Actuaries Institute

Research Note 4

Many countries have experienced markedly higher than expected mortality as a result of COVID-19 – what has been the experience for Australia?

How COVID-19 has affected Mortality and Morbidity in 2020 & 2021

JUNE 2022

Angelo Andrew, Karen Cutter, Jennifer Lang, Han Li, Richard Lyon, Zhan Wang and Mengyi Xu

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Research Note

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About the authors

This Research Note has been prepared by the Actuaries Institute's COVID-19 Mortality Working Group.

Working Group members are Angelo Andrew, Karen Cutter, Jennifer Lang, Han Li, Richard Lyon, Zhan Wang and Mengyi Xu.

Acknowledgement

The Actuaries Institute acknowledges the traditional custodians of the lands and waters where we live and work, travel and trade. We pay our respect to the members of those communities, Elders past and present, and recognise and celebrate their continuing custodianship and culture.

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Abstract

This paper uses available data (primarily sourced from Our World in Data (OWID) and the Australian Bureau of Statistics (ABS)) to assess the impact of COVID-19 on mortality in 2020 and 2021. In so doing, we concentrate on excess mortality, rather than reported COVID-19 deaths, because this largely avoids the measurement problems associated with COVID-19.

We find that the countries we could analyse (which exclude China and India but represent a combined population of almost 2 billion) experienced 17% excess mortality across the two years, compared with reported COVID-19 deaths at 11% of expected deaths.

Some parts of the world – and within them, some countries – have experienced markedly higher excess mortality than the average, while some have experienced much lower excess mortality. Countries with similar time zones to Australia have generally experienced low or negative excess mortality. The Americas, Asian countries near the Caspian Sea, Eastern Europe and South Africa have experienced excess mortality at or above average levels.

Australia has experienced slightly negative excess mortality across the two years (-1%). Detailed analysis shows that this is largely due to lower deaths from respiratory diseases and an absence of the large numbers of COVID-19 deaths experienced in much of the rest of the world. As borders open and defensive measures reduce, this benefit will disappear. Indeed, we conclude that cumulative negative excess mortality was eliminated in March 2022 by COVID-19 deaths from the Omicron wave.

The future of life with COVID-19 includes Long COVID, for which more studies are emerging. However, this is still a poorly understood condition, and it is hard to form a clear prognosis.

Similarly, the likely trend of future mortality is also hard to judge, although we estimate (very approximately and in the absence of major new variants) that there might be around 10,000 deaths from COVID-19[1] in Australia in 2022, equivalent to about 6% excess mortality across the whole year.

By comparison to some other parts of the world, Australia has generally experienced low or negative excess mortality as a result of COVID-19.

1 This corresponds to around 12,000 reported COVID-19 deaths, with the difference explained by deaths where COVID-19 is not the underlying cause.

1 Excess mortality around the world

1.1 Why measure excess mortality?

It is generally accepted[2] that the best way to measure the mortality impact of a pandemic is to measure excess deaths. In the context of COVID-19, the reasons for this include:

- deaths from COVID-19 may have been recorded as having been from other causes;
- deaths from other causes may have been recorded as having been from COVID-19; and
- the disruption caused by COVID-19 had flow-on effects on activity and, hence, on mortality.

While the official global death toll from COVID-19 passed 6 million early in March 2022, estimates of the actual impact of COVID-19 are far higher. For example, *The Economist* estimates that there have been 20.7 million excess deaths, with a 95% confidence interval of 14.3 million to 24.3 million[3].

In some countries and/or at certain high-stress times during the pandemic, many COVID-19 deaths will not have been recorded as such, simply because the infrastructure did not cope. Even under more 'normal' conditions, COVID-19 deaths may be misclassified where the deceased has not experienced noticeable symptoms.

Excess mortality is widely accepted as the best way to measure the impact of a pandemic.

On the other hand, necessary differences in criteria between surveillance reporting (which sacrifices accuracy for speed) and official death certificates mean that there may be systemic over- or under-reporting of COVID-19 deaths in the surveillance reports. This is the 'death with-not-from COVID' issue.

The impact of COVID-19 on mortality from other causes may have been positive or negative. For example, lockdowns, border closures and other measures appear to have reduced the spread of respiratory disease, with several countries benefiting from milder flu seasons[4]. But the same behavioural changes have led to a reduction in the rate of screenings and diagnostic tests and to mental stress – which, in turn, could lead to higher mortality, albeit potentially with a time lag.

The discussion above demonstrates why the impact of COVID-19 on global and national mortality can best be seen by considering excess mortality. It is, therefore, interesting to consider how excess mortality differs between countries. Fortunately, a rich data source is available in the form of OWID (ourworldindata.org). Except where otherwise specified, all data for the charts and tables in this section comes from this source.

1.2 Methodology

Our analysis of excess mortality in different countries revolves around two measures of mortality as a percentage of expected deaths:

- **total excess mortality**, which we have taken directly from OWID data, interpolating where required; and
- **COVID-19 mortality,** which we have calculated by dividing COVID-19 deaths by the expected deaths for the relevant period.

2 See, for example, Measuring Australia's excess mortality during the COVID-19 pandemic | Australian Bureau of Statistics (abs.gov.au) and Excess mortality during the Coronavirus pandemic (COVID-19) - Our World in Data.

3 The pandemic's true death toll | The Economist (extracted 15 April 2022).

4 This is a common shorthand for the seasonal impact of respiratory disease on mortality, whether directly from conditions such as pneumonia or flu or indirectly from other conditions (such as dementia) that leave the sufferer more vulnerable.

This has required us to derive expected deaths for each period, data that is not directly available in the OWID database[5]. We have done so by dividing actual deaths by (1 + excess mortality). Because of rounding, this will have introduced a small error that is unlikely to have had a material impact on our analysis.

1.3 Handle with care

We note that the approach used by OWID to calculate excess mortality is to compare reported deaths for each week or month with projected deaths[6] for that period based on the experience in 2015 to 2019. In turn, this generally uses estimates of expected deaths produced by Ariel Karlinsky and Dmitry Kobak as part of their World Mortality Dataset (WMD)[7].

This is subject to general uncertainty, to the extent that there may be reporting delays or errors. Also, there may be issues relating to the interpretation of data in some countries. For example, as we note in Section 2.10, the WMD appears to understate excess mortality in Australia, resulting in a more favourable view of Australian mortality experience in 2020 and 2021 than our own analysis would suggest. The differences, while material in Australia with comparatively low COVID-19 deaths in 2020 in 2021, are unlikely to be material in countries with significant COVID-19 deaths as a proportion of total deaths.

It is important to understand that the criteria counting COVID-19 deaths vary between countries.

In relation to COVID-19 deaths from surveillance reports, it is important to understand that the criteria vary between countries. For example:

- in Australia, it is a death following a positive test without a subsequent recovery, unless there is a clear alternative cause of death that cannot be related to COVID-19 (e.g. trauma); but

- in the UK, it is a death within 28 days of being identified as a COVID-19 case by a positive test, no matter what the cause of death or whether the person had recovered.

1.4 Selected countries[8]

Appendix A contains tables, derived from OWID data, showing COVID-19 deaths and total excess deaths for 37 countries, in 2020, 2021, and both years combined.

There are 84 countries for which, at the time of writing (April 2022), OWID had produced excess death data covering the whole of 2020 and 2021. We have selected the largest 30 of these (including Australia) by expected deaths, plus a further seven for their relevance.

These 37 countries represent about 92% of the 84 by population[9] and 93% by expected and actual deaths. They had 17.0% combined excess mortality across 2020-2021, with reported COVID-19 deaths representing 11.3% of expected deaths.

Notable omissions[10] from the list include:

- China, India and parts of Africa[11] – for which OWID has no data on excess mortality; and
- The Philippines, Egypt, Argentina, Canada, Algeria, and Malaysia – which are in the OWID top-30 for expected deaths but for which OWID's excess mortality data does not extend to the end of 2021.

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5 Note that OWID uses different expected values for each of 2020, 2021 and 2022, so the data item projected_deaths_2020_2022_all_ages is not useful.

6 This is theoretically more accurate than OWID's previous use of the simple average of 2015-19 deaths.

7 GitHub - akarlinsky/world_mortality: World Mortality Dataset: international data on all-cause mortality.

8 We use 'country' as a shorthand, given that the list includes Taiwan on the basis that it is in the top 30 territories by expected deaths in the available OWID data.

9 Total population of the 37 countries is almost 2 billion.

10 Countries that would have made the top 30.

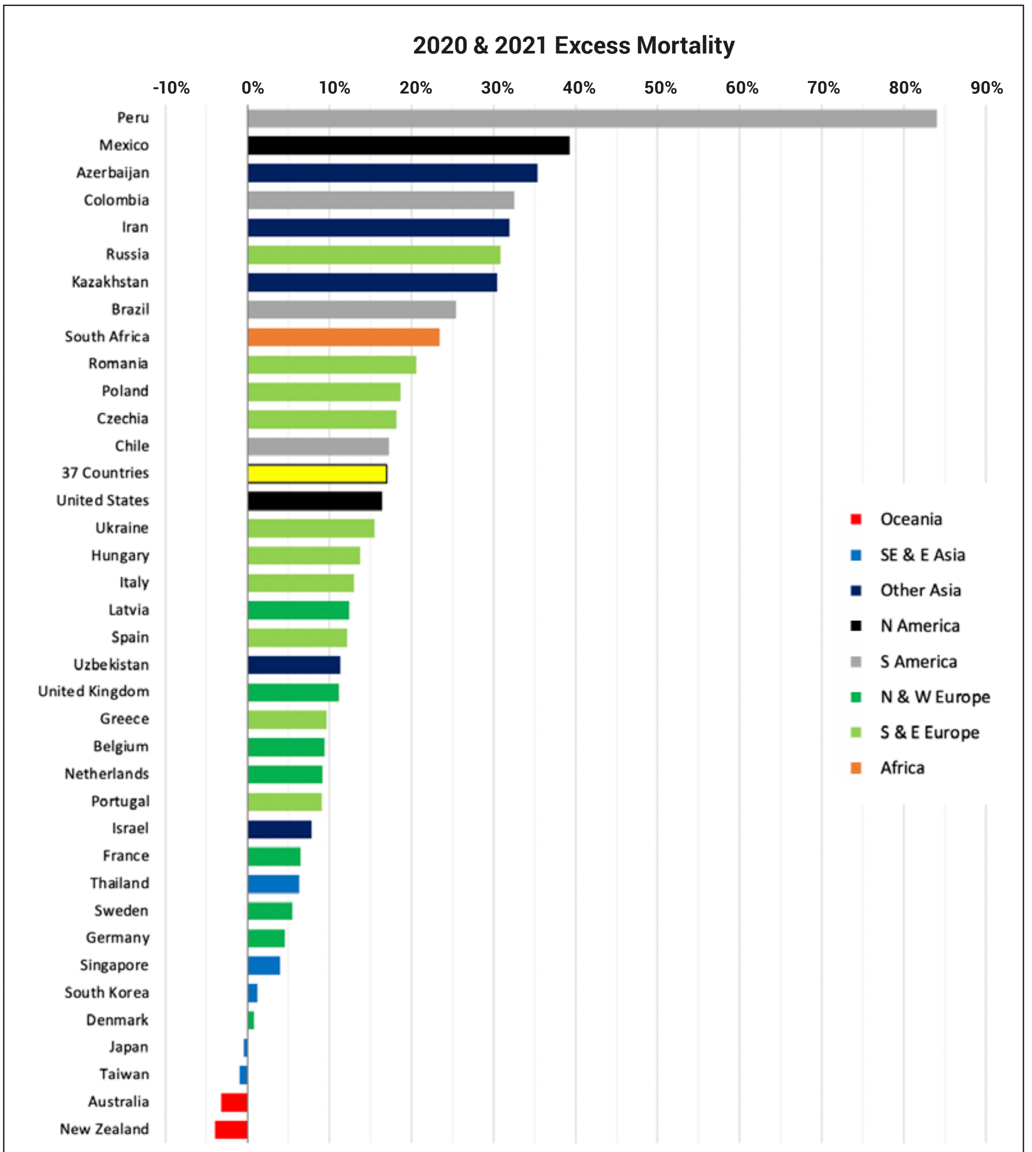
11 South Africa is the only African country for which OWID has excess mortality data extending to the end of 2021, and there are only three others for which OWID has any excess mortality data at all.

The latter six countries are included in individual country charts in Section 1.7.

In our analysis, we have grouped countries in accordance with the UN geoscheme[12] to provide an objective basis for comparison at a regional level.

1.5 Overall excess mortality by country in 2020 & 2021

Figure 1 – Excess mortality for two years ending 31/12/21, as a percentage of expected deaths



Source: Our World in Data (OWID) and analysis. Excess mortality relative to projectied deaths.

Excess mortality in Australia in the first two years of the pandemic was significantly lower than in many other countries.

Figure 1 shows that most of our 37 selected countries had positive total excess mortality across the two years, with an average of 17%. New Zealand, Australia, Taiwan and Japan were the exceptions.

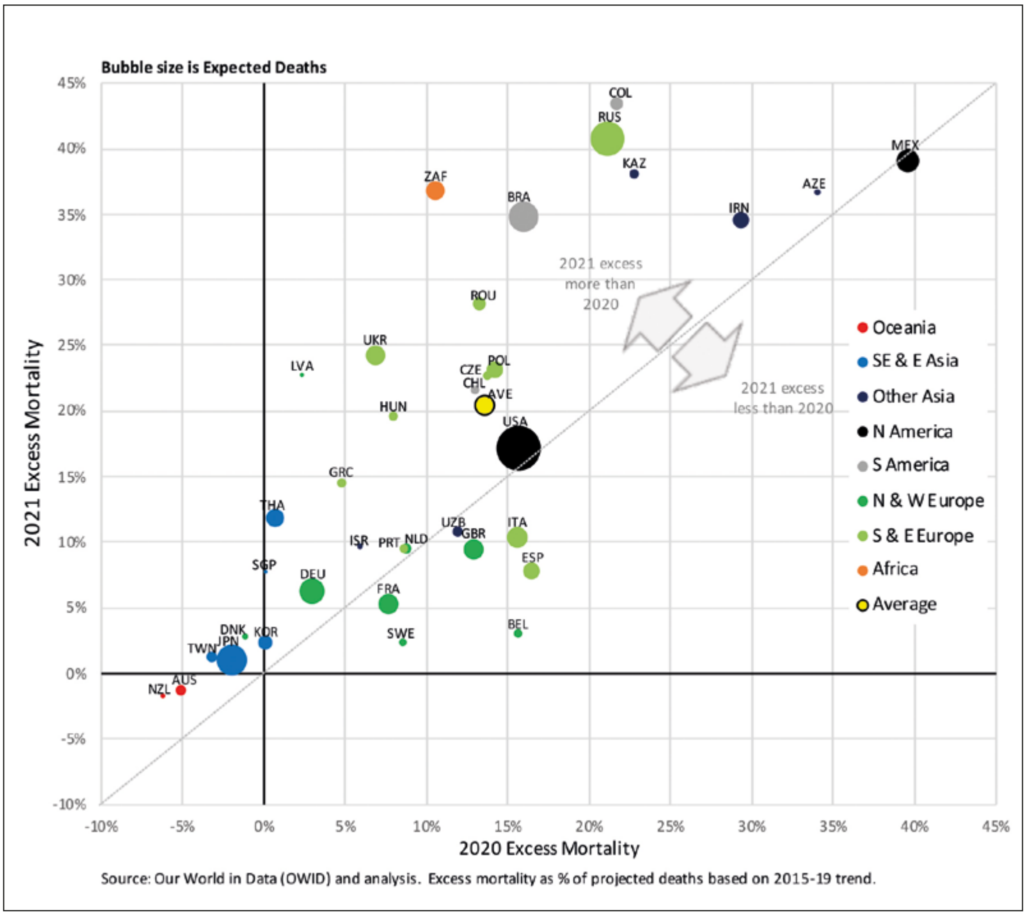
Excess mortality has been high in both North and South America. Indeed, all six representatives from the Americas had more than 15% excess mortality in the period – and Peru (84%) and Mexico (39%) topped the list. We note that Canada would have been different, with cumulative excess mortality of 3% at 31 October 2021.

South-East and East Asia have fared better than Other Asia (especially those countries bordering the Caspian Sea). Similarly, but less dramatically, North and Western Europe has generally lower excess mortality than South and Eastern Europe.

12 Found at https://en.wikipedia.org/wiki/List_of_countries_by_United_Nations_geoscheme.

It is interesting to compare excess mortality in 2021 with that in 2020 for each country. As the pandemic killed few people before March 2020, a simple comparison of calendar years would tend to favour 2020. However, 2021 could be expected to benefit from the increased protection available through vaccination. It is easy and objective to compare the two full years, relative to attempting to pick the start of 'pandemic mortality' for each country.

Figure 2 – Comparison of 2020 and 2021 excess mortality



As it happens, Figure 2 shows that excess mortality was generally higher in 2021 than in 2020, with the average increasing from 13.6% to 20.4%. The main exceptions are European countries that had very high mortality spikes early in the pandemic.

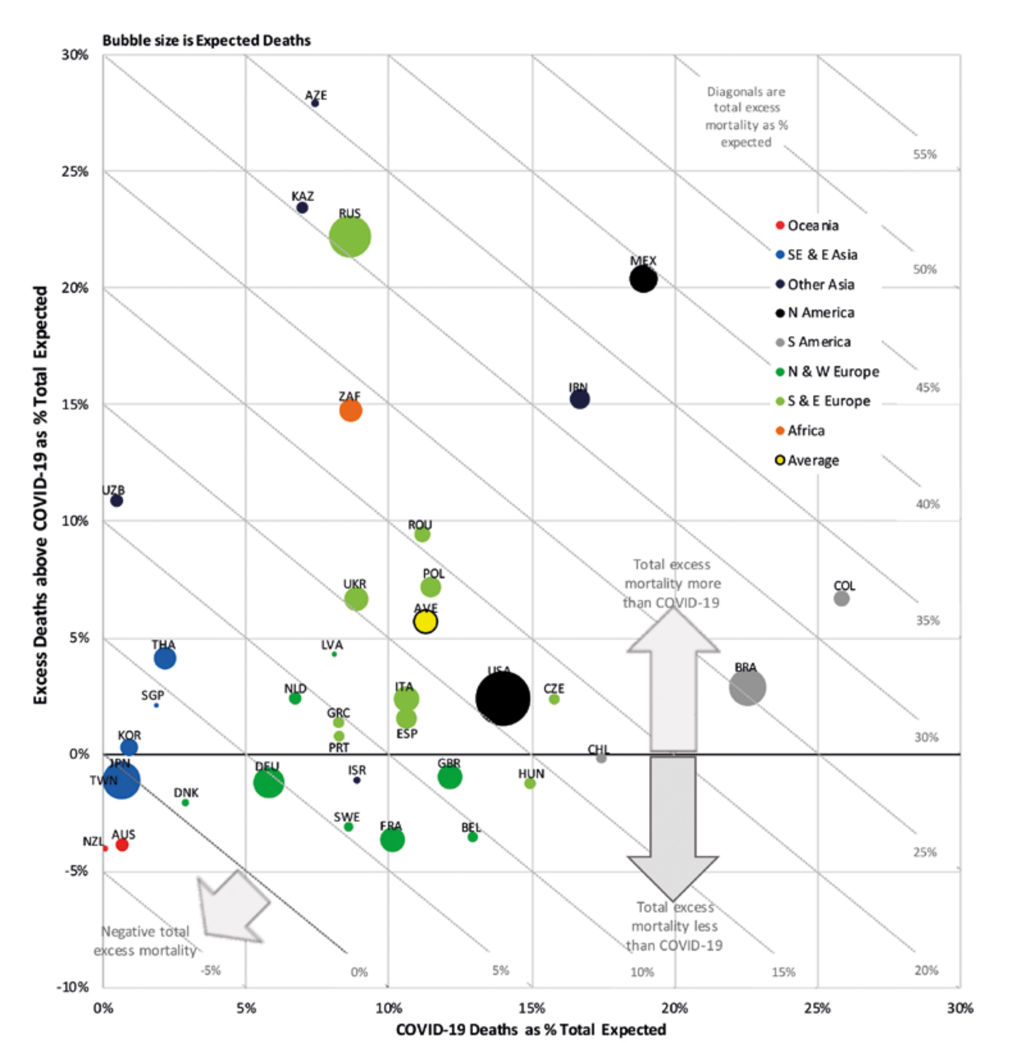
The general increase in mortality in 2021 may represent relaxation of non-pharmaceutical defence measures (such as lockdowns and mask wearing) at a faster pace than was justified by the growth in pharmaceutical defences, particularly vaccination, combined with the greater virulence of later variants of COVID-19. However, we have not tested these conjectures.

The general increase in mortality globally in 2021 may represent the relaxation of non-pharmaceutical defence measures.

1.6 Comparing excess mortality with reported COVID-19 deaths

37 countries had an average of 5.7% net excess mortality.

Figure 3 – Net excess mortality compared with reported COVID-19 mortality (2020 & 2021 Combined)



Source: Our World in Data (OWID) and analysis. Excess mortality as % of projected deaths based on 2015-19 trend.

