084, or 4.6% of all confirmed cases (COVID-19 NIRST 2021c).

The age distribution of COVID-19 cases among the Indigenous population was similar to that for the Australian population generally (see section titled 'Cases by age and sex' earlier in this article), with people aged 18–29 having the highest number and incidence of COVID-19 cases (Figure 1.16); 53% of cases were female.

Figure 1.16: Number and cumulative incidence of total PCR-confirmed COVID-19 cases for Indigenous Australians, by age group, 1 January 2021 to 2 January 2022.



Note: Cumulative incidence was calculated as the number of cases divided by the ABS 2016 Census-based population estimates and 30 June 2020 projection (series B).

Source: AIHW analysis of COVID-19 NIRST 2022a.

As at 10 April 2022, 107 deaths had been reported among Indigenous Australians, and 275 cases had been admitted to ICUs (COVID-19 NIRST 2022c). The overall rate of severe disease (defined as ICU admission or death) for Indigenous Australians during the Delta wave (June to December 2021) was 16.2 per 100,000, and rose to 26.9 per 100,000 by 10 April 2022 during the Omicron wave (COVID-19 NIRST 2022b, 2022c). Based on recent surveillance data supplied by the Department of Health and Aged Care, the rate of severe disease during the Omicron wave to 3 July 2022 for Indigenous Australians was 1.4 times as high compared with non-Indigenous Australians (54.0 per 100,000 compared with 37.8 per 100,000 respectively).

Around 42% of Indigenous Australians who contracted COVID-19 (cases) lived in a rural area (regional or remote). The overall COVID-19 rates were highest in people who lived in *Major cities*, with the rate decreasing as the level of remoteness increased (Table 1.11).

For more information on the impact of COVID-19 on Indigenous Australians, see Chapter 3 'Changes in Aboriginal and Torres Strait Islander people's use of health services in the early part of the COVID-19 pandemic.'

Table 1.11: Numbers and incidence of confirmed COVID-19 cases in Indigenous Australians, by area of remoteness, 1 January 2021 to 10 April 2022

	1 January – 5 December 2021		15 December 2021 - 10 April 2022	
Remoteness area	Number	Cases per 1000 (95% CI)	Number	Cases per 1000 (95% CI)
Major cities	5,035	15.3 (14.9–15.8)	39,329	120 (119–121)
Inner and outer regional	3,297	8.7 (8.4–9.0)	31,351	82 (81–83)
Remote and very remote	412	2.7 (2.4–2.9)	6,493	42 (41–43)
Total	8,744	10.1 (9.9–10.4)	77,173	89 (89–90)

CI = confidence interval

Notes

1. Incidence is calculated as the number of cases divided by ABS 2016 Census-based population estimates and 30 June 2020 projection (series B).
2. The 95% CI is the range of values that are likely to contain the true estimate with 95% confidence.
3. Table compiled from published NINDSS data for which breakdown by remoteness was possible. Data incomplete for 6 Dec 2021 to 14 Dec 2021 due to changes in calendar intervals used in published reports. Remoteness information for 63 cases in 2021 and 739 cases in the Omicron wave not available. Data are preliminary and will change as additional data are received.

Source: AIHW analysis of data extracted from COVID-19 NIRST 2021d, 2022c.

People with disability

Some people with disability may be more likely to get infected with COVID-19 or have severe illness if they are less able to physically distance and limit their close contact with others; this is particularly so if they live in congregate settings or have disability support workers (CDC 2021b). They may also have underlying health conditions that make them more susceptible to contracting or dying from COVID-19. As well, the public health response to COVID-19, characterised by lockdowns, has disadvantaged people with disability in several ways, such as in their access to medical care, support for their daily living activities, COVID-19 testing, and vaccination (Shakespeare et al. 2021). The escalating number of cases during the Omicron wave has resulted in staff shortages in health and disability services which is having an effect on access to essential support (CRE-DH n.d.).

Registered NDIS providers report COVID-19 infections in NDIS participants to the NDIS Quality and Safeguards Commission or the National Disability Insurance Agency. The data do not include all participants of the NDIS or people with disability who are not NDIS participants. By 1 May 2022, a total of 12,721 COVID-19 cases had been reported among NDIS participants and 74 COVID-19 related deaths (0.6% of NDIS participant cases) (Department of Health 2022e).

COVID-19 in residential aged care facilities

While the incidence of COVID-19 infection in older people has been relatively low in Australia compared with that for younger age groups, mortality rates were highest in people aged 80 years and over (see the section earlier in this article titled 'COVID-19 deaths from death registrations'). Minimising transmission of COVID-19 in residential aged care facilities and vaccination is important to prevent severe illness or death in this population group.

From the start of the pandemic until 28 April 2022, there have been 34,365 COVID-19 cases among residents of aged care facilities in Australia, which includes 4,096 outbreaks in 2,306 residential aged care facilities (Department of Health 2022h).

From the start of the pandemic until 28 April 2022, 2,181 residents of aged care facilities had died with or from COVID-19 (CFR 6.3%), accounting for 30% of all COVID-19 related deaths in Australia over this time (Department of Health 2022b). Despite most deaths occurring in 2022, the percentage of all COVID-19 deaths that have occurred among aged care residents has fallen over time from 75% in 2020 to 26% in 2022 (Table 1.12).

Table 1.12: COVID-19 related deaths in residential aged care facilities, by year, 2020–2022

Year	COVID-19 aged care deaths	Total COVID-19 deaths	% of total COVID-19 deaths
2020	686	909	75
2021	231	1,330	17
2022	1,264	4,924	26
Total	**2,181**	**7,163**	**30**

Note: Data for 2022 include deaths that have occurred by 28 April 2022 and include deaths both with and from COVID-19 where COVID-19 may not be a cause of death.

Sources: Department of Health 2020, 2021b, 2022b, 2022h.

The cumulative mortality rate is 1.0% of the total number of aged care residents (Department of Health 2022h), which is lower than seen for many other countries, such as Scotland (13%), the United States (13%) and Sweden (8.0%) (Comas-Herrera et al. 2022). It should be noted that the definition of care homes varies in the available international data, and some have both aged and younger residents.

Novel approaches to understanding the pandemic

Seroprevalence studies

Seroprevalence surveys can learn about the total number of people who have been infected, including those infections that might have been missed. This is done by studying the percentage of people who have antibodies in their blood against SARS-CoV-2 Spike (S) and Nucleocapsid (N) proteins at different times. The presence of antibodies indicates that a person has had a previous infection (antibodies against S and N proteins) or has been vaccinated (antibodies against S protein only) (CDC 2022b).

This means increasing levels of vaccination in a population over time can be differentiated from past infection in results from seroprevalence studies. Examples of seroprevalence studies include the WHO Unity studies (WHO 2022a), the United States COVID-19 Serology Surveillance Strategy (CDC 2021a), and the COVID-19 infection survey of the United Kingdom's general population (Walker et al. 2021). Serological surveys in Australia are being co-ordinated by the National Centre for Immunisation Research and Surveillance with The Kirby Institute (The Kirby Institute 2022).

The WHO Unity studies are a set of standardised protocols for conducting sero-epidemiological investigations to collect robust data on the pandemic that can be adapted to any setting (WHO 2022a). The aim is to facilitate international comparisons so that countries and the global community can address knowledge gaps and inform an evidence-based COVID-19 response particularly in resource limited settings. First results from a meta-analysis covering 92 countries including 53 low-to-middle income countries found that 45% of people globally had SARS-CoV-2 antibodies by July 2021 (Bergeri et al. 2022). Seroprevalence rose sharply in the first half of 2021 due to infection in some regions (for example, 30% to 70% in Africa), and vaccination and infection in others (for example, 6% to 95% in North America). In other regions, seroprevalence remained low (for example, 2.5% in the Western Pacific). These findings highlight the inequalities between regions whose populations remain susceptible to infection, and where efforts to scale up vaccination programs need to be prioritised.

Countries such as the United Kingdom that have had a high COVID-19 caseload and access to a comprehensive vaccine roll-out have nearly complete seroprevalence in their populations. Recent data from the COVID-19 infection survey of the United Kingdom's population estimated that around 99% of the adult population in England had antibodies against SARS-Cov-2 in the week starting 28 March 2022 (ONS 2022). This ranged from 95.3% in Northern Ireland to 97.6% in Scotland for children aged 12 to 15 and 83.7% in England to 85.9% in Scotland for children aged 8 to 11.

The only Australian data published to date relate to baseline data collected between 19 June and 6 August 2020 during the first wave of the COVID-19 pandemic and before the SARS-CoV-2 vaccine was available (Vette et al. 2022). Although seroprevalence was very low (<0.5%) the study estimated there were 7 missed infections for every notified case, with a credible range of 0–17 missed infections per case. Undetected transmission was not surprising due to the initially restricted testing policies, continuation of international travel until March 2020, and community transmission of mild disease (Vette et al. 2022).

Future releases from this study will shed further light on undetected transmission through the later waves, particularly during the Omicron wave where Australia experienced its highest case burden and when high vaccine coverage had been achieved in the adult population.

Wastewater-based surveillance testing

Population-wide tracking of the COVID-19 pandemic relies on clinical testing of individuals to identify cases. However, it is difficult to provide information rapidly on large populations through clinical testing alone. Genetic material of the SARS-CoV-2 virus is shed in the faeces of infected asymptomatic and symptomatic individuals which can be detected in wastewater on average 10 days before clinical cases are identified (Shah et al. 2022). Wastewater refers to water from baths, showers, washing machines and toilets that is processed by sewage treatment plants (Australian Academy of Science 2020).

Wastewater-based epidemiology techniques are already widely used for routine surveillance of pathogens, such as polio and norovirus, and for illicit drugs, pharmaceuticals, food consumption, and industrial chemicals (Australian Academy of Science 2020). Using wastewater-based epidemiology to track COVID-19 trends can provide early warnings for an increase in infections and emergence of variants of concern in communities. In the United States, testing wastewater processed by sewage treatment plants for COVID-19 has helped health departments to allocate testing resources, evaluate surveillance irregularities, refine health messaging and forecast clinical resource needs (Kirby et al. 2021). All state and territory health departments in Australia have been monitoring wastewater at sewage plants in support of their COVID-19 response since 2020.

Wastewater surveillance is useful to inform public health action at 3 different stages of a pandemic (WHO 2021b):

- during the *alert phase* when virus circulation is low – to detect early that a virus has entered a community. For example, Australian researchers have tested wastewater from aircraft and cruise ship sanitation systems as an additional means of assessing COVID-19 among people arriving at border entry points (Ahmed et al. 2020; Ahmed et al. 2022)
- during the *pandemic phase* when virus circulation is high – to monitor both the effect of public health measures, and specific settings that may accommodate vulnerable population groups such as schools, hospitals and aged care facilities
- During the *transition* or *interpandemic* phases – to continue ongoing monitoring over the longer term to confirm the absence or resurgence of COVID-19.

Surveillance for new variants of concern can occur at all these 3 stages.

Currently, guidance on the use of wastewater surveillance in Australia depends on 4 levels of community transmission (Department of Health 2022l):

- Epidemiological zone 1 – no community transmission: early warning to detect clusters or outbreaks in communities that have contained transmission
- Epidemiological zone 2 – community transmission: detecting new outbreaks or screening for outbreaks in defined settings (residential aged care facilities, detention facilities, public housing)
- Epidemiological zone 3 – community transmission is placing a burden on response capacity: monitor for genomic variations as outbreak evolves
- Epidemiological zone 4 – community transmission is exceeding response capacity: not recommended except in specific use cases, such as to detect emerging variants of concern.