This analysis of excess mortality is driven by our desire to understand the impact of COVID-19. We note that COVID-19 deaths are all 'excess' deaths, in the sense that there were no COVID-19 deaths in the 2015-19 data and thus none were 'expected' in 2020 or 2021. Therefore, despite caveats about the reporting of such deaths, it is interesting to compare excess COVID-19 deaths (from surveillance reports) with total excess mortality.

In order to compare COVID-19 mortality with total excess mortality, we have expressed COVID-19 deaths as a percentage of expected deaths. Figure 3 performs this comparison by plotting reported COVID-19 mortality against excess mortality **net** of COVID-19. This net excess mortality arises for the reasons given earlier (Section 1.1).

Subject to the caveat about the accuracy of excess mortality calculations, countries above/(below) the horizontal 0% line in Figure 3 have experienced positive/(negative) net excess mortality.

Arguably, a large positive net excess mortality (such as for Russia and Mexico in Figure 3) implies that many COVID-19 deaths are not being detected or reported as such. However, we have not performed the additional analysis that would be required to prove this. On the other hand, where there is negative excess mortality (such as for Australia and France), it is possible that surveillance reports overstate the true COVID-19 mortality and/or that mortality from other causes is lower than expected. We note that our 37 countries had an average of 5.7% net excess mortality.

Four countries sit to the left of the diagonal representing 0% total excess mortality. Australia, Japan, New Zealand and Taiwan have experienced negative excess mortality, so reported COVID-19 deaths have been more than offset by mortality savings and/or over-reporting. These are countries that have benefited from non-pharmaceutical defence measures. As they have had relatively low numbers of reported COVID-19 deaths up to the end of 2021, there can be little contribution from any overstatement of such deaths.

A further 21 countries have net excess mortality in the range +/-5% of expected deaths, suggesting that reported COVID-19 deaths are a reasonable measure of the overall impact on mortality for these countries. For these countries, it seems likely that various factors are at play. For example, there was significant under-reporting of COVID-19 mortality in the UK in the first few months of the pandemic, but more recent reporting generally overstates it, and there has been a favourable impact on non-COVID-19 mortality[13].

High net excess mortality rates in some countries may have been due to weak detection and reporting systems.

Apart from Israel (which one might expect to be different), the countries in the Other Asia group all have net excess mortality above 10%. Most[14] have relatively low official COVID-19 mortality but relatively high total excess mortality. This suggests that COVID-19 detection and reporting systems may be weak in those countries.

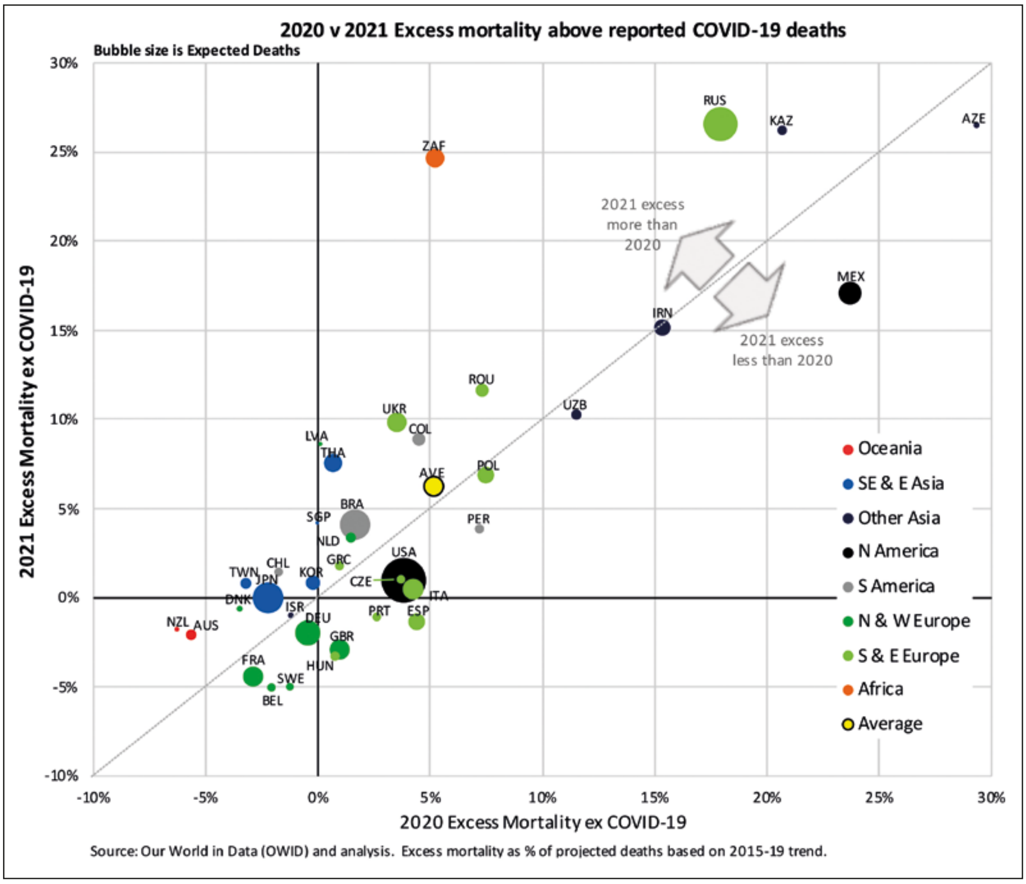
Net excess mortality among European countries tends to be negative for those in North or Western Europe but positive for those in South or Eastern Europe. Most of those from Eastern Europe have net excess mortality above 5%, with Russia above 20%, suggesting that detection/reporting systems may be an issue there.

In the Americas, COVID-19 mortality generally appears to be a good indicator of overall excess mortality, with Mexico the obvious exception. Even Peru, which has experienced 84% excess mortality, only has net excess mortality of just over 5%.

South Africa has experienced relatively high reported COVID-19 mortality that explains less than half of total excess mortality. Again, it seems likely that the main driver of net excess mortality is under-reporting of COVID-19 deaths.

As for total excess mortality, it is interesting to see how net excess mortality changed between 2020 and 2021.

Figure 4 – Comparison of net excess mortality in 2020 and 2021



13 See, for example, What has happened to non-COVID mortality during the pandemic? - The Health Foundation.

14 Further excluding Iran.

The lower net excess mortality in most European countries for 2021 compared to 2020 is likely to be because high excess mortality occurred early in the pandemic.

Figure 4 shows that net excess mortality in 2021 was generally similar to 2020 – that is, the bubbles representing most countries are quite close to the diagonal line of parity. The average net excess mortality of our 37 countries increased slightly – from 5.2% to 6.3%.

Most European countries experienced lower net excess mortality in 2021 than 2020. In many cases, this is likely to be because high excess mortality occurred early in the pandemic, when COVID-19 was significantly under-detected. More recently, COVID-19 mortality may be over-reported in some countries.

Australia, New Zealand and our Asian time-zone neighbours experienced higher net excess mortality in 2021 than in 2020. It seems likely that this is largely due to reduced mortality savings from non-COVID-19 causes.

The increase in net excess mortality in South Africa is connected[15] with higher COVID-19 mortality in 2021, suggesting that COVID-19 mortality is under-reported.

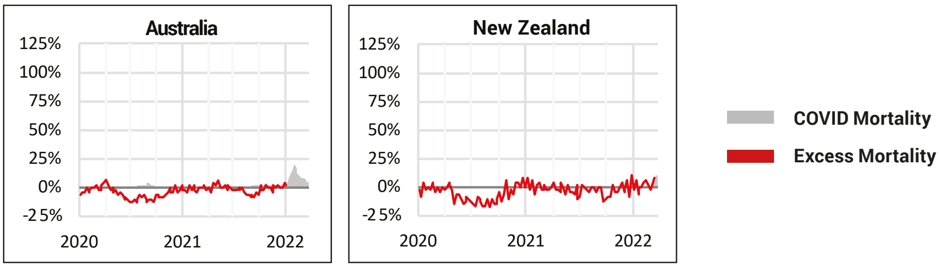
1.7 Comparison of COVID-19 and total excess mortality over time

OWID data enables us to see a weekly[16] comparison of COVID-19 and excess mortality for each of our selected countries. Because this comparison no longer requires data for the whole of 2021, we are also able to include the six countries listed in the second bullet point in section 1.4.

In this comparison, we have adopted a style modelled on similar charts produced by *The Economist*. Each chart, apart from Peru[17], uses the same scale for ease of comparison across countries[18]. For all charts, COVID-19 deaths (as a percentage of expected deaths[19]) are shown in grey, while total excess deaths are shown by a red line.

1.7.1 Oceania

Figure 5 – Weekly COVID-19 & total excess mortality – Oceania



Australia and New Zealand have generally experienced negative excess mortality during the pandemic, especially during winter months. The impact of the Omicron wave is apparent in 2022, although OWID has no excess mortality data for Australia in 2022.

15 See, for example, the South Africa chart in Tracking COVID-19 excess deaths across countries | The Economist.

16 In several countries, the data is only available monthly; these countries are indicated with (M).

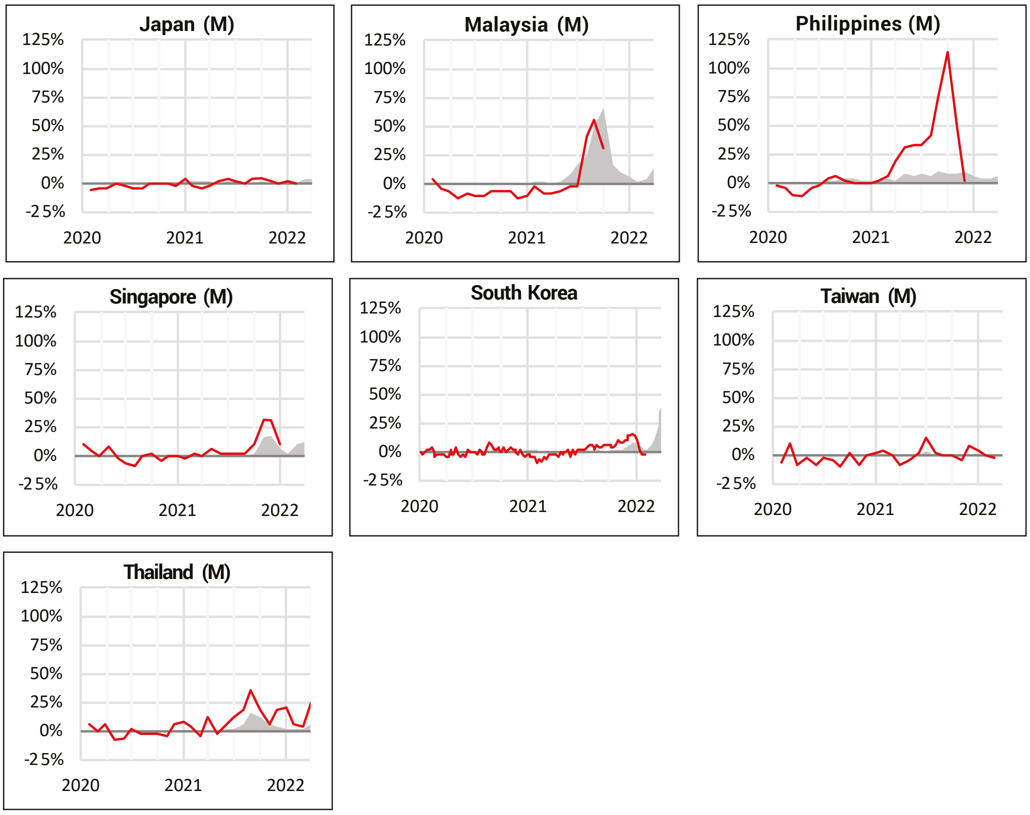
17 COVID-19 mortality has been so high in Peru that we have had to use double the standard scale.

18 For some countries, a peak of excess mortality exceeds the top end of the scale (-25% to +125%), but we consider that this does not detract from the reader's understanding.

19 Where necessary, expected deaths have been estimated, but any consequent error in the COVID-19 mortality rate will be extremely small.

1.7.2 South-East and East Asia

Figure 6 – Weekly COVID-19 & total excess mortality – SE & E Asia [(M) = monthly]

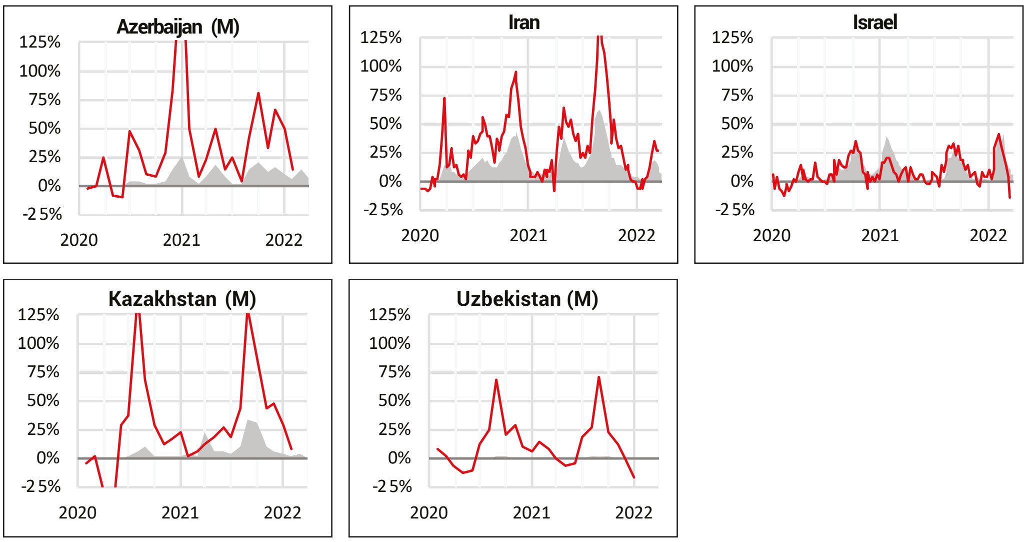


Major peaks in excess mortality coincide with the high global prevalence of Delta.

Countries in our region generally had low or negative excess mortality during 2020. However, excess mortality rose in 2021, sometimes quite significantly (e.g. Philippines). While reported COVID-19 mortality did not always explain this increase, it is notable that the major peaks coincide with high global prevalence of Delta.

1.7.3 Other Asia

Figure 7 – Weekly COVID-19 & total excess mortality – Other Asia [(M) = monthly]

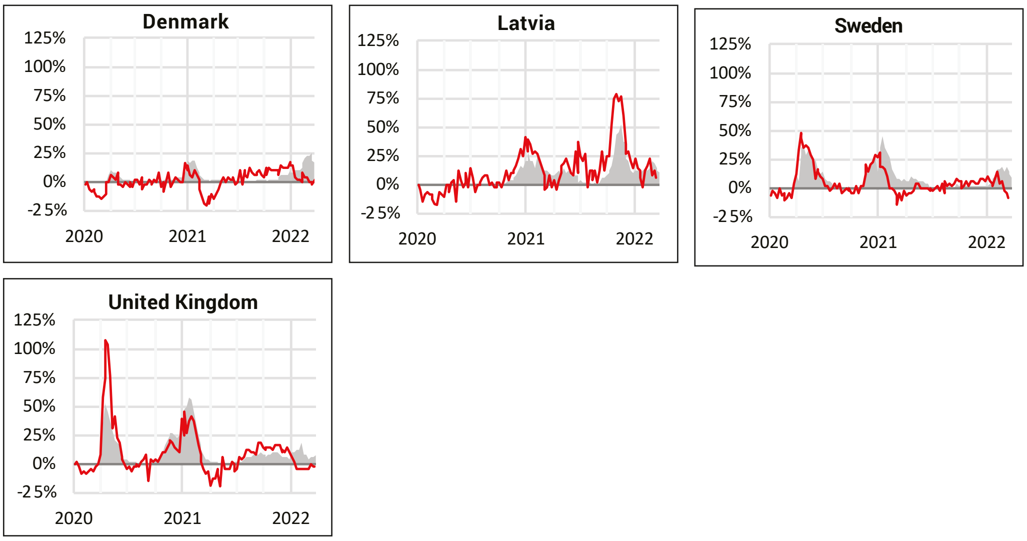


Israel's experience is like those European countries (below) that avoided the first major wave.

The other four countries (all near the Caspian Sea) have experienced two major peaks of excess mortality. Of these countries, only Iran has reported a significant proportion of this excess mortality as COVID-19. Azerbaijan's non-COVID-19 deaths in late 2020 would include direct and indirect casualties of the Nagorno-Karabakh war. Official Azerbaijani casualties of that war amount to about 70% of one month's expected deaths.

1.7.4 Northern Europe

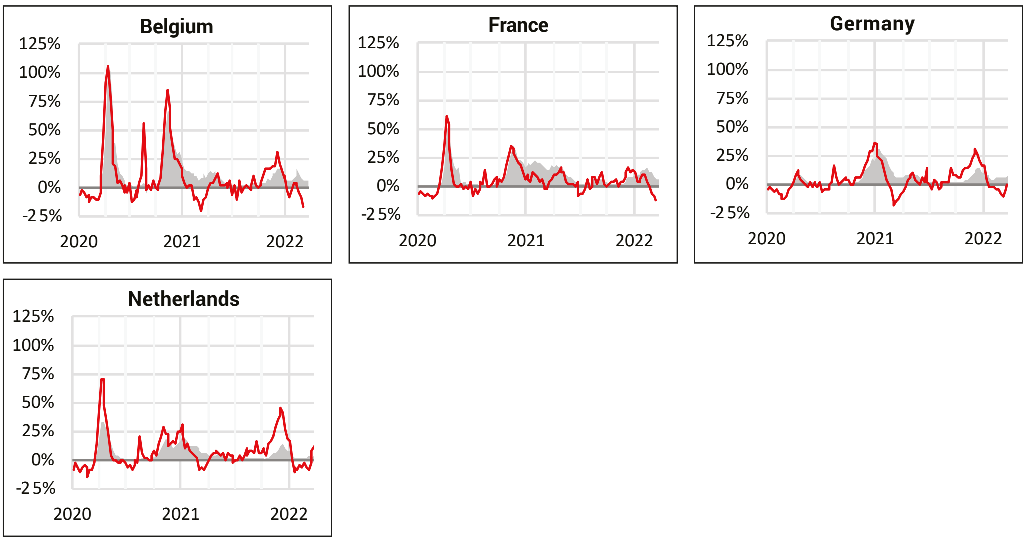
Figure 8 – Weekly COVID-19 & total excess mortality – Northern Europe



Denmark is representative of the Nordic countries, apart from Sweden, while Latvia is representative of the Baltic states – where there was a substantial impact from the Delta wave. It is interesting to compare the UK and Sweden, where the inclinations of the political leaders have arguably been quite similar. It is, perhaps, surprising that Sweden's early peak was so low – even more so, when compared with other European countries, below. Assuming another mild flu season, emerging UK experience in 2022 is consistent with our understanding that deaths from Omicron are running at about 80% of the reported COVID-19 deaths there.

1.7.5 Western Europe

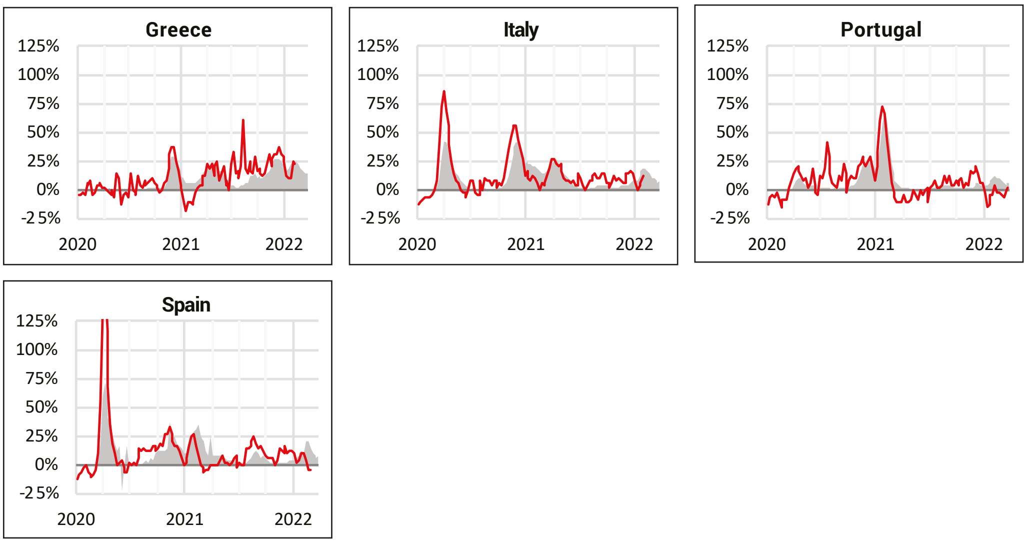
Figure 9 – Weekly COVID-19 & total excess mortality – Western Europe



These four countries have similar experience in 2021 and 2022. Excess mortality is generally explained by COVID-19 deaths, except during the Delta wave, and there are clear late-winter non-COVID-19 mortality savings.