Many factors influence the practical application of wastewater surveillance, including the sewage network infrastructure, shedding profile of infected individuals, sampling strategy, recovery methods and the detection limit of the instrument (Zhu et al. 2021). To confront these problems, many countries are developing and implementing national testing strategies for a co-ordinated and systematic approach to wastewater-based surveillance for COVID-19 including the ColoSSoS collaboration in Australia (Kayali 2021; Keshaviah et al. 2021; Water Research Australia 2022).

Future global monitoring of COVID-19

The broad impacts of the COVID-19 pandemic have highlighted the importance of open, consistent, and transparent data for evidence-based decision making. To date, non-government organisations such as COVID Live, Johns Hopkins University and Our World in Data have led the collation and publication of global data on COVID-19. The sources of data used to develop these rich resources is variable between countries, ranging from open access repositories, government websites, government social media accounts or press conferences, or little to no reporting (Mathieu 2022). See the next section in this article titled 'Data notes' for more information on the sources of data used in this article.

Despite the extraordinary efforts to track and document the COVID-19 pandemic, the lack of consistent data reporting by individual countries will inevitably result in data of variable quality. For example, there are concerns over the true death toll of COVID-19, with a 2–4 fold discrepancy between reported deaths and studies of excess mortality reported internationally (Adam 2022).

Moving forward, a global commitment to manage long-term pandemic data led by the WHO is needed to allow authorities to continue to collect, improve and provide data in a timely manner (Mathieu 2022). Good-quality data, including the linkage of different data sets, and timely and accurate reporting will be crucial as the pandemic evolves after Omicron, for example, for monitoring the emergence of new variants and studying the impact of long COVID on the Australian population.

Data notes

Data for this article have been obtained from the following publicly available sources:

- **Australian Bureau of Statistics:** death registrations processed by jurisdictional Registries of Births, Deaths and Marriages, and information on cause of death recorded on a Medical Certificate of Cause of Death, completed by a doctor or coroner (ABS 2022a). Registration data provide additional information on the underlying cause of death and other associated causes. It should be noted that the number of deaths from surveillance will differ from the number of registered deaths.
- **Australian Government Department of Health**: information on COVID-19 in residential aged care facilities and among NDIS participants, vaccine coverage from daily updates and weekly epidemiological reports (Department of Health 2022d, 2022e, 2022g).
- **COVID Live:** data collated from media releases, with verification against state and federal health departments. Used to report Australian data on cases, hospitalisations, and deaths collected by disease surveillance. Information on deaths from surveillance systems provide rapid, up-to-date daily information but this information has not yet been processed by jurisdictional Registries of Births, Deaths and Marriages (COVID Live 2022).
- **Our World in Data:** data and information on international comparisons of cumulative infection rates, CFRs and vaccination rates over time (Ritchie et al. 2022). Our World in Data uses raw data sourced from the COVID-19 Data Repository by the Center for Systems Science and Engineering at Johns Hopkins University. Confirmed cases that are collated are identified from aggregated data sources from such bodies as the WHO, ECDC (European Centre for Disease Prevention and Control) and from national, state and county health departments (Dong et al. 2020).
- **NSW Health:** cases by LGA for description of COVID-19 cases by rurality (NSW Health 2022d).

References

AAP (American Academy of Pediatrics) (2022) *Children and COVID-19 vaccinations trends*, AAP, accessed 6 May 2022, https://www.aap.org/en/pages/2019-novel-coronavirus-covid-19-infections/children-and-covid-19-vaccination-trends/.

ABC News (12 April 2022), 'New COVID-19 data shows unvaccinated have 'triple' the risk of death compared with fully jabbed' [news report], *ABC News*, Australia, accessed 20 April 2022, https://www.abc.net.au/news/2022-04-12/sa-health-data-shows-covid-unvaccinated-at-higher-risk-of-death/100983874.

ABS (Australian Bureau of Statistics) (2021) *Causes of death, Australia, 2020*, ABS, accessed 23 May 2022, https://www.abs.gov.au/statistics/health/causes-death/causes-death-australia/2020.

—– (2022a) *COVID-19 mortality in Australia: deaths registered until 30 April 2022*, ABS, accessed 19 May 2022, https://www.abs.gov.au/articles/covid-19-mortality-australia-deaths-registered-until-30-april-2022.

—– (2022b) *Measuring Australia's excess mortality during the COVID-19 pandemic*, ABS, accessed 4 May 2022, https://www.abs.gov.au/articles/measuring-australias-excess-mortality-during-covid-19-pandemic.

—– (2022c) *Provisional Mortality Statistics, January 2022*, ABS, accessed 19 May 2022, https://www.abs.gov.au/statistics/health/causes-death/provisional-mortality-statistics/january-2022.

Adam D (2022) 'The pandemic's true death toll: millions more than official counts', *Nature*, 601:312–315.

Ahmed W, Bertsch PM, Angel N, Bibby K, Bivins A, Dierens L, Edson J et al. (2020) 'Detection of SARS-CoV-2 RNA in commercial passenger aircraft and cruise ship wastewater: a surveillance tool for assessing the presence of COVID-19 infected travellers', *Journal of Travel Medicine*, 27:taaa116, doi:10.1093/jtm/taaa116.

Ahmed W, Bivins A, Smith WJM, Metcalfe S, Stephens M, Jennison AV, Moore FAJ et al. (2022) 'Detection of the Omicron (B.1.1.529) variant of SARS-CoV-2 in aircraft wastewater', *Science of the Total Environment*, 820:153171.

AIHW (Australian Institute of Health and Welfare) (2021a). 'Australian Burden of Disease Study: Impact and causes of illness and death in Australia 2018', *Australian Burden of Disease Study Series 23,* catalogue number BOD 29, AIHW, Australian Government, Canberra.

—– (2021b), *The first year of COVID-19 in Australia: direct and indirect health effects*, catalogue number PHE 287, AIHW, Australian Government, Canberra.

Andersson P, Sherry NL and Howden BP (2021) 'Surveillance for SARS-CoV-2 variants of concern in the Australian context', *Medical Journal of Australia*, 214:500–502.e1.

Antonelli M, Penfold RS, Merino J, Sudre CH, Molteni E, Berry S, Canas LS et al. (2022) 'Risk factors and disease profile of post-vaccination SARS-CoV-2 infection in UK users of the COVID Symptom Study app: a prospective, community-based, nested, case-control study', *The Lancet Infectious Diseases*, 22:43–55.

Australian Academy of Science (2020) *Monitoring wastewater to detect COVID-19* [PDF 515 KB], Australian Academy of Science, Canberra, accessed 3 March 2022, https://www.science.org.au/covid19/monitoring-waste-water.

Ayoubkhani D, Gaughan C and Jenkins J (2021) *Update on long COVID prevalence estimate*, Office for National Statistics, accessed 10 March 2022, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/962830/s1079-ons-update-on-long-covid-prevalence-estimate.pdf.

Bambra C, Riordan R, Ford J and Matthews F (2020) 'The COVID-19 pandemic and health inequalities', *Journal of Epidemiology and Community Health*, 74:964–968.

Bannister M (11 January 2022), 'State governments make moves to mandate rapid test reporting, while others call RATs a 'Band-Aid solution" [news report], accessed 10 March 2022, https://7news.com.au/lifestyle/health-wellbeing/state-governments-make-moves-to-mandate-rapid-test-reporting-while-others-call-rats-a-band-aid-solution-c-5262164.

Bergeri I, Whelan M, Ware H, Subissi L, Nardone A, Lewis HC, Li Z et al. (2022) 'Global epidemiology of SARS-CoV-2 infection: a systematic review and meta-analysis of standardized population-based seroprevalence studies, Jan 2020-Dec 2021', *medRxiv*:2021.12.14.21267791, doi:10.1101/2021.12.14.21267791.

Blomberg B, Mohn KG, Brokstad KA, Zhou F, Linchausen DW, Hansen BA, Lartey S et al. (2021) 'Long COVID in a prospective cohort of home-isolated patients', *Nature Medicine*, 27:1607–1613.

Caly L, Druce J, Roberts J, Bond K, Tran T, Kostecki R, Yoga Y et al. (2020) 'Isolation and rapid sharing of the 2019 novel coronavirus (SARS-CoV-2) from the first patient diagnosed with COVID-19 in Australia', *Medical Journal of Australia*, 212:459–462.

Carfì A, Bernabei R and Landi F (2020) 'Persistent Symptoms in Patients After Acute COVID-19', *Journal of the American Medical Association*, 324:603-605.

CDC (Centers for Disease Control and Prevention) (2021a) *COVID-19 Serology Surveillance Strategy*, CDC, accessed 25 February 2022, https://www.cdc.gov/coronavirus/2019-ncov/covid-data/serology-surveillance/index.html.

—– (2021b) *People with Disabilities*, CDC, accessed 4 May 2022, https://www.cdc.gov/ncbddd/humandevelopment/covid-19/people-with-disabilities.html.

—– (2022a) *COVID Data Tracker*, CDC, accessed 18 May 2022, https://covid.cdc.gov/covid-data-tracker/#pop-factors_totaldeaths.

—– (2022b) *Interim guidelines for COVID-19 antibody testing*, CDC, accessed 24 March 2022, https://www.cdc.gov/coronavirus/2019-ncov/lab/resources/antibody-tests-guidelines.html.

—– (2022c) *Omicron Variant: What You Need to Know*, CDC, accessed 7 March 2022, https://www.cdc.gov/coronavirus/2019-ncov/variants/omicron-variant.html.

Chen J and Wei GW (2022) 'Omicron BA.2 (B.1.1.529.2): High Potential for Becoming the Next Dominant Variant', *Journal of Physical Chemistry Letters*, 13:3840–3849.

Cheng VC, Ip JD, Chu AW, Tam AR, Chan WM, Abdullah SMU, Chan BP et al. (2022) 'Rapid spread of SARS-CoV-2 Omicron subvariant BA.2 in a single-source community outbreak', *Clinical Infectious Diseases*:ciac203, doi:10.1093/cid/ciac203.

Comas-Herrera A, Patel D, Arling G, Mossong J and Schmidt A (2022) *International data on deaths attributed to COVID-19 among people living in care homes*, International Long-term Care Policy Network, accessed 6 May 2022, https://ltccovid.org/2022/02/22/international-data-on-deaths-attributed-to-covid-19-among-people-living-in-care-homes/.

COVID-19 Excess Mortality Collaborators (2022) 'Estimating excess mortality due to the COVID-19 pandemic: a systematic analysis of COVID-19 related mortality, 2020-21', *The Lancet*, 399:1513–1536.

COVID-19 NIRST (COVID-19 National Incident Room Surveillance Team) (2021a) 'COVID-19 Australia: epidemiology report 34: reporting period ending 31 January 2021', *Communicable Diseases Intelligence*, 45, doi:10.33321/cdi.2021.45.8.

—– (2021b) 'COVID-19 Australia: epidemiology report 50: reporting period ending 12 September 2021', *Communicable Diseases Intelligence*, 45, doi:10.33321/cdi.2021.45.50.

—– (2021c) 'COVID-19 Australia: epidemiology report 53 reporting period ending 24 October 2021', *Communicable Diseases Intelligence*, 45, doi:10.33321/cdi.2021.45.61.

—– (2021d) 'COVID-19 Australia: epidemiology report 56: reporting period ending 5 December 2021', *Communicable Diseases Intelligence*, 45, doi:10.33321/cdi.2021.45.69.