1.7.6 Southern Europe

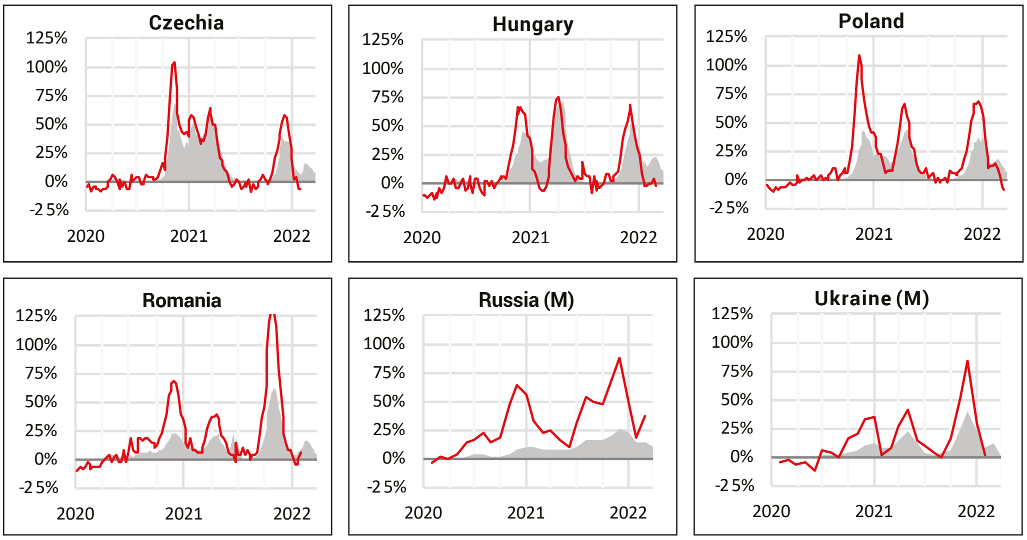
Figure 10 – Weekly COVID-19 & total excess mortality – Southern Europe



Interestingly, Greece and Portugal look similar to Germany, while Italy and Spain fit the pattern of the rest of Western Europe (plus Sweden and the UK).

1.7.7 Eastern Europe

Figure 11 – Weekly COVID-19 & total excess mortality – Eastern Europe [(M) = monthly

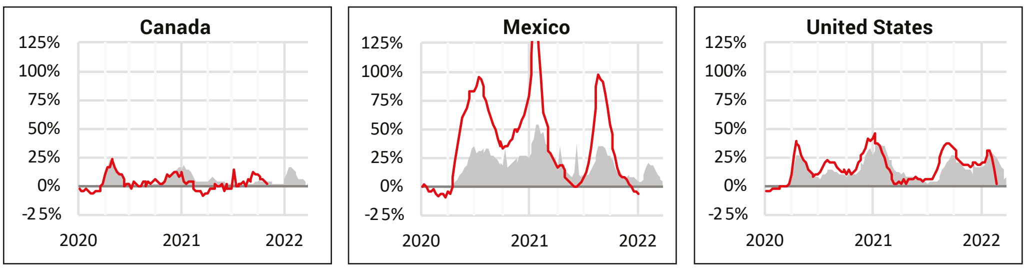


Eastern Europe was generally slow to experience excess mortality but experienced high waves in late 2020 and in 2021.

Eastern Europe was generally slow to experience excess mortality but has experienced high waves in late 2020 and in 2021. Several countries have only recorded a relatively low proportion of excess deaths as COVID-19.

1.7.8 North America

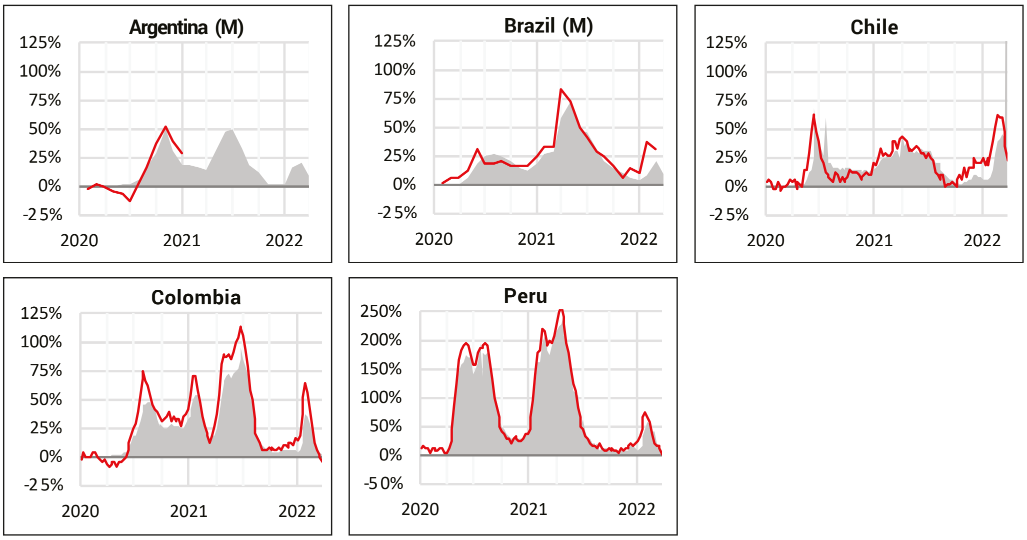
Figure 12 – Weekly COVID-19 & total excess mortality – North America



Mexico experienced one of the highest levels of excess mortality in the world in both 2020 and 2021, with most of these extra deaths not recorded as COVID-19. The USA has had relatively low mortality peaks, considering that excess mortality was above 15% in both 2020 and 2021. This may be related to its federal structure, where individual states made many of the key COVID-19 defence decisions, as in Australia. Despite its long border with the USA, Canada has experienced much lower excess mortality.

1.7.9 South America

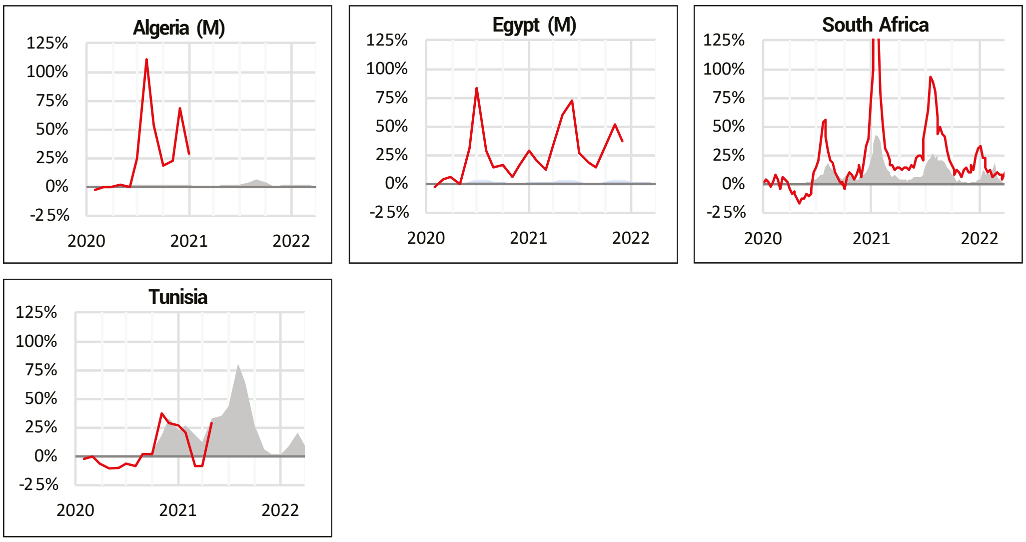
Figure 13 – Weekly COVID-19 & total excess mortality – South America [(M) = monthly] – Peru on double scale



South American countries generally experienced one major mortality peak in 2020 and one in 2021, although the precise timing varies. There is relatively little non-COVID-19 excess mortality – even in Peru, where excess mortality was well over 80% in both 2020 and 2021 and the peaks were at and above 200%. A strong growth in vaccinations in the second half of 2021 may be the key reason why most countries are experiencing a much lower mortality impact from Omicron in 2022.

1.7.10 Africa

Figure 14 – Weekly COVID-19 & total excess mortality – Africa [(M) = monthly]

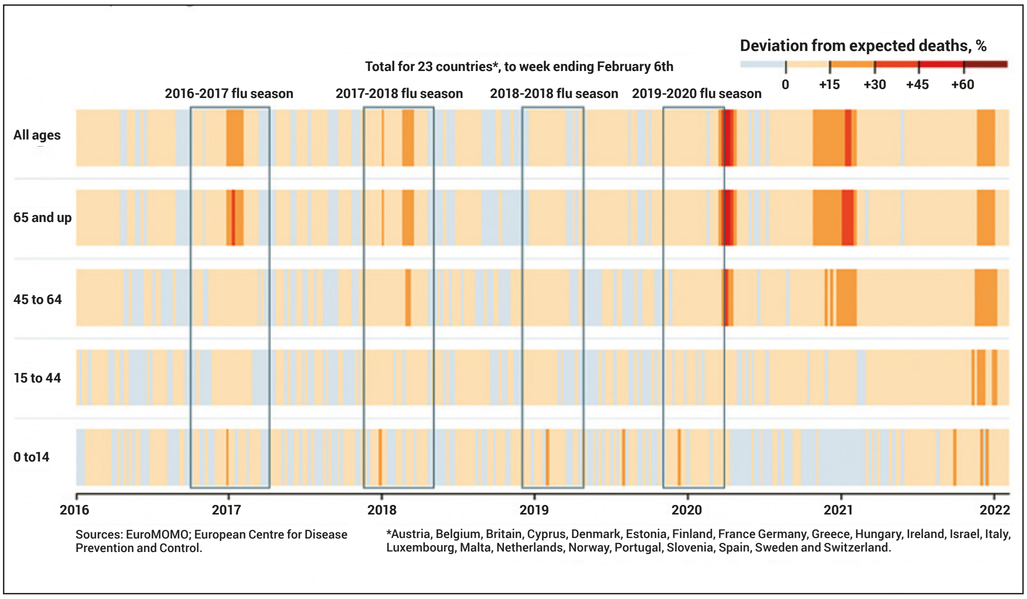


Excess mortality data is only available for four African nations – three northern countries on the Mediterranean coast, plus South Africa. Vaccination rates remain low in Africa, but where there is meaningful data (South Africa and Tunisia), Omicron does appear to be having a lower impact than previous variants.

1.8 The impact of age

Figure 15 – Excess mortality by age group (21 European countries + Cyprus & Israel)

Source: The Economist[20]



Despite vaccination and other measures, even the 'mild' Omicron wave has been worse than flu for those aged 15-64.

Figure 15 shows weekly estimated excess deaths by age group for 23 countries, colour-coded by the percentage deviation from expected deaths. The darker the colour, the greater the excess mortality. Apart from Cyprus[21] and Israel, the countries are all European.

We know that COVID-19 case fatality rates increase by age, faster than mortality from all other causes[22]. Figure 15 demonstrates this, but it contains a few other messages.

First, between ages 15 and 64, even the 'mild' Omicron wave has been worse than the worst flu season in the four years before the pandemic. This is despite the relatively high rates of vaccination, the high efficacy of the vaccines and the continuation of some mandated and voluntary non-pharmaceutical measures.

Secondly, the second wave saw lower peak mortality than the first, at all ages. This was before vaccines were widely available, so it demonstrates the value of the greater strength and breadth of non-pharmaceutical measures[23] in the second wave. It is easy to see the mid-January peak of the second wave, driven in part by relaxations of rules for Christmas.

Thirdly, there is far less difference in excess mortality by age group in the third wave than in the previous two. In part, this may reflect higher activity among the young, while many of the old remain cautious. However, it is surely also a consequence of vaccination at rates that generally increase by age.

20 Tracking COVID-19 excess deaths across countries | The Economist.

21 Cyprus is part of Asia in the UN geoscheme, although it is a member of the European Union.

22 See, for example, Research Note 3.

23 There were also improvements in COVID-19 treatment strategies.

2 Excess deaths in Australia – a deeper dive

This section includes analysis of excess deaths in Australia since the start of the pandemic. Our previous paper *Impact of COVID-19 on Mortality and Morbidity in 2020* included detailed analysis of mortality experience in 2020. This paper concentrates more on 2021, although information for 2020 is also shown. This section covers:

- the available data;
- our approach;
- doctor-certified deaths – in total, and also broken down by cause of death and by age band/gender;
- coroner-referred deaths;
- excess deaths in total for 2020 and 2021;
- preliminary estimates of excess deaths in 2022;
- a comparison of our excess death estimates with both the ABS estimates and OWID; and
- considerations for measuring excess deaths for 2022 and beyond.

2.1 Available data

There have been quite significant delays in releasing information on deaths in Australia.

There have traditionally been quite significant delays in releasing information on deaths in Australia given that there are delays between the time of death and registering a death, with these delays further exacerbated if a death is referred to the coroner.

Given the huge interest in death statistics due to the pandemic, the ABS has been releasing a subset of the death statistics each month since June 2020[24] in order to provide more timely information to the public. The ABS also periodically releases a more detailed report on COVID-19 deaths.

At the time of writing, the information available on Australian death statistics for 2020 and 2021 includes:

- From the ABS **Provisional Mortality Statistics**[25] publication: Doctor-certified deaths occurring in each week of 2015 to 2021, provided that the death had been registered by 28 February 2021. Due to delays in registration of deaths, most weeks of 2021 will be missing a small number of deaths (around 0.5% for the earliest weeks of 2021 increasing to around 2.5% for the last week of the year). Doctor certified deaths are available broken down by[26]:
  - cause of death, for 9 selected causes (including COVID-19);
  - age band and gender, summarised into five age bands for each gender; and
  - state/territory.

- From the ABS **Causes of Death, Australia**[27] publication: All deaths occurring[28] in each year 2010 to 2020, provided that the death had been registered by 31 December 2020. Due to delays in registration of deaths, the 2020 year of occurrence is missing a significant number of deaths. All deaths are available broken down by:
  - cause of death by ICD-10 code, including deaths from both disease and external causes;
  - gender; and
  - state/territory.

24 The first release covered mortality from January to March 2020.

25 https://www.abs.gov.au/statistics/health/causes-death/provisional-mortality-statistics/jan-2020-dec-2021.

26 Combinations are not available – so we cannot see NSW cancer mortality, for example.

27 https://www.abs.gov.au/statistics/health/causes-death/causes-death-australia/latest-release.

28 We note the majority of this publication is compiled by year of registration. Table 14 shows information by year of occurrence.

- From the ABS COVID-19 Mortality in Australia[29] articles: the number of deaths registered and received by the ABS by 31 March 2022 that included COVID-19 on the death certificate. This publication sets out whether deaths were from or with COVID-19, associated causes of death (i.e. pre-existing conditions and the chain of events leading to death), breakdowns by age/gender, state/territory, country of birth, socio-economic status, and the underlying causes of those dying with COVID-19 (rather than from COVID-19).

- The Australian Government via the Bureau of Infrastructure and Transport Research Economics (BITRE) publishes statistics on road accident deaths[30], including month of death and breakdowns by state/territory, age, gender, and road user type.

- For suicide deaths, three states (NSW[31], Victoria[32], and Queensland[33]) publish preliminary suicide statistics. For NSW and Victoria, data is available up to and including 2021, but for Queensland the data is only available to 31 December 2020.

As a result, we can undertake quite rigorous analysis of doctor-certified deaths in 2020 and 2021. We can also use historical data to draw broad conclusions on coroner-referred deaths and use this to derive overall excess mortality.

Table 1 shows the breakdown of total deaths in 2015-19 into these various categories[34]

Table 1 – Deaths by category – 2015-19

	Year of Occurrence				
	2015	2016	2017	2018	2019
Doctor-certified diseases	137,281	139,421	144,162	139,839	144,144
Coroner-referred diseases	9,454	8,421	8,960	8,431	9,208
Coroner-referred external causes	10,560	10,766	11,218	11,167	11,359
All deaths	**157,295**	**158,608**	**164,340**	**159,437**	**164,711**
Doctor-certified diseases	87%	88%	88%	88%	88%
Coroner-referred diseases	6%	5%	5%	5%	6%
Coroner-referred external causes	7%	7%	7%	7%	7%
All deaths	100%	100%	100%	100%	100%

2.2 Measuring excess deaths – approach

Measuring excess deaths is not straightforward.

Measuring excess deaths is not straightforward. In its simplest form, excess deaths are calculated as the difference between actual deaths occurring in a particular period less a 'baseline' level of deaths. But what to use for the baseline?

Early in the pandemic, most measures of excess deaths compared 2020 actual deaths to a simple average of deaths in 2015 to 2019. This approach is used by the ABS in their summary for each month. However, this approach does not allow for changes in either the size or the age structure of the population, or for the continuation of any trends in mortality that may have been expected in the absence of the pandemic.

29 https://www.abs.gov.au/articles/COVID-19-mortality-australia-deaths-registered-until-31-march-2022.
30 https://www.bitre.gov.au/publications/ongoing/road_deaths_australia_monthly_bulletins.
31 *NSW Suicide Monitoring System - Report 17 – Data to January 2022*, NSW Health.
32 *Coroners Court Monthly Suicide Data Report*, February 2022 update, Coroners Court of Victoria.
33 *Suicide in Queensland: Annual Reports 2018-2021*, Griffith University.
34 Doctor-certified deaths from *Provisional Mortality Statistics*; coroner-referred deaths from Table 14 of Causes of Death.

In their June 2021 paper[35], Karlinsky and Kobak took a different approach, fitting a trend to the 2015 to 2019 years to get their baseline. This approach, while allowing for past changes in size of population, age structure of the population and mortality trends, intermingles these three effects and assumes that their aggregate impact will continue on the same trend into 2020 and 2021.

Unlike Karlinsky and Kobak, who were projecting a baseline for each of 84 countries, we are focusing on Australia, so we have taken the opportunity to apply a more detailed approach. We have explicitly scaled past deaths to allow for changes in population size and age structure. Any modelled trends are the residual, being the improvement in the overall mortality rate over time[36]. As such our baseline predicted deaths are "predicted deaths in the absence of the pandemic, allowing for a continuation of pre-pandemic mortality improvement".

2.2.1 Doctor-certified deaths

In brief, for doctor certified deaths, for each cause of death and for each age band/gender combination we:

- scaled actual weekly deaths from 2015 to 2020 so that they are representative of the number of deaths in those years if they had the 2021 population size (a 9% increase over six years, or an average of 1.5% per annum) and age mix (an 11% increase over six years, or an average of 1.8% per annum);
- fitted a linear regression model to the scaled deaths from 2015 to 2019, giving overall mortality improvements of around 1.8% per annum over the five-year period;
- extrapolated the linear regression model to arrive at a predicted number of deaths for each week in 2020 and 2021 (assuming that the same 1.8% per annum mortality improvement continues and ignoring the impact of the pandemic); and
- compared predicted deaths to the actual deaths in 2021 (after a small allowance for late reported deaths).

It is important to note that expected deaths are increasing faster from demographic changes (ageing and population size) than they are reducing due to mortality improvement. As a result, our model predicts higher deaths each successive year. Our prediction for 2021 is higher than for 2020 and both are higher than the 2015-19 average. Thus, despite the overall mortality improvements, our predicted doctor-certified deaths for 2021 are 7,800 (6%) above the 2015-19 average.

Details of our approach and the adjustments made are included in Appendix B and Appendix C

2.2.2 Coroner-referred deaths

Coroner-referred deaths comprise two main categories – those that are as the result of a disease (and may be referred to the coroner as the person died unexpectedly, for example) and those that are the result of 'external causes' such as accidents, poisonings, suicide, medical misadventure (and are generally referred to the coroner as the cause of death may not be obvious and to rule out foul play).

In relation to deaths from diseases, we have assumed that, for each cause of death, the proportion of doctor-certified deaths from disease in each of 2020 and 2021 is the same as for the 2015-19 years, noting that this proportion has been very stable from year-to-year.