—– (2021e) 'Technical supplement - COVID-19 Australia: epidemiology reporting last updated 19 January 2021', *Communicable Diseases Intelligence*, 44, doi:10.33321/cdi.2021.45.2.

—– (2022a) 'COVID-19 Australia: epidemiology report 57: reporting period ending 16 January 2022', *Communicable Diseases Intelligence*, 46, doi:10.33321/cdi.2022.46.4.

—– (2022b) 'COVID-19 Australia: epidemiology report 59 reporting period ending 13 March 2022', *Communicable Diseases Intelligence*, 46, doi:10.33321/cdi.2022.46.25.

—– (2022c) 'COVID-19 Australia: Epidemiology Report 60: Reporting period ending 10 April 2022', *Communicable Diseases Intelligence*, 46, doi:10.33321/cdi.2022.46.33.

COVID Live (2022) *COVID Live*, accessed 2 May 2022, https://covidlive.com.au/.

CRE-DH (Centre of Research Excellence in Disability and Health) (n.d.) *Living with COVID-19 in the time of OMICRON: Escalating risks for people with disability in Australia*, CRE-DH, accessed 4 May 2022, https://credh.org.au/disability-and-health-sectors-need-a-coordinated-response-during-covid-19/covid-19-and-people-with-disabilities/.

Cuschieri S, Calleja N, Devleesschauwer B and Wyper GMA (2021) 'Estimating the direct Covid-19 disability-adjusted life years impact on the Malta population for the first full year', *BMC Public Health*, 21:1827.

Daoud E (22 December 2021), 'Warning as COVID testing queues balloon in Sydney and Melbourne' [news report], *7 News*, Australia, accessed 7 March 2022, https://7news.com.au/lifestyle/health-wellbeing/warning-as-covid-testing-queues-balloon-in-sydney-and-melbourne--c-5044870.

Darley DR, Dore GJ, Cysique L, Wilhelm KA, Andresen D, Tonga K, Stone E et al. (2021) 'Persistent symptoms up to four months after community and hospital-managed SARS-CoV-2 infection', *Medical Journal of Australia*, 214:279–280.

Department of Health (2020) *Coronavirus (COVID-19) at a glance – 31 December 2020*, Department of Health, accessed 5 May 2022, https://www.health.gov.au/resources/publications/coronavirus-covid-19-at-a-glance-31-december-2020.

—– (2021a) *Australia vaccinating children against COVID-19 from early next year*, Department of Health, accessed 14 April 2022, https://www.health.gov.au/news/australia-vaccinating-children-against-covid-19-from-early-next-year.

—– (2021b) *Coronavirus (COVID-19) at a glance – 31 December 2021*, Department of Health, accessed 5 May 2022, https://www.health.gov.au/resources/publications/coronavirus-covid-19-at-a-glance-31-december-2021.

—– (2021c) *First COVID-19 vaccinations in Australia*, Department of Health, accessed 24 February 2022, https://www.health.gov.au/news/first-covid-19-vaccinations-in-australia.

—– (2022a) *Clinical recommendations for COVID-19 vaccines*, Department of Health, accessed 14 April 2022, https://www.health.gov.au/initiatives-and-programs/covid-19-vaccines/advice-for-providers/clinical-guidance/clinical-recommendations.

—– (2022b) *Coronavirus (COVID-19) at a glance – 28 April 2022*, Department of Health, accessed 5 May 2022, https://www.health.gov.au/resources/publications/coronavirus-covid-19-at-a-glance-28-april-2022.

—– (2022c) *Coronavirus (COVID-19) at a glance – 30 April 2022*, Department of Health, accessed 2 May 2022, https://www.health.gov.au/resources/publications/coronavirus-covid-19-at-a-glance-30-april-2022.

—– (2022d) *Coronavirus (COVID-19) at a glance infographic collection*, Department of Health, accessed 6 May 2022, https://www.health.gov.au/resources/collections/coronavirus-covid-19-at-a-glance-infographic-collection.

—– (2022e) *Coronavirus (COVID-19) case numbers and statistics*, Department of Health, accessed 2 May 2022, https://www.health.gov.au/health-alerts/covid-19/case-numbers-and-statistics.

—– (2022f) *Coronavirus disease 2019 (COVID-19) CDNA national guidelines for Public Health units. Version 6.7*, Department of Health, accessed 20 April 2022, https://www1.health.gov.au/internet/main/publishing.nsf/Content/cdna-song-novel-coronavirus.htm.

—– (2022g) *Coronavirus disease 2019 (COVID-19) epidemiology reports, Australia, 2020–2022*, Department of Health, accessed 9 May 2022, https://www1.health.gov.au/internet/main/publishing.nsf/Content/novel_coronavirus_2019_ncov_weekly_epidemiology_reports_australia_2020.htm.

—– (2022h) *COVID-19 outbreaks in Australian residential aged care facilities - 29 April 2022*, Department of Health, accessed 4 May 2022, https://www.health.gov.au/resources/publications/covid-19-outbreaks-in-australian-residential-aged-care-facilities-29-april-2022.

—– (2022i) *COVID-19 vaccine rollout update - 1 May 2022*, Department of Health, accessed 5 May 2022, https://www.health.gov.au/resources/publications/covid-19-vaccine-rollout-update-1-may-2022.

—– (2022j) *COVID-19 vaccine rollout update - 3 January 2022*, Department of Health, accessed 2 May 2022, https://www.health.gov.au/resources/publications/covid-19-vaccine-rollout-update-3-january-2022.

—– (2022k) *Oral treatments for COVID-19*, Department of Health, accessed 24 February 2022, https://www.health.gov.au/health-alerts/covid-19/treatments/oral.

—– (2022l) *Revised testing framework for COVID-19 in Australia. March 2022*, Department of Health, accessed 9 March 2022, https://www.health.gov.au/resources/publications/coronavirus-covid-19-testing-framework-for-covid-19-in-australia.

—– (2022m) *Testing for COVID-19*, Department of Health, accessed 17 February 2022, https://www.health.gov.au/health-alerts/covid-19/testing.

Dong E, Du H and Gardner L (2020) 'An interactive web-based dashboard to track COVID-19 in real time', *The Lancet Infectious Diseases*, 20:533–534.

Douaud G, Lee S, Alfaro-Almagro F, Arthofer C, Wang C, McCarthy P, Lange F et al. (2022) 'SARS-CoV-2 is associated with changes in brain structure in UK Biobank', *Nature*, 604:697–707.

Downy Jr. K (2022) *Q&A: How will omicron affect long COVID?*, Healio, accessed Mar 8, 2022, https://www.healio.com/news/infectious-disease/20220106/qa-how-will-omicron-affect-long-covid.

Gianino MM, Savatteri A, Politano G, Nurchis MC, Pascucci D and Damiani G (2021) 'Burden of COVID-19: Disability-Adjusted Life Years (DALYs) across 16 European countries', *European Review of Medical and Pharmacological Sciences*, 25:5529–5541.

Giattino C (2020) *How epidemiological models of COVID-19 help us estimate the true number of infections*, Our World in Data, accessed 29 April 2022, https://ourworldindata.org/covid-models.

Government of Canada (2022) *COVID-19 vaccination in Canada*, Government of Canada, accessed 2 May 2022, https://health-infobase.canada.ca/covid-19/vaccination-coverage/#a5.

Grimly N, Cornish J and Stylianou N (5 May 2022), 'Covid: World's true pandemic death toll nearly 15 million, says WHO' [news report], *BBC News*, accessed 6 May 2022, https://www.bbc.com/news/health-61327778.

Hanly M, Churches T, Fitzgerald O, MacIntyre CR and Jorm L (2022) 'Vaccinating Australia: How long will it take?', *Vaccine*, 40:2491–2497.

Hayes LD, Ingram J and Sculthorpe NF (2021) 'More than 100 persistent symptoms of SARS-CoV-2 (long COVID): a scoping review', *Frontiers in Medicine (Lausanne)*, 8:750378.

Hoang T, da Silva AG, Jennison AV, Williamson DA, Howden BP and Seemann T (2022) 'AusTrakka: Fast-tracking nationalized genomics surveillance in response to the COVID-19 pandemic', *Nature Communications*, 13:865.

Iacobucci G (2021) 'Covid and flu: what do the numbers tell us about morbidity and deaths?', *BMJ*, 375:n2514.

Jin R (2021) 'The lag between daily reported Covid-19 cases and deaths and its relationship to age', *Journal of Public Health Research*, 10:2049.

Kayali L (2021) *Brussels calls on EU countries to monitor wastewater for COVID-19*, Politico, Brussels, accessed Mar 3, 2022, https://www.politico.eu/article/brussels-calls-on-eu-countries-to-monitor-wastewater-for-covid-19/.

Keshaviah A, Hu XC and Henry M (2021) 'Developing a flexible national wastewater surveillance system for COVID-19 and beyond', *Environmental Health Perspectives*, 129:45002.

Kirby AE, Walters MS, Jennings WC, Fugitt R, LaCross N, Mattioli M, Marsh ZA et al. (2021) 'Using wastewater surveillance data to support the COVID-19 response - United States, 2020-2021', *Morbitity and Mortality Weekly Report*, 70:1242–1244.

Lau H, Khosrawipour T, Kocbach P, Ichii H, Bania J and Khosrawipour V (2021) 'Evaluating the massive underreporting and undertesting of COVID-19 cases in multiple global epicenters', *Pulmonology*, 27:110-115.

Ledford H (2021) 'Do vaccines protect against long COVID? What the data say', *Nature*, 599:546–548.

Logue JK, Franko NM, McCulloch DJ, McDonald D, Magedson A, Wolf CR and Chu HY (2021) 'Sequelae in Adults at 6 Months After COVID-19 Infection', *JAMA Network Open*, 4:e210830.

Lu D (23 December 2021), 'Covid testing sites cut hours over Australia's Christmas period despite 'unprecedented demand" [news report], *The Guardian, Australian Edition*, accessed 7 March 2022, https://www.theguardian.com/australia-news/2021/dec/23/covid-testing-sites-reduce-hours-over-australias-christmas-period-despite-unprecedented-demand.

Lyngse FP, Kirkeby CT, Denwood M, Christiansen LE, Mølbak K, Møller CH, Skov RL et al. (2022) 'Transmission of SARS-CoV-2 Omicron VOC subvariants BA.1 and BA.2: Evidence from Danish Households', *medRxiv*:2022.01.28.22270044, doi:10.1101/2022.01.28.22270044.

Malone U (16 August 2021), 'Regional NSW towns fear the worst as Sydney's COVID-19 outbreak spreads' [news report], *ABC News*, accessed 10 March 2022, https://www.abc.net.au/news/2021-08-14/covid-19-spreads-to-regional-rural-nsw/100376764.

Mathieu E (2022) 'Commit to transparent COVID data until the WHO declares the pandemic is over', *Nature*, 602:549.

Mathieu E and Roser M (2021) *How do death rates from COVID-19 differ between people who are vaccinated and those who are not?*, Our World in Data, accessed 20 May 2022, https://ourworldindata.org/covid-deaths-by-vaccination.

Moran D, Pires SM, Wyper G, Devleesschauwer B, Cuschieri S and Kabir Z (2022) 'Estimating the direct Disability-Adjusted Life Years (DALYs) associated with SARS-CoV-2 (COVID-19) in the Republic of Ireland: The first full year', *medRxiv*:2021.12.29.21268120, doi:10.1101/2021.12.29.21268120.