We have predicted deaths from external causes using a simple linear projection of the numbers of such deaths in 2015 to 2019. 'Actual' deaths from external causes are estimated from Table 14.1 of the ABS Causes of Death publication, adding about 10% to allow for late reported deaths, based on

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35 Karlinsky & Kobak, 2021, *Tracking excess mortality across countries during the COVID-19 pandemic with the World Mortality Dataset.*

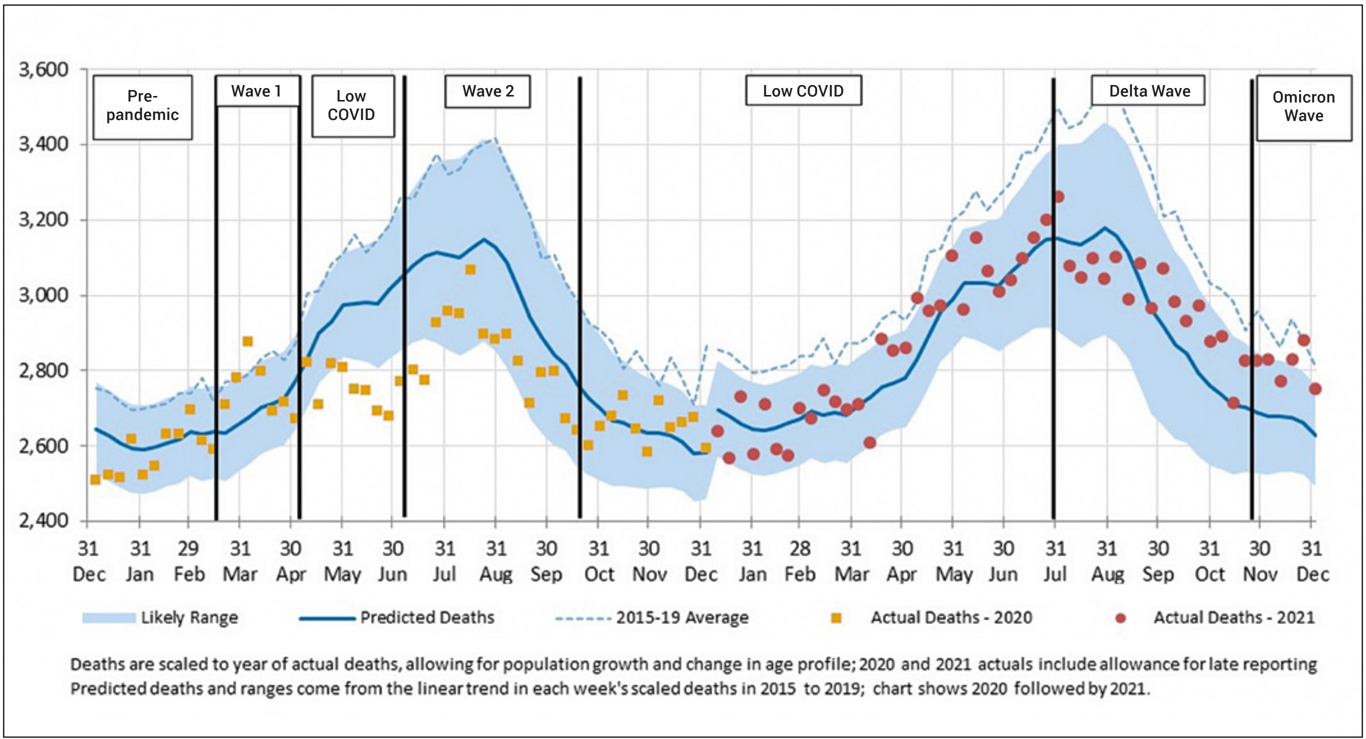
36 We identified this trend for each separate cause of death and age/gender combination for which we have data.

experience from previous years. This results in deaths from external causes being slightly below predicted, which is consistent with preliminary data on the number of deaths from road accidents and suicide.

2.3 Excess doctor-certified deaths

The graph below shows actual doctor certified deaths for each week of 2021 compared with predicted. We have also shown the results for 2020. (Note that in the following sections we have used the same definition of a week/year as the ABS, namely that weeks are based on the International Organization for Standardisation (ISO) week date system. This results in the 2020 'year' including exactly 53 weeks and the 2021 'year' including exactly 52 weeks.)

Figure 16 – Actual doctor-certified deaths in 2020 and 2021, compared with predicted deaths[37] in the absence of a pandemic.



In 2021, doctor-certified deaths from all causes were around 2,000 (1%) higher than predicted. This compares to 2020 where doctor-certified deaths were around 4,400 (3%) fewer than predicted.

In 2021, there were many weeks where deaths were higher than predicted during the 'low COVID' period in the first half of the year. In contrast to the lower than usual 'winter hump' of 2020, the winter hump of 2021 was similar to predicted. Deaths were again higher than predicted towards the end of the Delta wave and during the Omicron wave.

It is also worth noting that 2020 and 2021 have lower age-standardised death rates than 2015-19; mortality in Australia has continued to improve during 2020 and 2021.

2.4 Excess doctor-certified deaths by cause of death

For context, Figure 17 shows the mix of deaths by cause over the 2015 to 2019 years[38] .

37 Note that we scale predicted deaths annually, creating a break between 2020 and 2021.

38 Doctor-certified deaths from *Provisional Mortality Statistics*; coroner-referred deaths from Table 14 of *Causes of Death*.

Figure 17 – Doctor-certified deaths in 2015-19 broken down by cause

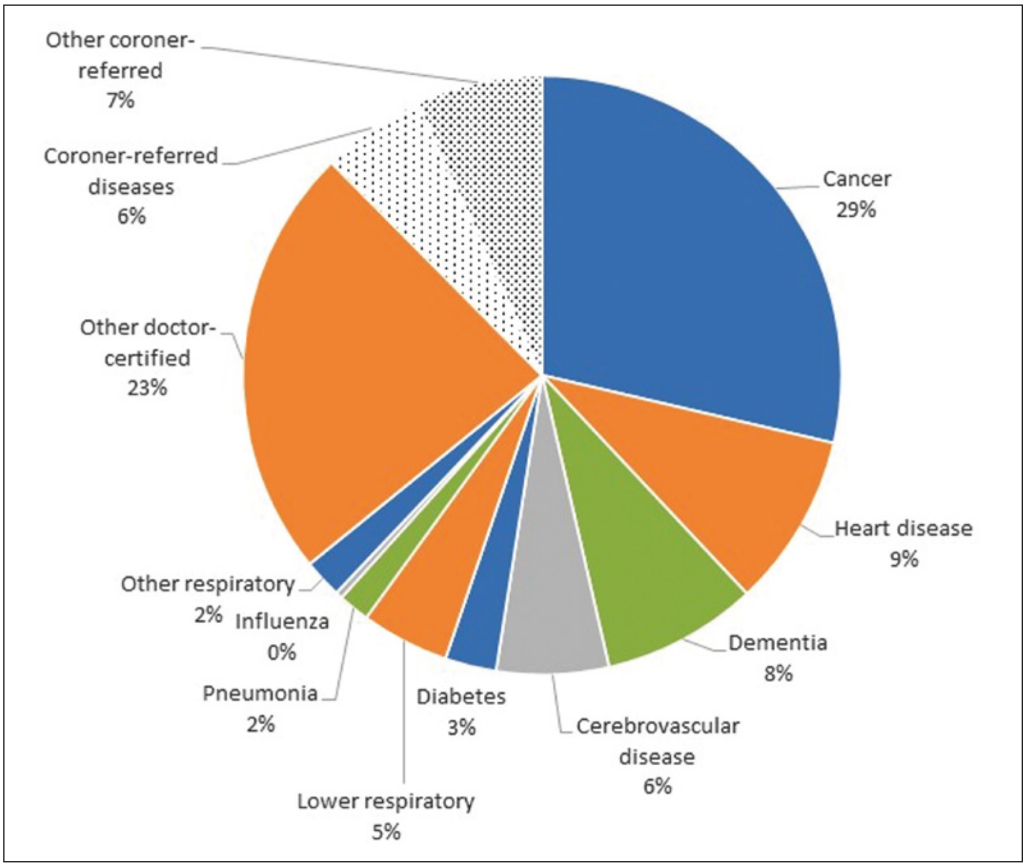


Table 2 summarises the results of the analysis by cause of death, for both 2020 and 2021.

Table 2 – Excess doctor-certified deaths by cause – 2020 and 2021

Cause of Death	2021 (52 weeks)				2020 (53 weeks)			
	Actual	Predicted	Diff	% Diff	Actual	Predicted	Diff	% Diff
COVID-19	**1,217**	**-**	**1,217**	**100%**	**855**	**-**	**855**	**100%**
Respiratory disease								
Influenza	2	840	(840)	-100%	50	780	(730)	-94%
Pneumonia	2,140	3,100	(950)	-31%	2,140	3,040	(900)	-30%
Lower respiratory	7,280	8,070	(790)	-10%	6,850	8,080	(1,220)	-15%
Other respiratory	3,770	3,880	(110)	-3%	3,280	3,790	(510)	-14%
All Respiratory Disease	**13,200**	**15,900**	**(2,700)**	**-17%**	**12,300**	**15,700**	**(3,400)**	**-21%**
Other disease								
Cancer	49,490	49,670	(180)	0%	48,750	49,500	(750)	-2%
Heart disease	13,960	13,030	930	7%	13,780	13,820	(40)	0%
Cerebrovascular disease	9,150	8,730	420	5%	9,160	9,160		0%
Diabetes	4,970	4,640	330	7%	5,020	4,660	350	8%
Dementia	15,540	16,030	(490)	-3%	14,750	15,560	(810)	-5%
Other unspecified diseases	42,900	40,400	2,500	6%	39,600	40,300	(700)	-2%
All Other Disease	**136,000**	**132,500**	**3,500**	**3%**	**131,100**	**133,000**	**(1,900)**	**-1%**
Total	**150,400**	**148,400**	**2,000**	**1%**	**144,200**	**148,600**	**(4,400)**	**-3%**

* Figures shaded green indicate that the observed values are below the 95% prediction interval while figures shaded red are above the 95% prediction interval.

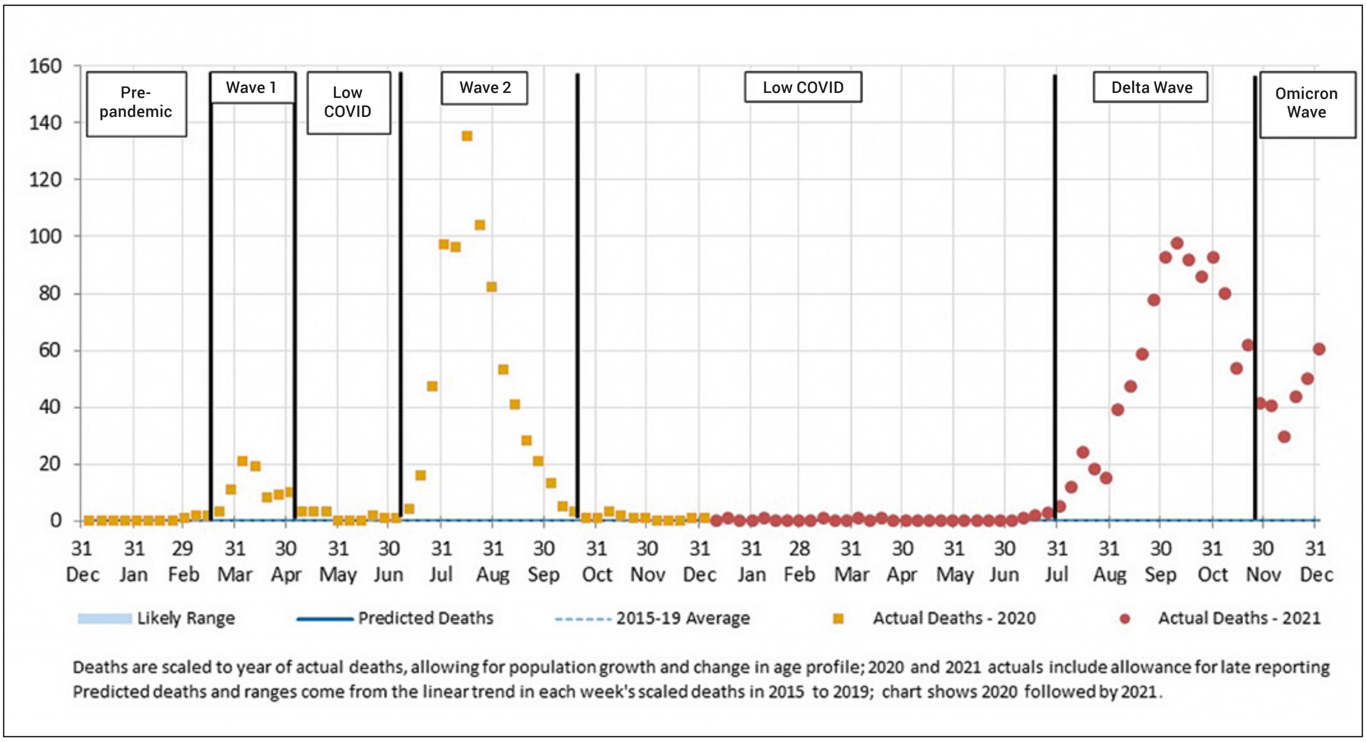
When broken down by cause of death, in 2021:

- there were 1,217 doctor-certified COVID-19 deaths;
- deaths from respiratory disease were around 2,700 (17%) less than predicted, which is significantly lower than the 2.5th percentile. While clearly respiratory deaths in 2021 were much lower than pre-pandemic levels, they were not as low as in 2020;
- cancer deaths were very close to predicted, following the slightly lower than predicted experience in 2020;
- deaths from dementia were around 490 (3%) less than predicted, which is also lower than the 2.5th percentile. The experience for dementia mirrors that of respiratory disease, with the lower-than-predicted experience for 2021 not being as low as for 2020. Deaths from dementia are heavily influenced by the levels of respiratory illness in the community; data shows that for deaths registered in 2015-2019, influenza and pneumonia were associated causes of death in 18% of dementia deaths[39];
- there were more deaths than expected from heart disease (up 930 or 7%), cerebrovascular disease (up 420 or 5%), and other causes (up 2,500 or 6%) in 2021, and these deaths were higher than the 97.5th percentile. This is different to the experience of 2020 where deaths from these causes were similar to expected; and
- there were more deaths than expected from diabetes (up 330 or 7%) and these deaths were higher than the 97.5th percentile, similar to the experience for 2020. Diabetes is a comorbidity of COVID-19, and around 45% of deaths from diabetes have ischaemic heart disease as an associated cause of death[40].

Higher deaths from non-respiratory causes exceeded the lower deaths from respiratory disease and dementia.

Appendix D includes graphs of the weekly actual versus predicted experience for each individual cause of death. Below is the experience for i) COVID-19, ii) deaths from non-COVID-19 respiratory diseases, and iii) non-COVID-19 and non-respiratory deaths.

Figure 18 – Weekly actual v predicted doctor-certified deaths – COVID-19



39 From Table 10 of the ABS *Causes of Death, Australia*.

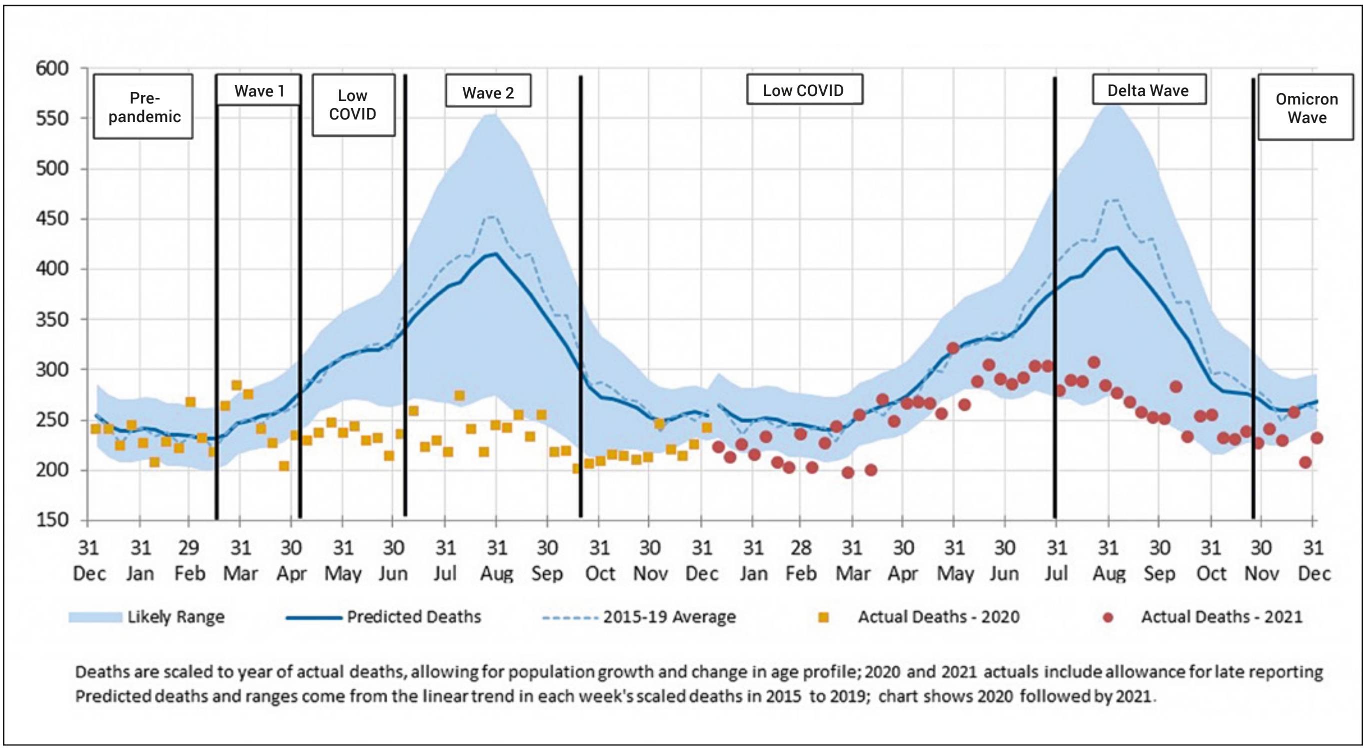
40 From Table 10 of the ABS *Causes of Death, Australia*.

In 2021, there were 1,217 doctor-certified deaths, compared with 1,402 COVID-19 deaths included in the daily surveillance reporting of the state/territory health authorities. We would not expect the numbers to be identical, because:

- there are delays between time of death and lodgement of the doctor's certificate (noting that we have not made any allowance for late reported COVID-19 deaths);
- the reporting criteria are slightly different; and
- some COVID-19 deaths will be referred to the coroner (e.g. deaths occurring at home).

Looking at each of the waves, there were approximately 95 COVID-19 deaths in the first wave, 750 deaths in the (mostly Victorian) second wave, 960 in the Delta wave and 270 in the first part of the Omicron wave (noting there has subsequently been much larger numbers of Omicron deaths in 2022).

Figure 19 – Weekly actual v predicted doctor-certified deaths – All respiratory disease



Following the trend observed since the beginning of the COVID-19 pandemic, Australia continued to see lower deaths from all respiratory disease in 2021 (Figure 19). While deaths from respiratory disease continue to be lower than expected, deaths from this cause were not as low as in 2020; in 2020, deaths were clearly lower than the lower bound of the prediction interval for most weeks after the first wave, whereas in 2021, deaths were mostly similar to the lower bound.