Murray CJ, Ezzati M, Flaxman AD, Lim S, Lozano R, Michaud C, Naghavi M et al. (2012) 'GBD 2010: design, definitions, and metrics', *The Lancet*, 380:2063–2066.

NICE (National Institute for Health and Care Excellence) (2021) *COVID-19 rapid guideline: managing the long-term effects of COVID-19* [NICE guideline [NG188], NICE, accessed 8 March 2022, https://www.nice.org.uk/guidance/ng188.

NINDSS (National Interoperable Notifiable Diseases Surveillance System) (2022) *Aboriginal and Torres Strait Islander PCR confirmed and RAT positive COVID-19 cases by notification date (year and month), 1 January 2020 to 22 May 2022*, Department of Health.

NSW Health (2022a) *COVID-19 surveillance reports*, NSW Health, accessed 3 May 2022, https://www.health.nsw.gov.au/Infectious/covid-19/Pages/weekly-reports.aspx.

—– (2022b) *COVID-19 weekly overview report - epidemiological week 16, ending 23 April 2022*, NSW Health, accessed 28 April 2022, https://www.health.nsw.gov.au/Infectious/covid-19/Documents/weekly-covid-overview-20220423.pdf.

—– (2022c) *COVID-19 weekly surveillance in NSW - epidemiological week 06, ending 12 February 2022*, NSW Health, accessed 3 March 2022, https://www.health.nsw.gov.au/Infectious/covid-19/Documents/covid-19-surveillance-report-20220303.pdf.

—– (2022d) *NSW COVID-19 cases by location*, NSW Health, accessed 27 April 2022, https://data.nsw.gov.au/search/dataset/ds-nsw-ckan-aefcde60-3b0c-4bc0-9af1-6fe652944ec2/details?q=.

—– (2022e) *NSW COVID-19 related deaths*, NSW Health, accessed 31 March 2022, https://www.health.nsw.gov.au/Infectious/covid-19/Documents/nsw-covid-19-related-deaths-march-2022.pdf.

OECD (Organisation for Economic Co-operation and Development) (2021a), 'The COVID-19 crisis in urban and rural areas', *OECD regional outlook 2021: addressing COVID-19 and moving to net zero greenhouse gas emissions*, OECD Publishing, Paris.

—– (2021b), 'The health impact of COVID-19', *Health at a Glance 2021*, OECD Publishing, Paris.

ONS (Office for National Statistics) (2022) *Coronavirus (COVID-19) infection survey, antibody data, UK: 20 April 2022*, accessed 20 April 2022, https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/bulletins/coronaviruscovid19infectionsurveyantibodyandvaccinationdatafortheuk/20april2022.

OWID (Our World in Data) (2022) *Coronavirus (COVID-19) Vaccinations*, accessed 5 May 2022, https://ourworldindata.org/covid-vaccinations.

PHLN (Public Health Laboratory Network) (2022) *PHLN guidance on laboratory testing for SARS-CoV-2 (the virus that causes COVID-19)*, PHLN, accessed 14 March 2022, https://www.health.gov.au/resources/publications/phln-guidance-on-laboratory-testing-for-sars-cov-2-the-virus-that-causes-covid-19.

Piroth L, Cottenet J, Mariet AS, Bonniaud P, Blot M, Tubert-Bitter P and Quantin C (2021) 'Comparison of the characteristics, morbidity, and mortality of COVID-19 and seasonal influenza: a nationwide, population-based retrospective cohort study', *The Lancet Respiratory Medicine*, 9:251–259.

Rajan S, Khunti K, Alwan N, Steves C, Greenhalgh T, MacDermott N, Sagan A et al. (2021) *In the wake of the pandemic. Preparing for long COVID, policy brief 39*, European Observatory on Health Systems and Policies, accessed 12 January 2022, https://www.euro.who.int/en/about-us/partners/observatory-old/publications/policy-briefs-and-summaries/in-the-wake-of-the-pandemic-preparing-for-long-covid-2021.

Ritchie H, Mathieu E, Rodés-Guirao L, Appel C, Giattino C, Ortiz-Ospina E, Hasell J et al. (2022) *Coronavirus Pandemic (COVID-19)*, Our World in Data, accessed 1 May 2022, https://ourworldindata.org/coronavirus.

Sakay Y (18 January 2022), 'Omicron and Long COVID: What We Know So Far' [news report], *Healthline*, accessed 8 March 2022, https://www.healthline.com/health-news/omicron-and-long-covid-what-we-know-so-far.

Salinas-Escudero G, Toledano-Toledano F, García-Peña C, Parra-Rodríguez L, Granados-García V and Carrillo-Vega MF (2021) 'Disability-Adjusted Life Years for the COVID-19 Pandemic in the Mexican Population', *Frontiers in Public Health*, 9:686700.

Shah S, Gwee SXW, Ng JQX, Lau N, Koh J and Pang J (2022) 'Wastewater surveillance to infer COVID-19 transmission: A systematic review', *Science of the Total Environment*, 804:150060.

Shakespeare T, Ndagire F and Seketi QE (2021) 'Triple jeopardy: disabled people and the COVID-19 pandemic', *The Lancet*, 397:1331–1333.

Singh BB, Devleesschauwer B, Khatkar MS, Lowerison M, Singh B, Dhand NK and Barkema HW (2022) 'Disability-adjusted life years (DALYs) due to the direct health impact of COVID-19 in India, 2020', *Scientific Reports*, 12:2454.

State Government of Victoria (2022) *Victorian COVID-19 data*, Victorian Government, accessed 2 May 2022, https://www.coronavirus.vic.gov.au/victorian-coronavirus-covid-19-data.

Steger S and Luff B (23 December 2021), 'Perth COVID scare: Scorching heat, long wait-times ahead at testing clinics amid pre-Christmas surge' [news report], *The West Australian*, accessed 7 March 2022, https://thewest.com.au/news/coronavirus/perth-covid-scare-scorching-heat-long-wait-times-ahead-at-testing-clinics-amid-pre-christmas-surge-c-5066664.