Figure 20 – Weekly actual v predicted doctor-certified deaths – All causes other than respiratory disease and COVID-19

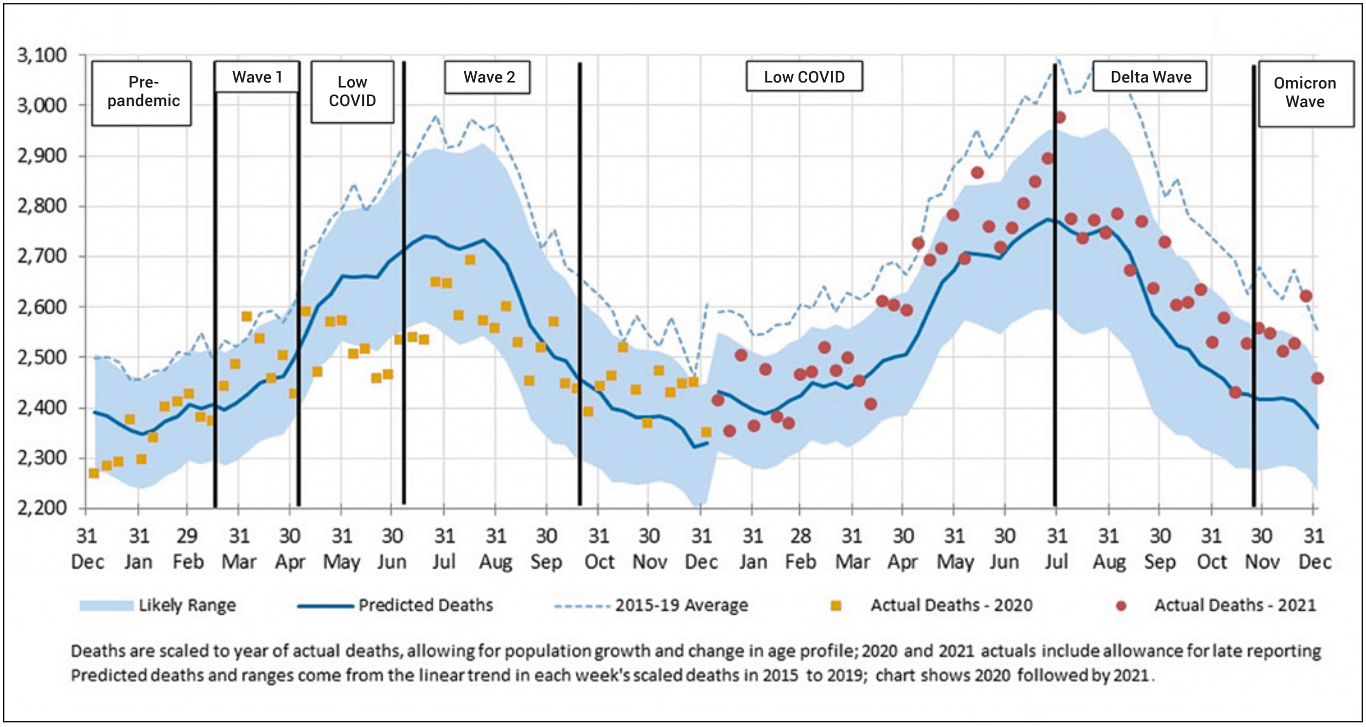
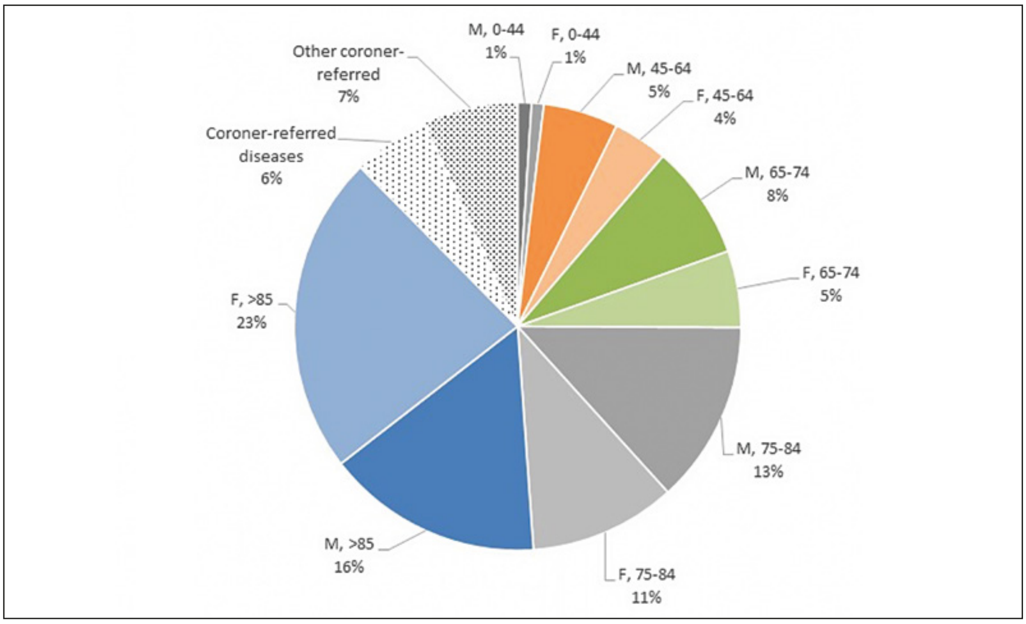


Figure 20 shows the comparison for deaths from all causes excluding COVID-19 and respiratory disease. For these causes combined, deaths in 2021 have generally been above predicted for most weeks, a trend that commenced in early November 2020. This is mainly driven by much higher-than-expected deaths from heart disease and 'other' diseases. ABS data shows that the age-standardised death rates for 2020 and 2021 are lower than the 2015-19 years[41], suggesting that the pace of mortality improvement in these causes of death has slowed down (rather than representing an increase in mortality rates).

2.5 Excess doctor-certified deaths by age and gender

For context, Figure 21 shows the mix of deaths by gender and age band over the 2015 to 2019 years.

Figure 21 – Doctor-certified deaths in 2015-19 broken down by age and gender



41 Tables 2.2, 4.4 and 4.5 of the ABS *Provisional Mortality Statistics.*

Unfortunately, there are not any breakdowns of the age/gender data by cause of death, however the ABS have supplied us with a breakdown of COVID-19 deaths by age/gender (see Appendix E.1).

Table 3 summarises the results of the analysis by age band and gender, for both 2020 and 2021. We have shown the percentage excess mortality both including COVID-19 deaths and net of COVID-19 deaths.

Table 3 – Excess doctor-certified deaths by age and gender, showing the proportion that were from COVID-19 – 2020 & 2021

Age Band and Gender	2021 (52 weeks)						2020 (53 weeks)					
	Actual	Predicted	Excess	% Excess	% COV-19	% Net	Actual	Predicted	Excess	% Excess	% COV-19	% Net
Males, 0-44	1,580	1,580	-	0%	0.8%	-1%	1,500	1,590	(90)	-5%	0.1%	-5%
Males, 45-64	8,530	8,890	(360)	-4%	1.2%	-5%	8,780	8,860	(80)	-1%	0.2%	-1%
Males, 65-74	14,090	14,180	(90)	-1%	1.1%	-2%	14,010	14,190	(180)	-1%	0.4%	-2%
Males, 75-84	23,550	22,500	1,050	4%	1.0%	3%	22,180	22,790	(610)	-3%	0.6%	-3%
Males, 85+	27,860	27,390	470	2%	0.7%	1%	26,250	27,300	1,050	-4%	0.8%	-5%
Males, All ages	**75,600**	**74,500**	**1,100**	**1%**	**1.0%**	**0%**	**72,700**	**74,700**	**(2,000)**	**-3%**	**0.6%**	**-3%**
Females, 0-44	1,330	1,360	(30)	-2%	0.6%	-2%	1,320	1,370	(50)	-4%	0.0%	-4%
Females, 45-64	6,340	6,550	(210)	-3%	0.8%	-4%	6,510	6,520	(10)	0%	0.2%	0%
Females, 65-74	9,810	9,710	100	1%	1.0%	0%	9,410	9,700	(290)	-3%	0.3%	-3%
Females, 75-84	18,450	17,750	700	4%	0.7%	3%	17,570	17,970	(400)	-2%	0.6%	-3%
Females, 85+	38,850	38,480	370	1%	0.5%	0%	36,690	38,350	(1,660)	-4%	0.8%	-5%
Females, All ages	**74,800**	**73,800**	**1,000**	**1%**	**0.7%**	**0%**	**71,500**	**73,900**	**(2,400)**	**-3%**	**0.6%**	**-4%**
Person, 0-44	2,910	2,930	(20)	-1%	0.7%	-1%	2,820	2,960	(140)	-5%	0.1%	-5%
Person, 45-64	14,880	15,450	(570)	-4%	1.0%	-5%	15,290	15,390	(100)	-1%	0.2%	-1%
Person, 65-74	23,900	23,890	10	0%	1.1%	-1%	23,420	23,890	(470)	-2%	0.3%	-2%
Person, 75-84	42,000	40,250	1,750	4%	0.9%	3%	39,750	40,760	(1,010)	-3%	0.6%	-3%
Person, 85+	66,710	65,870	840	1%	0.6%	0%	62,930	65,650	(2,720)	-4%	0.8%	-5%
Person, All ages	**150,400**	**148,400**	**2,000**	**1%**	**0.8%**	**0%**	**144,200**	**148,600**	**(4,400)**	**-3%**	**0.6%**	**-4%**

* Figures shaded green indicate that the observed values are below the 95% prediction interval while figures shaded red are above the 95% prediction interval.

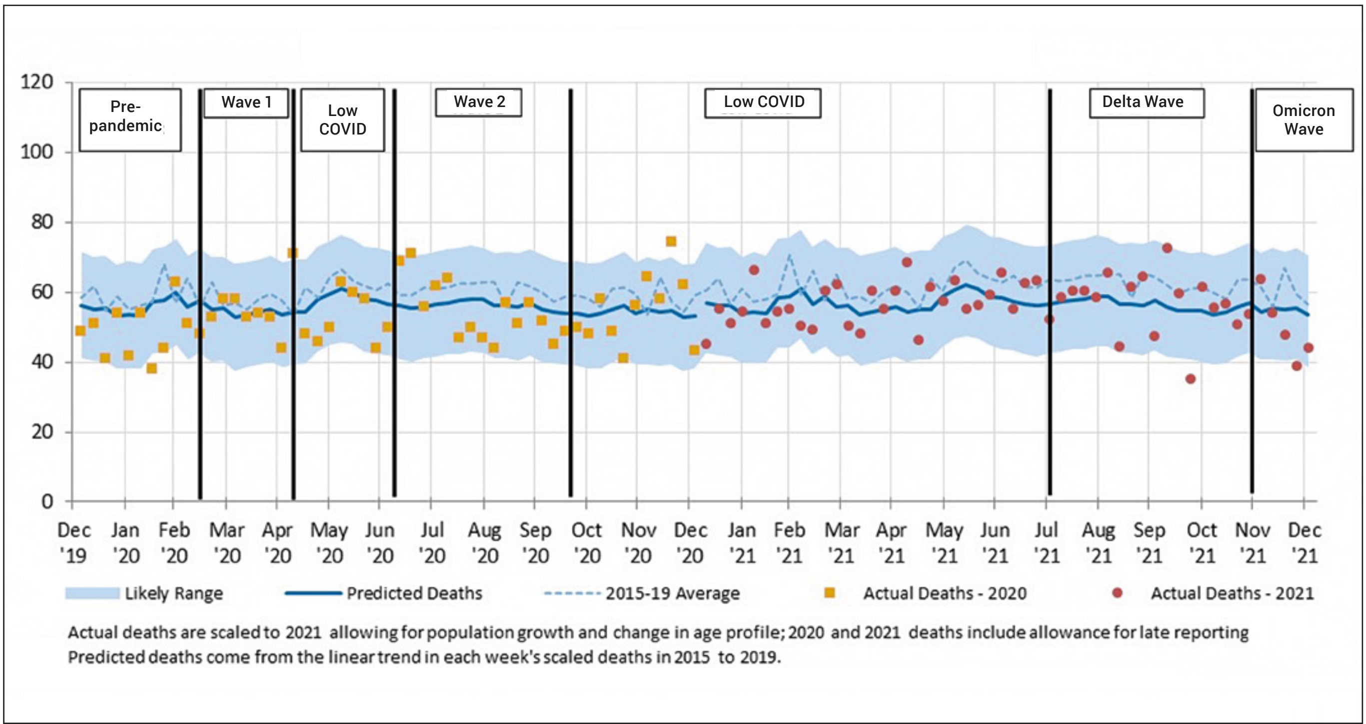
When broken down by age band and gender:

- in both 2021 and 2022, the results for males and females are similar, despite COVID-19 tending to cause higher absolute mortality in males – perhaps because COVID-19 deaths in Australia were relatively light in both years and expected male mortality is higher anyway. In 2020 the proportion of all deaths that were from COVID-19 was the same in males and females (0.6%), and in 2021 COVID-19 accounted for only a slightly higher proportion of all deaths in males (1.0% versus 0.7%);
- in 2020, deaths were lower than expected in the oldest age groups – probably because the main driver of lower-than-expected deaths in 2020 was respiratory disease, which primarily affects older-age cohorts[42]; and
- in 2021, for both males and females, deaths were significantly lower than expected in the 45-64 years age band but significantly higher than expected in the 75-84 age band, while deaths in the 85+ age band were close to expected. Perhaps the differences between the two oldest age bands are due to higher levels of protection in aged care homes, home care and hospitals than in the general community, possibly leading to much fewer-than-expected deaths from respiratory disease. There was not a huge difference in the proportion of deaths that were from COVID-19 in the two oldest age groups (0.9% for 75-84 age band and 0.6% for 85+).

Appendix E includes graphs of the weekly actual versus predicted experience for each age band/gender combination. Below is the experience for each age band for males and females combined.

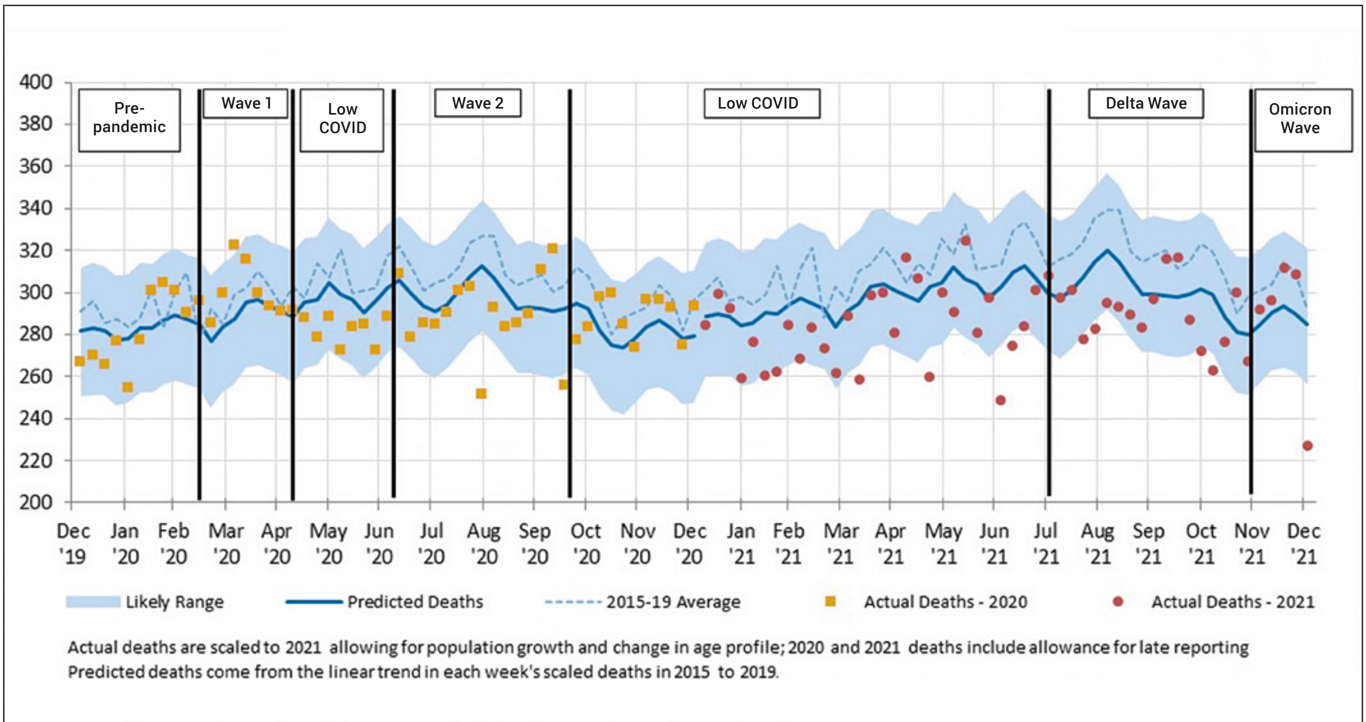
42 Note that the winter hump is almost non-existent at younger ages.

Figure 22 – Weekly actual v predicted doctor-certified deaths – Males and Females 0-44 years



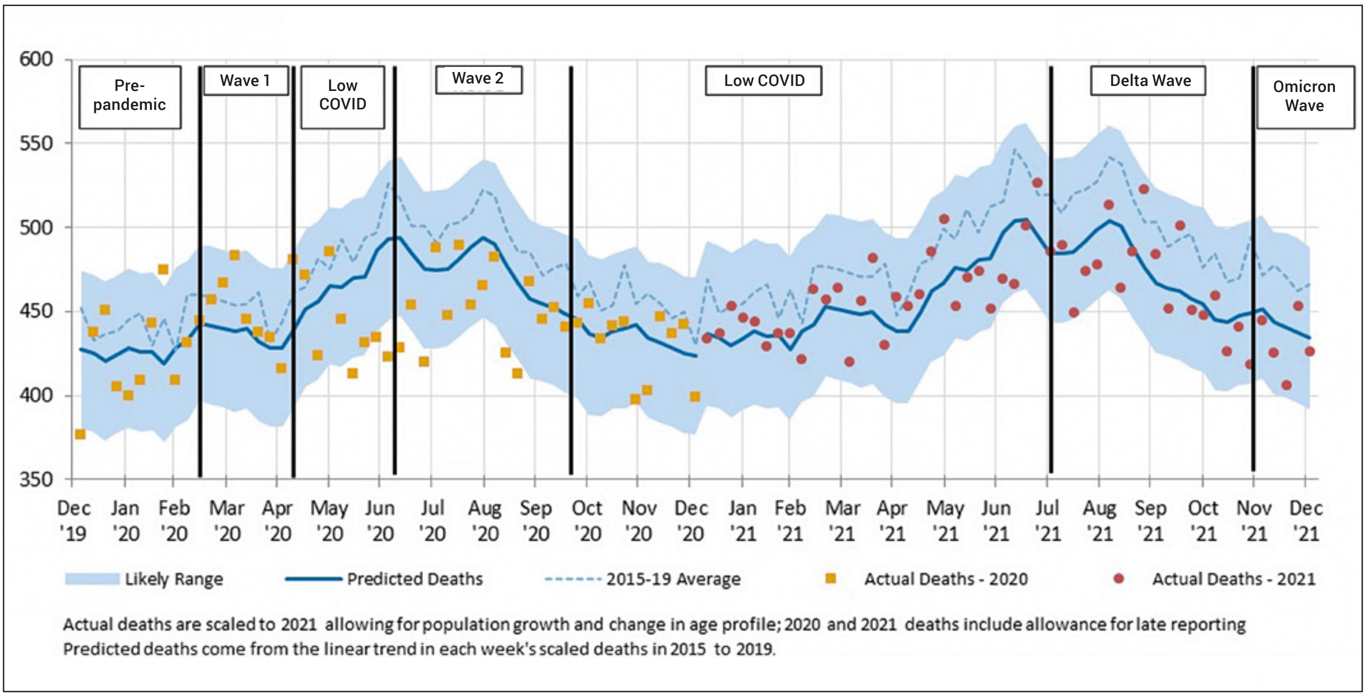
Aside from a small number of weeks outside the 95% prediction interval, actual deaths have been close to expected for the 0-44 age group.

Figure 23 – Weekly actual v predicted doctor-certified deaths – Males and Females 45-64 years



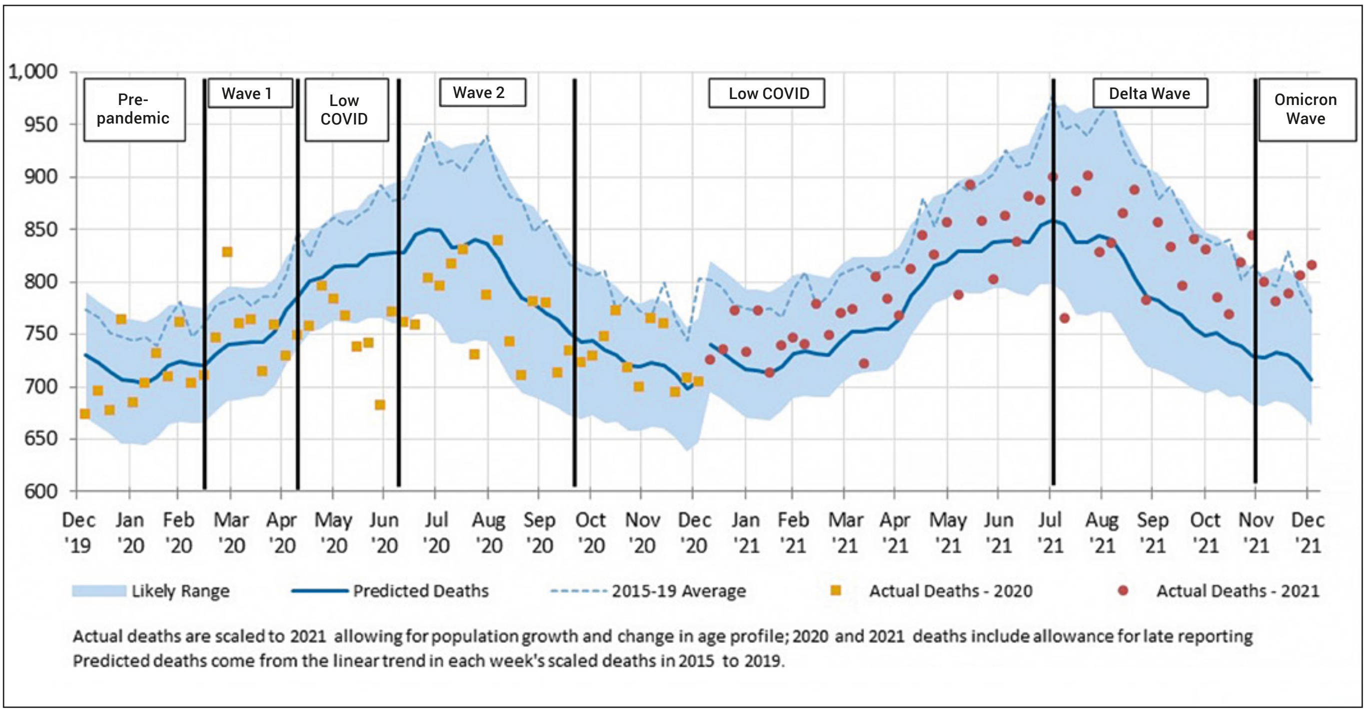
Deaths in the 45-64 age band have been lower than expected across most weeks of 2021, and lower than 2020. It is unclear why this is the case.

Figure 24 – Weekly actual v predicted doctor-certified deaths – Males and Females 65-74 years



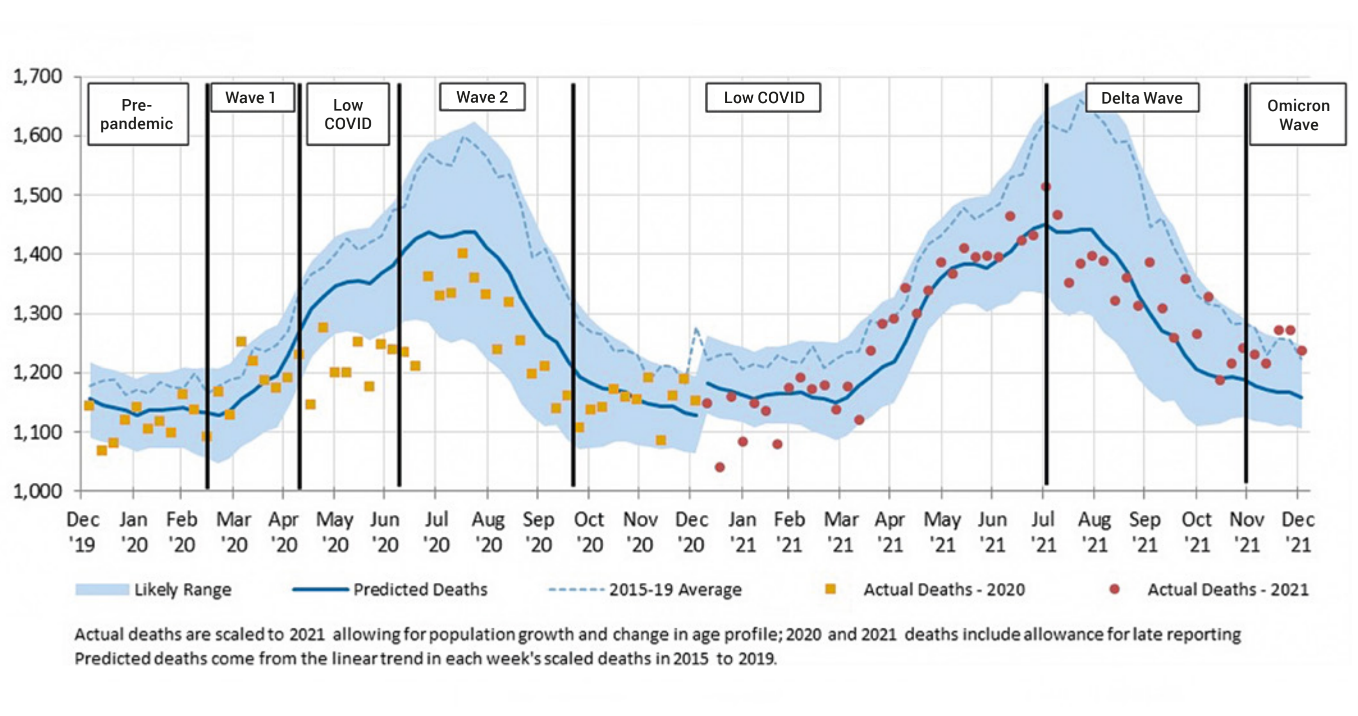
For the 65-74 years age band, we can see the impact of respiratory disease with a small winter hump apparent. Actual deaths were lower than expected during the winter months of 2020 (likely due to lower respiratory disease) but have been closer to expected across 2021. Perhaps this age group has become less vigilant in 2021?

Figure 25 – Weekly actual v predicted doctor-certified deaths – Males and Females 75-84 years



In the 75-84 age group, the winter hump is much more pronounced than in younger age groups. In 2020, we can see the impact of lower levels of respiratory illness. However, for 2021, almost all weeks are above predicted. The presence or absence of COVID-19 at different points in the year has made little difference to the pattern of deaths relative to expected. We can only speculate, but wonder if perhaps this age group is the one most affected by missing/delaying medical care in 2020?

Figure 26 – Weekly actual v predicted doctor-certified deaths – Males and Females 85+ years



In 2020, deaths in the 85+ age band were much lower than predicted in the low COVID period between the first and second waves, when deaths from respiratory illness and dementia were much lower than expected. During the second wave in 2020, deaths continued to be lower than expected, but not as low as for earlier weeks. COVID-19 deaths during the second wave will have offset some of the lower-than-expected respiratory deaths, especially given the impact of that wave on aged care homes.

In 2021, deaths in this age band were close to expected for most weeks in the first half of the year. We then see lower than expected deaths in August/September with the lower respiratory season. Towards the latter half of the Delta wave and into the Omicron wave, deaths are higher than expected which will be at least partially due to COVID-19.

In 2021, the 85+ age band experienced much lower excess mortality than the 75-84 band, perhaps because of defence measures practised by aged care homes.

It is unclear why there is such a disparity in mortality experience between the 75-84 and the 85+ age bands in 2021. Perhaps it is due to continued protection from respiratory disease because of the defence measures practised by aged care homes?

2.6 Excess coroner-referred deaths

This section sets out our estimate of excess deaths for coroner-referred diseases, briefly touches on road and suicide deaths (where there is some contemporary data for 2020 and 2021), and sets out our estimate of excess deaths for deaths from external causes.

2.6.1 Coroner-referred diseases

Table 4 shows the total number of deaths from diseases (i.e. excluding external causes) for the 2015 to 2019 years, broken down by cause of death. We have shown all deaths[43] and those that were doctor-certified[44], with the difference being the implied number of coroner-referred diseases.

43 From Table 14 of the ABS *Causes of Death, Australia.*

44 From the ABS *Provisional Mortality Statistics* including deaths registered by 31 December 2020.

Table 4 – All deaths from disease versus doctor-certified deaths – 2015-2019

Cause of Death	All Deaths 2015-19	Doctor-Certified 2015-19	Proportion Doctor-Certified	Proportion doctor-certified by year				
				2015	2016	2017	2018	2019
Respiratory disease								
Influenza	3,256	3,047	94%	91%	92%	95%	86%	95%
Pneumonia	14,668	13,617	93%	92%	92%	92%	94%	94%
Lower respiratory	40,680	38,267	94%	94%	94%	94%	94%	94%
Other respiratory	17,569	16,822	96%	95%	96%	96%	95%	96%
All Respiratory Disease	**76,173**	**71,753**	**94%**	**94%**	**94%**	**94%**	**94%**	**95%**
Cancer	234,103	230,366	98%	98%	98%	98%	98%	98%
Heart disease	93,445	75,415	81%	81%	82%	81%	80%	80%
Cerebrovascular disease	51,181	48,725	95%	95%	95%	95%	95%	95%
Diabetes	23,897	22,257	93%	93%	93%	93%	93%	92%
Dementia	68,410	67,516	99%	98%	99%	99%	99%	99%
Other unspecified diseases	202,112	188,431	93%	92%	94%	94%	94%	92%
All Other Disease	**673,148**	**632,710**	**94%**	**94%**	**94%**	**94%**	**94%**	**94%**
Total	**749,321**	**704,463**	**94%**	**94%**	**94%**	**94%**	**94%**	**94%**

Almost all cancer and dementia deaths are doctor certified. Around 95% of deaths from other specified diseases are doctor-certified, with the exception of heart disease[45] where only around 80% of deaths are doctor-certified. This is not surprising given the unexpected nature of many deaths from heart disease and hence their referral to the coroner.

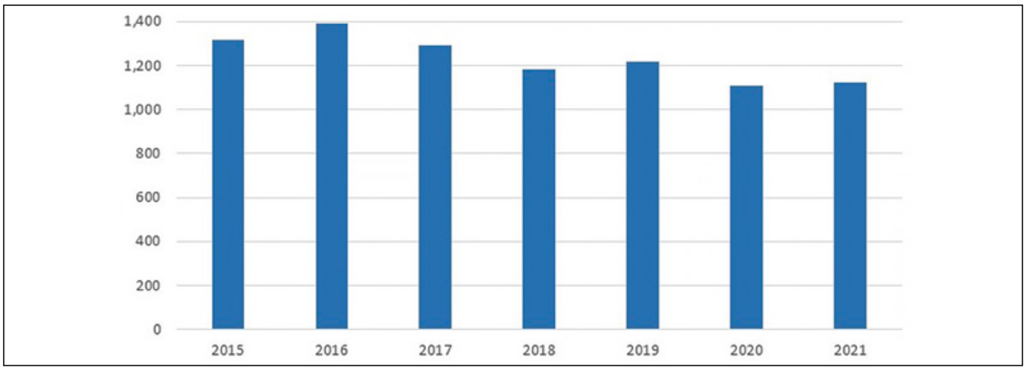
We have applied the proportion of doctor-certified deaths across the 2015-19 years (in Table 4) to the actual and predicted doctor-certified deaths (in Table 2) to estimate the actual and predicted coroner-referred diseases for 2020 and 2021. This assumes that the actual versus predicted experience of coroner-referred diseases will match that of doctor-certified diseases.

We estimate that actual deaths from coroner-referred diseases in 2020 will be a little lower than predicted deaths (-2% or around 200 deaths), and that actual deaths in 2021 will be a little higher than predicted (4% or around 300 deaths). The difference in percentage terms for coroner-referred diseases compared with doctor-certified diseases arises due to the different mix of diseases by cause (e.g. a higher-than-average proportion of heart disease deaths are referred to the coroner, and a lower-than-average proportion of cancer deaths).

2.6.2 Road deaths

Figure 27 shows the number of road deaths in each year, after adjustment for changes in population size.

Figure 27 – Yearly road deaths, adjusted to 2021 population size



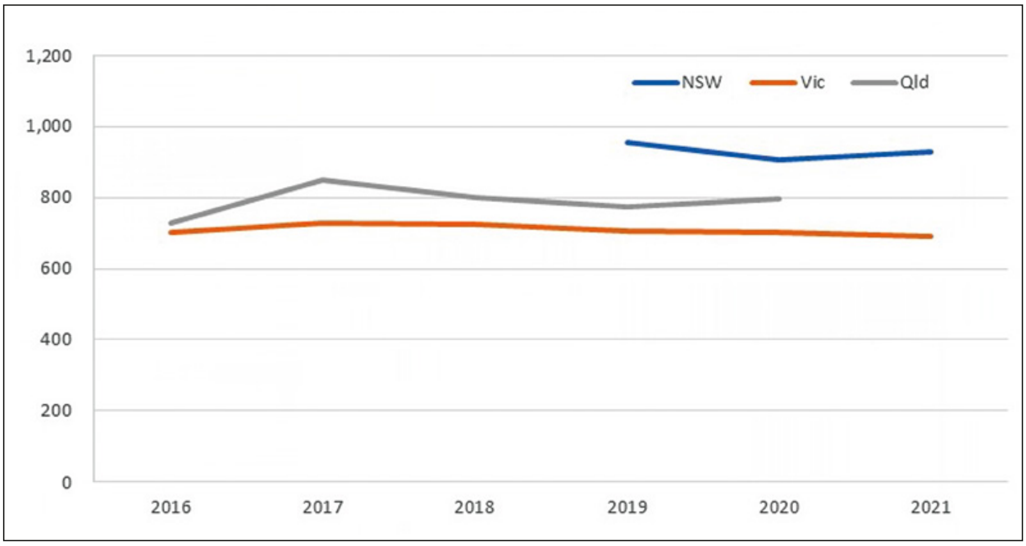
45 Heart disease in this paper means ischaemic heart disease, a condition where the heart is starved of oxygen due to a reduced blood supply. In turn, the reduced blood supply is usually caused by the build-up of plaque, which narrows the arteries. Ischaemic heart disease accounts for about 60% to 65% of all deaths from heart disease and is the subset of heart disease for which data is provided by the ABS. Other deaths from heart disease will appear in the 'Other Causes' category.

For the 2020 year, the number of road deaths (after adjustment for changes in population size) was 9% lower than 2019. For 2021, road deaths were up marginally on 2020 (+1%). The figures for 2020 and 2021 are the lowest per capita since records began in Australia, and broadly a continuation of existing trends. There were around 90-95 fewer deaths in each of 2020 and 2021 compared with the scaled average of 2018 and 2019.

2.6.3 Suicide deaths

Figure 28 shows the number of suicide deaths in each year for Victoria, NSW and Queensland, after adjustment for changes in population size.

Figure 28 – Yearly suicide deaths, adjusted for 2021 population size – NSW, Victoria and Queensland



After adjusting for changes in the size of the population, suicide deaths in the three states shown are largely unchanged pre- and post-pandemic:

- in NSW, suicide deaths in 2020 were 5% lower than in 2019, but then increased by 2% in 2021;
- suicide deaths in Victoria in 2020 were the same as 2019, while 2021 was then 2% lower; and
- in Queensland, suicide deaths in 2020 were 3% higher than in 2019.

There has been plenty of anecdotal evidence of the impact of lockdowns and other stresses on mental health, but the number of suicide deaths appears not to have increased.

There has been plenty of anecdotal evidence of the impact of lockdowns and other stresses on mental health, so we were pleasantly surprised to see that the number of suicide deaths appears not to have increased, at least not in the three biggest states of Australia. We could speculate on the reasons for this, but we do not consider that we have any special insight. Mathematically, one of two things has happened: either there has been no mortality impact from these stresses or there has been an offsetting reduction in other drivers of suicide.

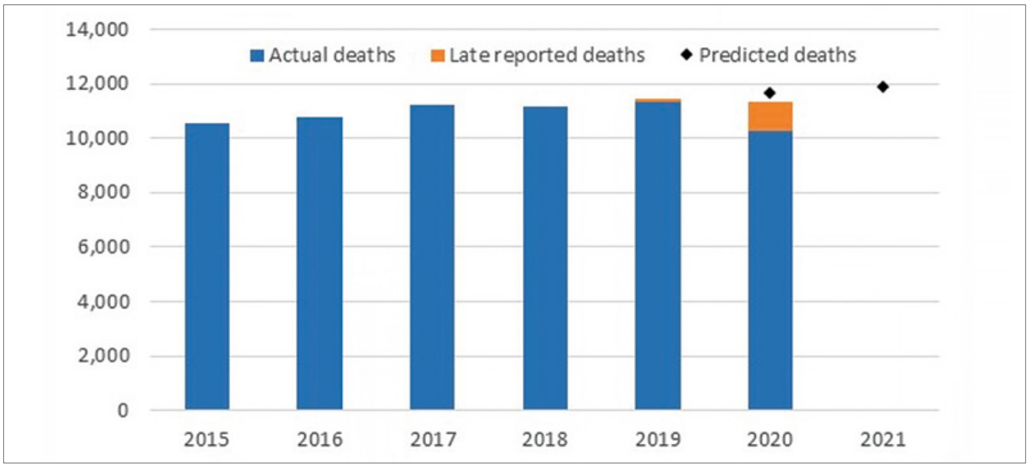
We are also cognisant of the potential for increases in rates of suicide in the next few years as the longer-term consequences of financial and other distress can take some time to emerge.

If you or anyone you know needs support call Lifeline on 13 11 14, or Beyond Blue's coronavirus mental wellbeing support service on 1800 512 348.

2.6.4 Deaths from external causes

Figure 29 shows coroner-referred deaths from external causes by year of occurrence as reported by the ABS, including allowance for late-registered deaths, plus our predicted deaths using a simple trend on the 2015-19 years.

Figure 29 – All coroner-referred deaths



We estimate that actual deaths from external causes[46] in 2020 will be a little lower than predicted deaths (-3% or around 400 deaths). For 2021, there is no information available yet on actual deaths from external causes (other than for road deaths and suicide as mentioned above). As such, we have assumed that the 2021 experience will be similar to 2020.

2.7 Excess deaths in total in 2020 and 2021

Table 5 shows our estimate of total excess deaths for 2020 and 2021, bringing together our estimates for doctor-certified deaths (Table 2), coroner-referred diseases (Section 2.6.1) and external causes (Section 2.6.4).

Table 5 – Total excess deaths – 2020 and 2021

	Actual	Predicted	Excess	% Excess
Doctor-certified deaths				
2020 (53 weeks)	144,200	148,600	(4,400)	-3%
2021 (52 weeks)	150,400	148,400	2,000	1%
Coroner-referred disease deaths				
2020 (53 weeks)	8,800	9,000	(200)	-2%
2021 (52 weeks)	9,200	8,800	400	4%
External Causes				
2020 (53 weeks)	11,500	11,900	(400)	-3%
2021 (52 weeks)	11,500	11,900	(400)	-3%
All deaths				
2020 (53 weeks)	164,500	169,600	(5,100)	-3%
2021 (52 weeks)	171,100	169,100	2,000	1%
2020 and 2021			**(3,100)**	**-1%**

We estimate that total excess deaths are around -5,100 (-3%) for 2020 and +2,000 (+1%) for 2021. Over the two years combined, that gives a total of -3,100 (-1%).

2.8 Preliminary estimates of excess deaths in 2022

While the ABS *Provisional Mortality Statistics* data is only available up to the end of December 2021, the surveillance COVID-19 deaths are available daily. Figure 30 shows the number of such deaths in each month of 2020, 2021 and the first 3 months of 2022[47].

On 31 March 2022, NSW Health released a report[48] that detailed the outcomes of a reconciliation between their daily death counts and data held by Births, Deaths and Marriages (which is the basis of the ABS data). This reconciliation identified 331 deaths that had not been captured in the daily

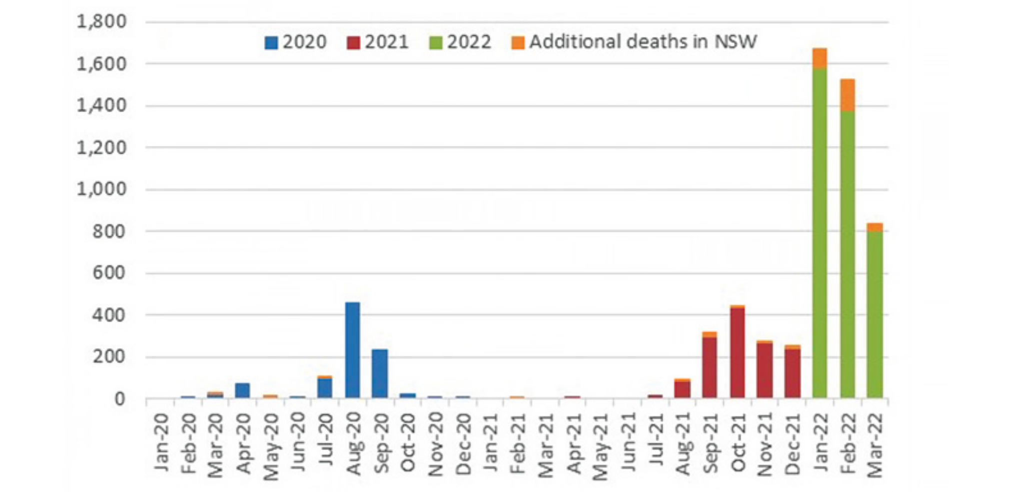
46 From Table 14 of the ABS *Causes of Death, Australia*.

47 Source: COVIDLive.

48 NSW Ministry of Health, *NSW COVID-19 Related Deaths*, March 2022.

counts. We have shown these deaths separately in the chart, allocated to the months when the deaths occurred.

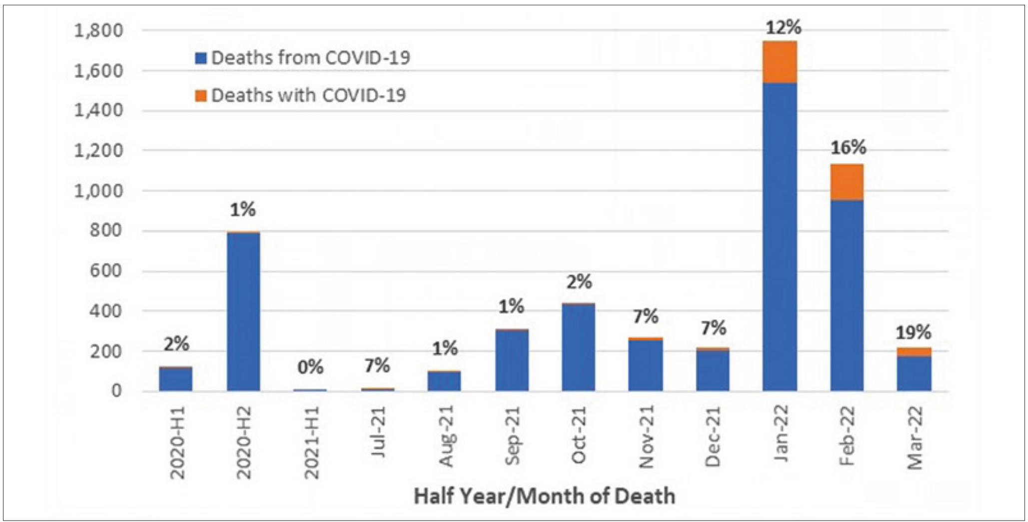
Figure 30 – Surveillance COVID-19 deaths



Including the additional NSW deaths, there were 912 surveillance COVID-19 deaths in 2020 (including 854 doctor-certified) and a further 1,402 deaths in 2021 (1,198 doctor-certified). By comparison, there were 4,027 COVID-19 deaths in the first quarter of 2022 (1,668 in January, 1,520 in February, and 839 in March). In other words, almost two-thirds of the 6,341 COVID-19 deaths recorded up to 31 March 2022 happened in 2022.