Sudre CH, Murray B, Varsavsky T, Graham MS, Penfold RS, Bowyer RC, Pujol JC et al. (2021) 'Attributes and predictors of long COVID', *Nature Medicine*, 27:626–631.

Taquet M, Dercon Q, Luciano S, Geddes JR, Husain M and Harrison PJ (2021) 'Incidence, co-occurrence, and evolution of long-COVID features: A 6-month retrospective cohort study of 273,618 survivors of COVID-19', *PLoS Med*, 18:e1003773.

The Kirby Institute (2022) *Serosurveillance for SARS-CoV-2 infection to inform public health responses*, The Kirby Insitute, University of New South Wales, accessed 28 February 2022, https://kirby.unsw.edu.au/project/serosurveillance-sars-cov-2-infection-inform-public-health-responses.

Therapeutic Goods Administration (2022a) *COVID-19 rapid antigen self-tests that are approved in Australia*, Department of Health, accessed 17 February 2022, https://www.tga.gov.au/covid-19-rapid-antigen-self-tests-are-approved-australia.

—– (2022b) *How testing works for COVID-19*, Department of Health, accessed 28 February 2022, https://www.tga.gov.au/how-testing-works-covid-19.

Timms P and Lloyd P (5 January 2022), 'COVID-19 testing under pressure across Australia, as rapid antigen tests remain hard to find amid long delays for PCRs' [news report], *ABC News*, accessed 17 February 2022, https://www.abc.net.au/news/2022-01-05/covid-testing-pcr-delays-rat-test-supply-issues/100738982.

Vette KM, Machalek DA, Gidding HF, Nicholson S, O'Sullivan MVN, Carlin JB, Downes M et al. (2022) 'Seroprevalence of Severe Acute Respiratory Syndrome Coronavirus 2-Specific Antibodies in Australia After the First Epidemic Wave in 2020: A National Survey', *Open Forum Infectious Diseases*, 9:ofac002.

Vidler A, Swain S and Lal S (27 December 2021), "It's a ridiculous situation': Health Services Union State Secretary says about testing chaos' [news report], *9 News*, accessed 7 March 2022, https://www.9news.com.au/national/coronavirus-australia-updates-testing-chaos-long-waits-clinics-closing/57eb1905-0d18-45dd-9368-942298def06e.

Walker A, Diamond I, Rourke E and Farrar J (2021) *COVID-19 infection survey of the UK general population*, ISRCTN Registry, accessed 28 February 2022, https://doi.org/10.1186/ISRCTN21086382.

Wang CC, Prather KA, Sznitman J, Jimenez JL, Lakdawala SS, Tufekci Z and Marr LC (2021) 'Airborne transmission of respiratory viruses', 373, doi:10.1126/science.abd9149.

Water Research Australia (2022) *ColoSSoS Collaboration on Sewage Surveillance of SARS-CoV-2*, accessed 3 March 2022, https://www.waterra.com.au/research/communities-of-interest/covid-19/.

Weber L (30 September 2021), 'Covid is killing rural Americans at twice the rate of people in urban areas' [news report], *NBC News*, accessed 10 March 2022, https://www.nbcnews.com/health/health-news/covid-killing-rural-americans-twice-rate-people-urban-areas-n1280369.

WHO (World Health Organization) (2020) *SCORE global report 2020 - A visual summary*, WHO, accessed 6 May 2022, https://www.who.int/data/stories/score-global-report-2020---a-visual-summary.

—– (2021a) *A clinical case definition of post COVID-19 condition by Delphi consensus, 6 October 2021*, WHO, accessed 18 February 2022, https://www.who.int/publications/i/item/WHO-2019-nCoV-Post_COVID-19_condition-Clinical_case_definition-2021.1.

—– (2021b) *Expert consultation on public health needs related to surveillance of SARS-CoV-2 in wastewater: summary report: virtual meeting, 30 November 2020*, WHO Regional Office for Europe, Copenhagen, accessed 3 March 2022, https://www.euro.who.int/en/health-topics/environment-and-health/water-and-sanitation/publications/2021/expert-consultation-on-public-health-needs-related-to-surveillance-of-sars-cov-2-in-wastewater-summary-report-virtual-meeting,-30-november-2020.

—– (2022a) *Coronavirus disease (COVID-19) technical guidance: The Unity Studies: early investigation protocols*, WHO, accessed 25 February 2022, https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance/early-investigations.

—– (2022b) *Enhancing response to Omicron SARS-CoV-2 variant: technical brief and priority actions for Member States*, accessed 24 February 2022, https://www.who.int/publications/m/item/enhancing-readiness-for-omicron-(b.1.1.529)-technical-brief-and-priority-actions-for-member-states.

—– (2022c) *Global excess deaths associated with COVID-19, January 2020 - December 2021*, WHO, accessed 6 May 2022, https://www.who.int/data/stories/global-excess-deaths-associated-with-covid-19-january-2020-december-2021.

Wyper GMA, Fletcher E, Grant I, McCartney G, Fischbacher C, Harding O, Jones H et al. (2022) 'Measuring disability-adjusted life years (DALYs) due to COVID-19 in Scotland, 2020', *Archives of Public Health*, 80:105.

Xie Y, Xu E and Al-Aly Z (2022) 'Risks of mental health outcomes in people with covid-19: cohort study', *BMJ*, 376:e068993.

Xie Y, Xu E, Bowe B and Al-Aly Z (2022) 'Long-term cardiovascular outcomes of COVID-19', *Nature Medicine*, 28:583–590.

Zhu Y, Oishi W, Maruo C, Saito M, Chen R, Kitajima M and Sano D (2021) 'Early warning of COVID-19 via wastewater-based epidemiology: potential and bottlenecks', *Science of the Total Environment*, 767:145124.