The ABS report *Australian COVID-19 Mortality* released on 20 April 2022 showed that, since the Omicron wave, an increasing proportion of deaths mentioning COVID-19 are in people where COVID-19 is on the death certificate but is not the underlying cause of death.

Figure 31 – Deaths 'from' versus 'with' COVID-19



In January 2022, 12% of COVID-19 deaths were with COVID-19. The proportion is higher in February and March, but many deaths occurring in those months are not yet included in the ABS data (as the deaths have not been registered yet). We have assumed that in the first quarter of 2022 that 15% of people have died with COVID-19 rather than from COVID-19. Therefore, we estimate that, of the 4,027 deaths reported in 2022, around 3,400 may be due to COVID-19.

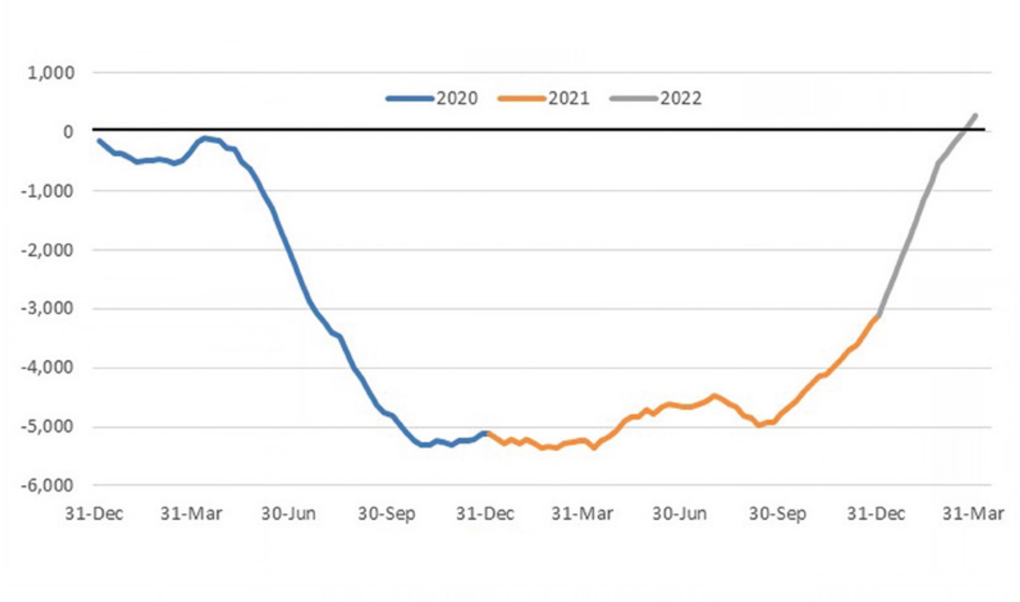
Our prediction model suggests that, without a pandemic and including allowance for coroner-referred deaths, there would have been a total of around 40,000 deaths in the first quarter of 2022 (around 13,700 in January, 12,400 in February and 13,800 in March).

Thus, if mortality from other causes is in line with our pre-pandemic predictions, the COVID-19 deaths will increase excess mortality by around 9% over the quarter (by around 10% in January and February and by about 5% in March). There is unlikely to have been a corresponding reduction in deaths from respiratory disease, as we have observed very little reduction in overall mortality during the summer months of 2020 and 2021 from this cause. Further, we consider it unlikely that mortality from non-COVID-19, non-respiratory causes will be in line with our pre-pandemic predictions, given the experience over 2021 (higher than expected). As such, we would view 9% excess mortality for the first quarter of 2022 to be at the bottom end of a reasonable range.

Combining the excess deaths for 2020 (-5,100) and 2021 (+2,000) with the expected excess mortality in the first quarter of 2022 (+3,400), we can see that deaths from the Delta wave in the latter part of 2021 and the Omicron wave in early 2022 have fully eroded the negative excess deaths experienced earlier in the pandemic.

This can be seen in Figure 32, showing Australia's estimated cumulative excess deaths from 1 January 2020 to 31 March 2022.

Figure 32 – Estimated cumulative excess deaths in Australia since the start of 2020



2.9 Comparison to ABS excess deaths

When it released the full-year data on doctor-certified deaths, the ABS also released an analysis of excess deaths, showing -1,734 for 2020 and +5,090 for 2021. By comparison, we have estimated (Table 2 above) that excess doctor-certified deaths were -4,400 for 2020 and +2,000 for 2021.

A key difference in approach between our estimate of excess deaths and the ABS estimate is the data used to form the estimate of predicted deaths. We have used data from 2015 to 2019 to form an estimate of the expected number of deaths in 2020 and 2021 in the absence of the pandemic. The ABS has used data from 2016 to 2020 to form an estimate of the expected deaths in each year 2016-2021. Compared with our approach:

- the ABS estimates are not "in the absence of a pandemic", given that they use the 2020 year in forming their predictions;
- the ABS prediction for 2020 is based on data that includes the 2020 year, so is not formed independently; and
- the ABS predictions do not explicitly allow for changes in population size and age distribution, rather implicitly assuming them from prior trends.

A comparison of our estimate and the ABS estimate is shown below.

Table 6 – Comparison of our estimates of excess mortality with the ABS – doctor-certified deaths

	Actual	Predicted	Excess	% Excess
Our estimates				
2020 (53 weeks)	144,200	148,600	(4,400)	-3%
2021 (52 weeks)	150,400	148,400	2,000	1%
ABS estimates				
2020 (53 weeks)	144,121	145,855	(1,734)	-1%
2021 (52 weeks)	149,198	144,108	5,090	4%
Difference				
2020 (53 weeks)	79	2,745	(2,666)	-2%
2021 (52 weeks)	1,202	4,292	(3,090)	-2%

The ABS estimate of excess deaths is around 2 percentage points higher than our estimate for both 2020 and 2021:

- Our predicted numbers of deaths are higher than the ABS. This is likely to be largely due to the ABS including the year 2020 (with low deaths from respiratory diseases) in the predictive model, as well as allowing only implicitly for changes in population size and age distribution.

- Our estimate includes a higher number of 'actual' doctor-certified deaths. This is due to our inclusion of an allowance for late-registered deaths.

2.10 Comparison to OWID excess deaths

OWID includes information on all excess deaths in Australia. It draws its analysis from the World Mortality Dataset (WMD) that uses the approach of the June 2021 Karlinsky and Kobak paper. The full database of actual deaths, predicted deaths and excess deaths for each country is available on GitHub.

Table 7 – Comparison of our estimates of excess deaths with WMD - total deaths

As with the ABS comparison, there is quite a sizeable difference in the estimates of excess deaths between us and WMD. The bulk of the difference comes from a difference in the 'actual' number of deaths, with our predicted values being quite close.

	Actual	Predicted	Excess	% Excess
Our estimates				
2020 (53 weeks)	164,500	169,600	(5,100)	-3%
2021 (52 weeks)	171,100	169,100	2,000	1%
ABS estimates				
2020 (53 weeks)	160,949	169,581	(8,631)	-5%
2021 (52 weeks)	166,619	168,771	(2,152)	-1%
Difference				
2020 (53 weeks)	3,551	19	3,531	2%
2021 (52 weeks)	4,481	329	4,152	2%

We have been in discussions with the WMD modellers over the past few months to try to resolve the differences between our estimates. They have made one change that has brought our excess death estimates closer together (incorporated in the figures above). The remaining difference stems from the way that WMD modifies the doctor-certified deaths to estimate total deaths, and we believe that there is an error in their approach. In March 2022, the ABS stated that they would be releasing weekly data on all deaths (including coroner-referred) in late April 2022, and the WMD modellers decided to make no further changes to the Australian estimates until this data became available.

2.11 Considerations for measuring excess deaths for 2022 and beyond

There are several enhancements that we plan to make in measuring excess deaths for 2022 and future years. Two of these are reasonably straightforward:

1. At the end of April 2022, the ABS will release more information on coroner-referred deaths. Statistics on coroner-referred deaths will be provided weekly from 2015, but with no breakdown by cause of death[49].

   We plan to model coroner-referred deaths in the same way that we have been able to model each doctor-certified cause, which should be quite straightforward, albeit with a different allowance for late-registered deaths. The delay to record a provisional coroner death is longer on average than to record a doctor-certified death[50].

2. The ABS has been publishing standardised death rates (SDRs) as part of the *Provisional Mortality Statistics* reports since their inception in 2020. They commenced publishing SDRs to 3 decimal places in 2021, which makes them eminently more useful. We intend to change our modelling to use the SDRs (rather than scaled deaths) as the basis of our projections for 2022 as SDRs encapsulate more information than our scaled deaths. One obvious improvement is that our scaling adjustments are made annually, whereas the base for SDRs is reset quarterly, resulting in smaller and more frequent step changes. Note that we will continue to communicate our findings in terms of numbers of excess deaths, which are intuitively easier to understand.

A difficult aspect moving forward is what to use as the baseline against which to measure actual deaths in 2022 and beyond.

The more difficult aspect of our work moving forward is what to use as the baseline against which to measure actual deaths in 2022 and beyond. As discussed in Section 2.2, so far we have used the 2015-19 years as the basis for our projection, and have been able to attribute excess deaths to the impacts of the pandemic i.e. our baseline is expected deaths in the absence of the pandemic.

However, as time marches on, this measure becomes more problematic; the 2015-19 years are getting old. While it is absolutely reasonable to project mortality out for one year (2020), and still justifiable to project mortality out for a second year (2021), projecting out for a third year (2022) feels like a stretch. Ignoring the latest two years of mortality data in forming projections for 2022 does not 'feel right'.

So what to use instead? And if we use data from 2020 and 2021, what does our baseline represent? It is no longer *in the absence of the pandemic*.

In the UK, the Office of National Statistics (ONS, equivalent to the ABS) uses the average of 2016-19 and 2021 (i.e. five years excluding 2020) to determine their baseline. This specifically excludes the 2020 year that was very heavily impacted by COVID-19, particularly in the first wave.

But it is interesting that they include 2021; the OWID data shows that excess mortality was 13% in 2020 and 10% in 2021. The UK actuaries (Continuous Mortality Investigation Bureau) use the age-standardised mortality in 2019 as the baseline. In neither case do they adjust for mortality improvements[51].

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49 To provide as complete a picture as possible, the ABS will use provisional reports of deaths to the coroner, which enables the death to be counted and basic demographic information such as age, gender and state/territory to be reported. However, by their very nature, provisional reports to the coroner have not yet had cause of death determined, hence why the ABS will not report by cause.

50 The ABS have said that, with doctor-certified deaths, 95% are recorded within 2 months and for coroner-referred this is about 80%; by the end of 3 months, the proportion increases to 92% for coroner-referred deaths.

51 We understand that mortality improvement was much slower (and sometimes negative) in the UK, before the pandemic.

It is unclear how much a slow-down in mortality improvement is due to the pandemic as opposed to other factors.

Thinking about the various causes of death in Australia, we have:

- an entirely new cause of death, namely COVID-19;
- causes (such as pneumonia and diabetes) that were potentially overstated in the first wave of the pandemic by undiagnosed COVID-19 deaths;
- causes (such as stroke) where the inability or unwillingness to access timely treatment perhaps led to more deaths than normal;
- a significant reduction in deaths due to respiratory disease;
- a flow-on impact on other causes (such as dementia) where respiratory disease is an associated cause in a large proportion of deaths;
- causes (such as cancer) where the pandemic appears to have had a negligible impact on mortality; and
- causes where the pandemic may have had a moderate adverse impact on mortality. These causes (such as heart disease, cerebrovascular disease, diabetes and other unspecified causes) have largely seen a slow-down in mortality improvement, rather than an actual increase in mortality. It is unclear how much of this slow-down in mortality improvement is due to the pandemic per se, as opposed to other factors.

While still exploratory, our current thinking is that, in determining our baseline for 2022, we will:

- exclude COVID-19 deaths – i.e. COVID-19 deaths will remain a direct cause of excess mortality;
- ignore high data points during the first wave of 2020 (i.e. those outside the 95th percentile) for cerebrovascular disease, diabetes, pneumonia and dementia. This will allow for any potential misclassification of COVID-19 deaths over that short period where testing was limited and will ensure that deaths from those causes are not over-estimated in the equivalent weeks in the baseline; and
- run our projection models three times for each cause of death:
  - once using data for the five pre-pandemic years 2015 to 2019;
  - once using data for the two pandemic years 2020 to 2021; and
  - once using data for all seven years 2015 to 2021.

It is unclear how these models may differ, and it is likely that we will use different years as the baseline for different causes. For example:

- for cancer, heart disease, cerebrovascular disease, diabetes, and other unspecified causes, we may use the 2015-2021 models – allowing any changes in mortality improvement over the last two years to be built into the forecasts; while
- for respiratory disease and dementia, it is unclear how deaths may change in 2022 and beyond, with:
  - international borders now open (thus influenza will become a cause of death once again, noting that Influenza A is already circulating in NSW[52]); but
  - the likelihood that those most susceptible to respiratory disease will continue to protect themselves (or will be protected by their aged care homes and hospitals).

We may end up with two different scenarios against which to measure excess deaths for these causes – one representing pre-pandemic experience and one representing the 2020 and 2021 years.

52 NSW COVID-19 Weekly Data Overview, Epidemiological week 15, ending 16 April 2022.

3 What does the future hold?

Prediction is very difficult, especially if it's about the future! [53]

We include this quote from Niels Bohr, because it has been hard enough to form a view about what has already happened, and yet we will now attempt to predict (or at least sketch) the future.

3.1 Mortality

We have seen (Section 2.8) that COVID-19 deaths in the first three months of 2022 have probably resulted in the elimination of Australia's cumulative negative excess mortality, measured to the end of 2021. But where will we end up by the end of 2022? And what about the longer term?

For simplicity, we will focus on deaths from COVID-19. If total non-COVID-19 mortality is in line with non-pandemic trends[54], this will be an estimate of total excess mortality.

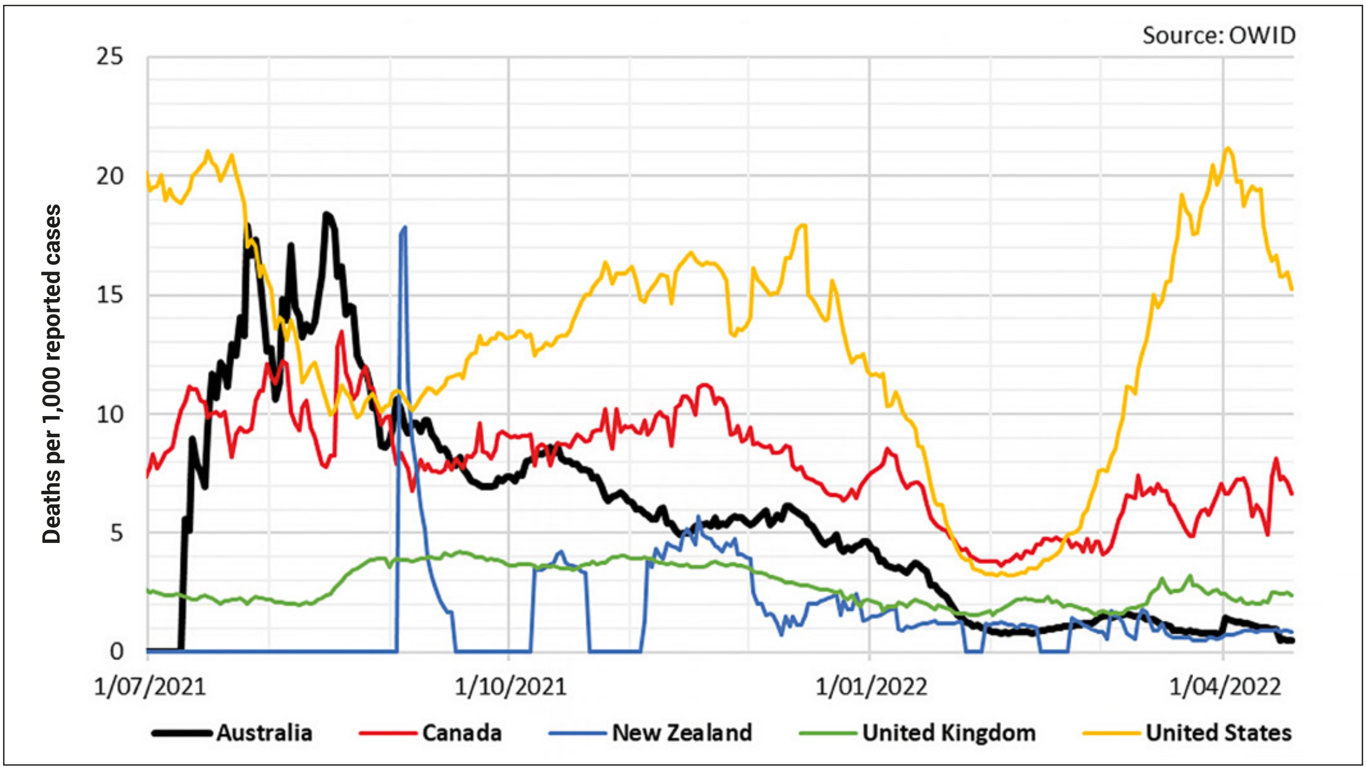
3.1.1 2022 mortality

Up to 18 May 2022, there had been 7,977 reported surveillance COVID-19 deaths in Australia, from just over 6.8 million reported cases. That is a case fatality rate (CFR) of about 0.12%.

The vast majority of cases (almost 6.4 million) have occurred in 2022, with 5,724 deaths in that time[55]. That is a case fatality rate of about 0.09%.

While it is not clear that Omicron is less virulent than the initial strain, both measured CFRs are far lower than the 2% to 3% seen earlier in the pandemic, indicating the value of vaccination, as well as improved care.

Figure 33 – 14-day rolling average COVID-19 CFR, allowing for 17 days lag from cases to deaths



53 Niels Bohr, atomic physicist.

54 This is broadly consistent with recent history, with lower respiratory deaths and higher deaths from other non-COVID-19 causes mostly offsetting each other (on an annual basis).

55 This figure has not been adjusted to respread the late-reported NSW deaths, most of which occurred in 2022 anyway.

Recognising that there is a delay[56] between confirmed infection and death, Figure 33 shows how the Australian CFR has fallen since the start of the Delta wave in 2021, compared with a selection of other 'Anglosphere' nations. OWID data has been used without adjustment, and the impact of the late-reported NSW deaths on 31 March 2022 can be clearly seen. Since infections and deaths are still quite high, this suggests that the CFR may average below 0.1% for the remainder of 2022 – assuming that there is no new, nastier variant.

Cases to-date in 2022 are likely to be significantly understated, for reasons that include:

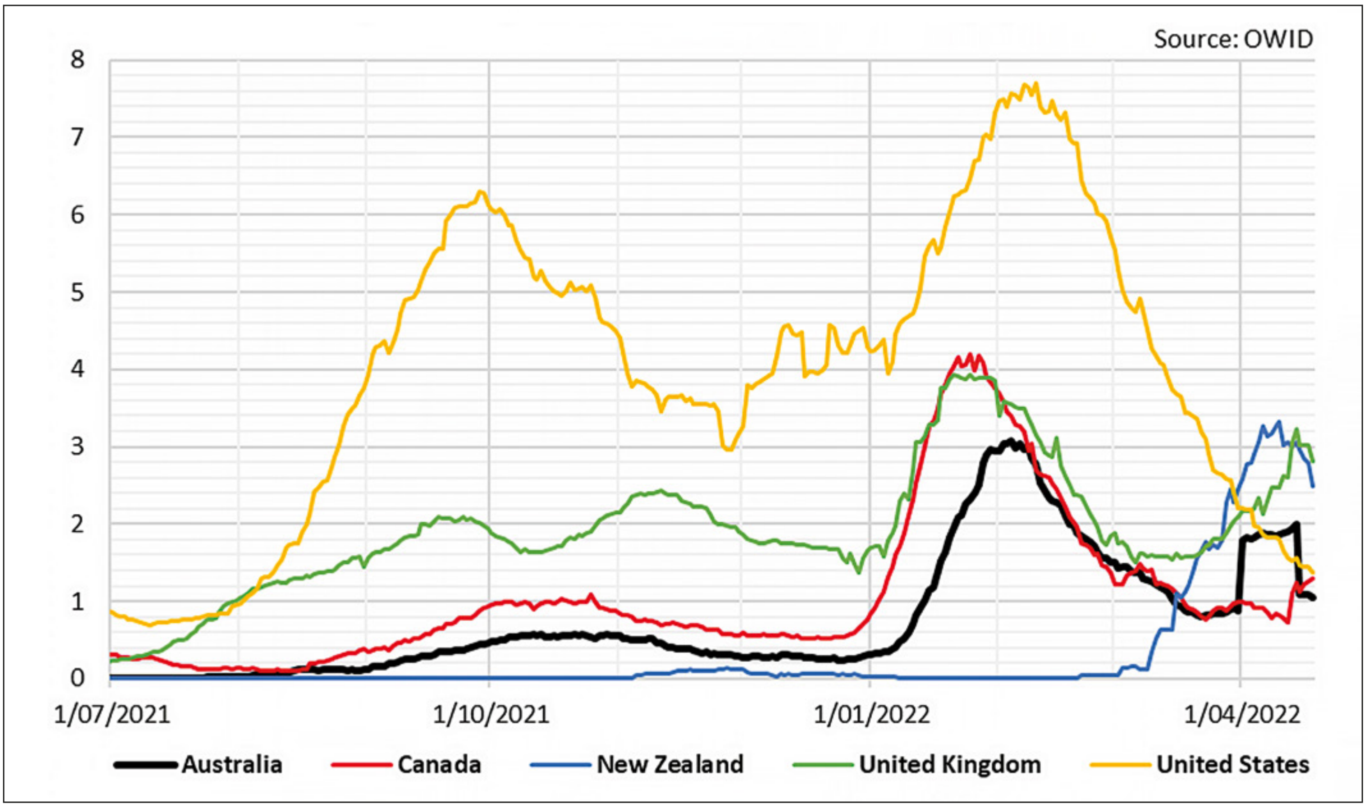
- a person without symptoms is unlikely to test[57];
- some people will ignore their symptoms or will not report a positive RAT; and
- RATs have a fairly high rate of false negatives.

Professor Catherine Bennett recently[58] published an estimate that less than 50% of infections were being reported, citing the reasons given above. On that basis – and ignoring pre-2022 cases to allow for a degree of reinfection – at least 13 million Australians have had COVID-19, with an infection fatality rate (IFR) of about 0.05%.

If a further 7 million[59] are infected in 2022, with a similar IFR, we might see a further 3,500 deaths, for a full-year total of 9,200.

As discussed in Section 2.8, about 15% of these deaths will not be from COVID-19, so we will assume that they do not add to excess mortality. If we assume that non-COVID mortality is broadly as expected, we obtain excess mortality of around 4.5% to 5%, or about 7,500 to 8,500 extra deaths in the full year 2022.

Figure 34 – 14-day rolling average of daily COVID-19 deaths per million of population



56 We understand that 17 days is a reasonable estimate of the average delay in Australia.

57 This may change as a result of new close-contact rules and as more people seek to travel to places requiring proof of a negative test.

58 COVID restriction wind-backs mark a shift in managing pandemic (smh.com.au).

59 This would take the total infected to 20 million, which should be an upper limit.

It seems clear that COVID-19 is becoming increasingly normalised in the population.

Alternatively, we can look at deaths, thereby removing the uncertainty about the relativity between cases and infections. Figure 34 suggests that we might expect a daily rate of at least 1.5 per million (39 deaths per day[60]) for a while. If we assume that this is the daily average for the remainder of 2022, that translates to 5,724 + 39 x 227 = 14,600 COVID-19 deaths in 2022. Multiplying by 85% gives 12,400 – i.e. excess mortality of around 7% to 7.5%.

Combining the two estimates gives us a rather approximate estimate of around 6% excess mortality (10,000 extra deaths) across the whole of 2022. We think that it is more likely that this is an underestimate than that it is an overestimate, partly because of the risk of excess mortality in non-COVID causes.

3.1.2 Future mortality

It seems clear to us that COVID-19 is becoming normalised in the population. For example, our own observations suggest that mask-wearing mandates (where they remain in force) are increasingly disobeyed, following trends that are observable overseas. Therefore, we assume that COVID-19 will continue to circulate and, as immunity wanes and new strains arise, people will be reinfected. However, there may well be a greater residual immunity than existed in our largely uninfected population at the start of 2022.

At the same time, it is also possible that increased defence measures[61] will persist in places of high vulnerability, including aged care.

We note that we measured a 1.8% per annum mortality improvement trend in 2015-19 (see Section 2.2.1), so our estimated excess mortality in 2022 is equivalent to a reversal of between three and four years of mortality improvement.

Overall, we expect that the legacy of COVID-19 will be one of higher mortality than would otherwise have been expected, perhaps equivalent to a permanent two-year delay in the long-term mortality improvement trend.

In reality, of course, we are not able to make any estimate with any degree of reliability.

3.2 Morbidity – Long COVID

In this section, we consider Long COVID, which is increasingly recognised as a long-term complication from contracting COVID-19. But what is it? And how worried should we be?

We know that it can be very serious, such that avoiding infection is a good idea. But what is actually known about it, including the risk of suffering from it and its potential impact?

In general, what we do seem to know is that:

- there is a non-trivial chance of being seriously disabled for a prolonged period by Long COVID for those who contract COVID-19;
- the chances of Long COVID are higher if the initial COVID-19 illness was worse;
- Long COVID affects people of working age more than children and older people;
- women seem to be affected worse than men;
- vaccination reduces (but does not eliminate) the chances of Long COVID;
- a wide variety of organs can be affected in the long term by an initial illness of COVID-19; and
- Long COVID outcomes have a wide range, from ongoing mild symptoms to serious limitations on day-to-day activity.

This means that, so long as people continue to contract COVID-19, a fraction of them will develop

60 By comparison, we had 5,724 deaths in the first 138 days of 2022, at a daily average of 41.5.

61 Primarily, perhaps, vaccination of residents and testing of visitors.

long-COVID. While this may not have been a significant national issue[62] in Australia when cases were low, the extensive spread of COVID-19 will generate large numbers of Long COVID cases, with significant implications for both the health system and the economy.

Therefore, it is important to try to understand this condition.

3.2.1 What is Long COVID?

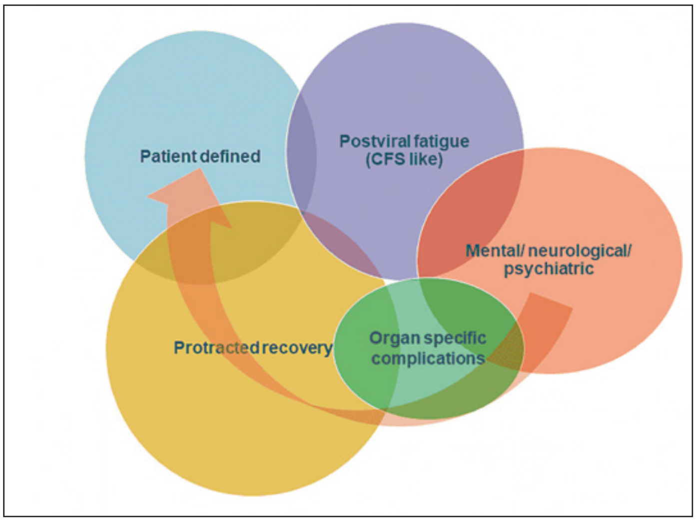
Dr Achim Regenauer has written a great summary[63] of what we know so far. He says:

The list of long COVID symptoms is now longer (at over 200), there is still no one clinical case definition (although the WHO's ICD-10 U09 is a helpful reference), no clear routine laboratory or imaging diagnostics, no clear duration, and no effective treatment (nor is one in sight)....it has unknown but potentially long-term duration, lack of a uniform, internationally applied definition, and complex, diverse set of symptoms, including post-viral fatigue, joint pain and organ-centered manifestations, such as impaired lung function.

It is likely that Long COVID has multiple COVID-19-related causes, as shown in Figure 35, in which Dr Regenauer attempts to demonstrate the likely proportions of the different types of COVID-19- caused long term diseases. They are likely to have overlapping systems, but potential separate causes:

- post viral fatigue – a well-known phenomenon from many viral diseases, including the 1918 flu pandemic, and polio[64];
- organ-specific complications – there are documented examples of damage to specific organs post- COVID-19 infections (for example, one study[65] shows that heart damage is much more likely after a COVID-19 infection than in patients with other respiratory diseases and another[66] looks at damage to the heart, lungs and kidneys);
- mental/neurological/psychiatric – a study[67] looked at long term nervous system consequences of COVID-19 and found a number of different neurological and psychiatric outcomes (this may be a subset of organ specific complications, but for the brain);
- protracted recovery – COVID-19 is a complex disease, and it seems likely that some patients take a long time to recover; and
- patient defined – covering symptoms with as yet unknown causes that are not caught above.

Figure 35 – Schematic of Long COVID symptoms[68]



62 As distinct from the impact on the individuals concerned.

63 New Long COVID Research – Considerations for Life & Health Insurance – PartnerRe.

64 See Pandemics disable people — the history lesson that policymakers ignore (nature.com).

65 https://www.nature.com/articles/s41591-022-01689-3.pdf.

66 Study confirms: even a mild course of COVID-19 damages organs | 24 Hours World (24hoursworlds.com).

67 Nervous system consequences of COVID-19 (science.org).

68 A working hypothesis by Dr Regenauer to reflect the comprehensive and complex nature of long COVID's more than 200 symptoms. The author breaks down long COVID into five subgroups. The size of the bubbles mirrors the approximate relative incidence of each subgroup. Source: PartnerRe.

3.2.2 How likely is Long COVID?

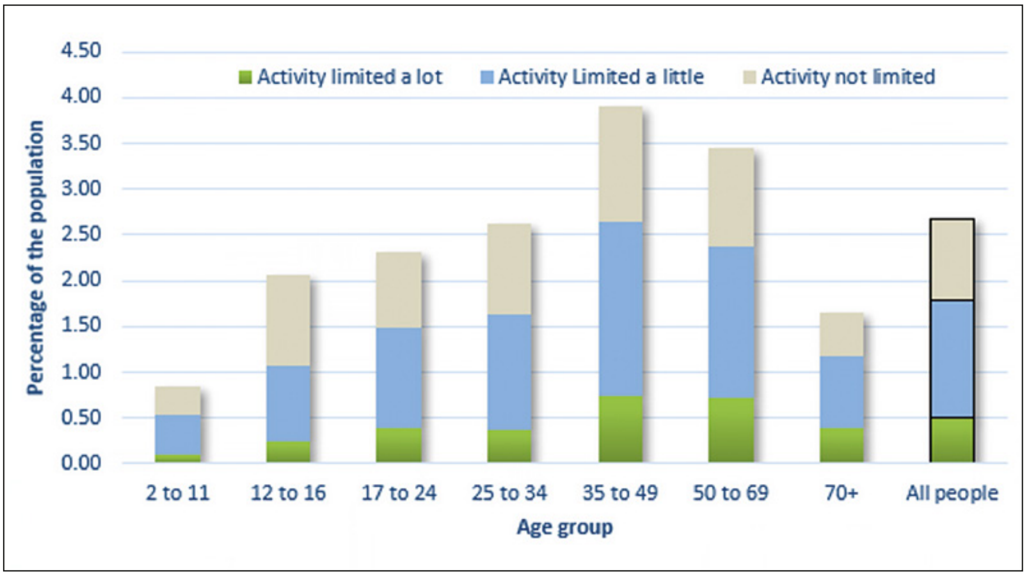
Now that we are two years into this pandemic, it is possible to look at long-term disease. But the nature of the surges around the world, the disruptions to the health system for those who are not acutely ill, and the vagueness of many symptoms have made Long COVID particularly challenging to study. Given that Long COVID is probably a combination of a number of different underlying causes, with different trajectories[69] and a complex constellation of symptoms, it is very hard to measure the overall risk. Measurement is also complicated by periods when there may have been considerable unidentified COVID-19, because testing rates were inconsistent with the spread of the pandemic[70].

The complexity of the wide variety of symptoms makes a prospective gold standard study relating to Long COVID a difficult task.

The gold-standard would be a prospective study that recruits a random selection of people testing positive for COVID-19, matches them with similar people (from an otherwise identical population) who test negative for COVID-19, and then tracks them both for an extended period. But the complexity of the wide variety of symptoms makes even this difficult.

Despite the time that has elapsed, it is also more challenging than it appears to define Long COVID in a way in which statistical comparisons can be usefully made, given how variable the symptoms are.

Figure 36 – Estimated prevalence of Long COVID in the UK population on 5 March 2022



The UK Office of National Statistics (ONS) runs a population-level survey asking respondents about their symptoms of Long COVID and releases the resultant statistics. As shown in Figure 36 on 5 March 2022, 2.7% of the population was estimated to have some symptoms of Long COVID at least 4 weeks after their COVID-19 illness (based on the self-reporting of both the initial illness and the subsequent symptoms of the sample) and 0.5% of the population had their activity limited a lot by their symptoms, with another 1.3% with some activity limitations.

In the UK, the total reported cases to the middle of January (the midpoint of four weeks before this survey was conducted[71]) represented 22% of the total UK population[72]. So, if those were all the cases, 2.3% of all verified COVID-19 cases have led to serious activity-limiting symptoms, with up to another 5.8% of verified COVID-19 cases leading to some limits on activity. Both the numerator and the denominator of this measure are likely to be inaccurate; there were almost certainly more cases than this, but also some people would not have identified themselves as having Long COVID because they will not have realised that they had contracted COVID-19.

69 e.g. protracted recovery will get better over time, but the organ-specific complications may well get worse.

70 This will include the early days of the pandemic, when tests were limited, but also the Omicron wave, where many asymptomatic (or even symptomatic) cases may either not test or not register positive results.

71 The ONS survey was conducted over four weeks, and the minimum qualifying period for Long COVID in the survey is four weeks since original illness.

72 Source: OWID.

At 0.5% of the population, this study suggests that more than 320,000 people in the UK suffer from Long COVID that has seriously limited their activity for a prolonged period. And the study shows that this outcome is more likely in those of peak working age: 35-69.

3.2.3 How much does vaccination help?

Many of the studies of Long COVID occurred before the population was generally vaccinated so there is limited information about the likelihood of Long COVID post vaccination. However, what there is suggests about a 40%-50% reduction in risk[73].

This seems intuitively plausible, given that the risk of Long COVID reduces with milder disease, as well as some evidence that vaccination helps reduce symptoms for those who already have Long COVID. Therefore, it seems likely that vaccination reduces the risk of Long COVID, but it doesn't eliminate it (just as it reduces but doesn't eliminate the risk of hospitalisation and death).

3.2.4 Some individual diseases have increased prevalence post COVID-19

It is very difficult to look at specifics with Long COVID as there are so many different types. However, there have been some major studies of long-term outcomes of specific diseases or serious hospitalisation post COVID-19.

First, there is a very recent preprint study from Hong Kong researchers[74] into overall hospitalisation and death post COVID-19 in the UK. This study is based on the UK biobank and covers more than 400,000 people aged 50 to 87. It looks at the risk of subsequent hospitalisation or death from a wide variety of diseases and disorders, following a bout of COVID-19. The conclusion is that COVID-19 is associated with increased risk of subsequent mortality and hospitalisation, with the risk increasing the more severe the disease – e.g. a 24% increase in mortality risk subsequent to mild COVID-19, and mortality nearly 15 times higher after severe (hospitalised) COVID-19. The conclusion (on page 15 of the study) was:

Overall, we found that COVID-19, especially severe disease, was associated with increased risks of hospitalization and/ or mortality due to pulmonary, cardiovascular, digestive, neurological, genitourinary and musculoskeletal disorders in the post-infection period. These results were largely consistent and robust to multiple sensitivity analysis, and after PERR and PTDM adjustment.

Next, we turn to individual diseases.

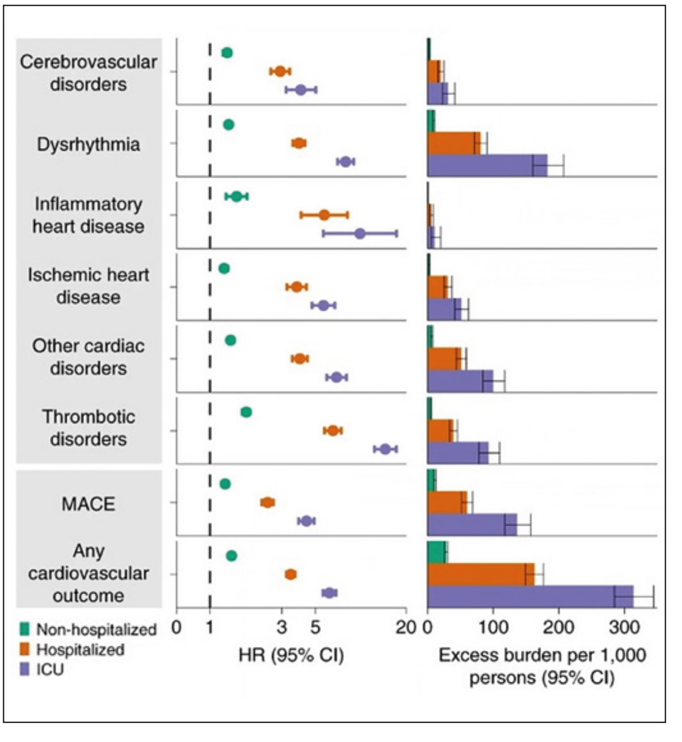


Figure 37 – Comparative risk and excess burden of various cardiovascular outcomes after acute COVID-19[75]

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73 See, for example, Thread by @ahandvanish on Thread Reader App – Thread Reader App or Six-month sequelae of post-vaccination SARS-CoV-2 infection: a retrospective cohort study of 10,024 breakthrough infections | medRxiv.

74 Association of COVID-19 with risks of hospitalisation and mortality from other disorders post-infection: A study of the UK Biobank https://www.medrxiv.org/content/10.1101/2022.03.23.22272811v1.full.pdf.

75 A major adverse cardiac event (MACE) is defined as a composite of all-cause mortality, stroke and myocardial infarction.

A US study[76] looks at the long-term cardiovascular outcomes after a COVID-19 infection. It uses data from the Department of Veterans Affairs to match COVID-19 infected individuals with control individuals (selected to match the characteristics of those with a COVID-19 infection). Then it investigates various cardiovascular diseases more than 30 days after the initial infection date (or start date for matched non-COVID-19 individuals, who were matched according to severity of initial disease).

Figure 37 shows that the risk of a major adverse cardiac event (MACE) – which is defined in the study as a composite of all-cause mortality, stroke and myocardial infarction – is substantially higher after a COVID-19 infection than in the controls. Indeed, this has an average hazard ratio of 1.55 (i.e. the chance of MACE after COVID-19 is 155% that of the control). That poor outcome is considerably higher if the initial COVID-19 infection led to hospitalisation, or intensive care – the hazard ratio for MACE is 1.30 for the non-hospitalised, 2.50 for those who were hospitalised with COVID-19 and 4.51 for those who were admitted to ICU because of COVID-19.

Diabetes

A study in the Lancet[77] also uses data from the US Department of Veterans affairs. As with the previous study, a possibly major problem is that it is disproportionately a study into men (nearly 90% of those studied). However, it is a very large group of people – in this case around 180,000 COVID-19 positive cases compared with around 4 million controls.

Figure 38 – Relative prevalence of post-COVID-19 diabetes, compared with a control group – US military veterans

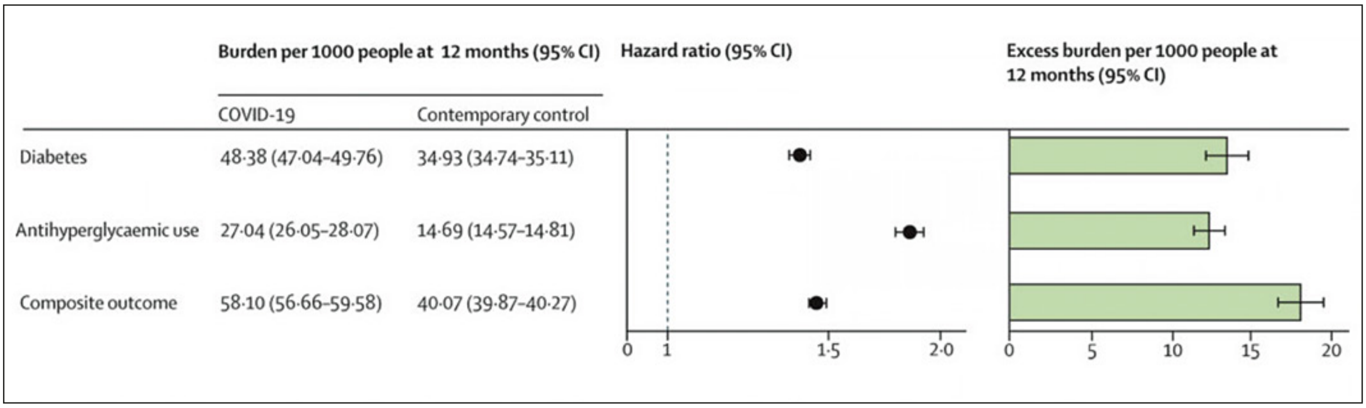

Figure 38 shows that COVID-19 increases the risk of diabetes by almost 50%. Overall, it increases the proportion of the population with diabetes by just over 1%. And, once again, the worse the initial COVID-19 disease, the bigger the increase in the follow-on disease (see Figure 39). The conclusion of the Lancet paper on page 319 is quite clear:

In conclusion, we suggest that in the post-acute phase of the disease, people with COVID-19 exhibit increased risk and burden of diabetes, and antihyperglycaemic use. The risks and burdens were evident among those who were non-hospitalised during the acute phase of the infection and increased according to the severity of the acute infection as proxied by the care setting (non-hospitalised, hospitalised, and admitted to intensive care).

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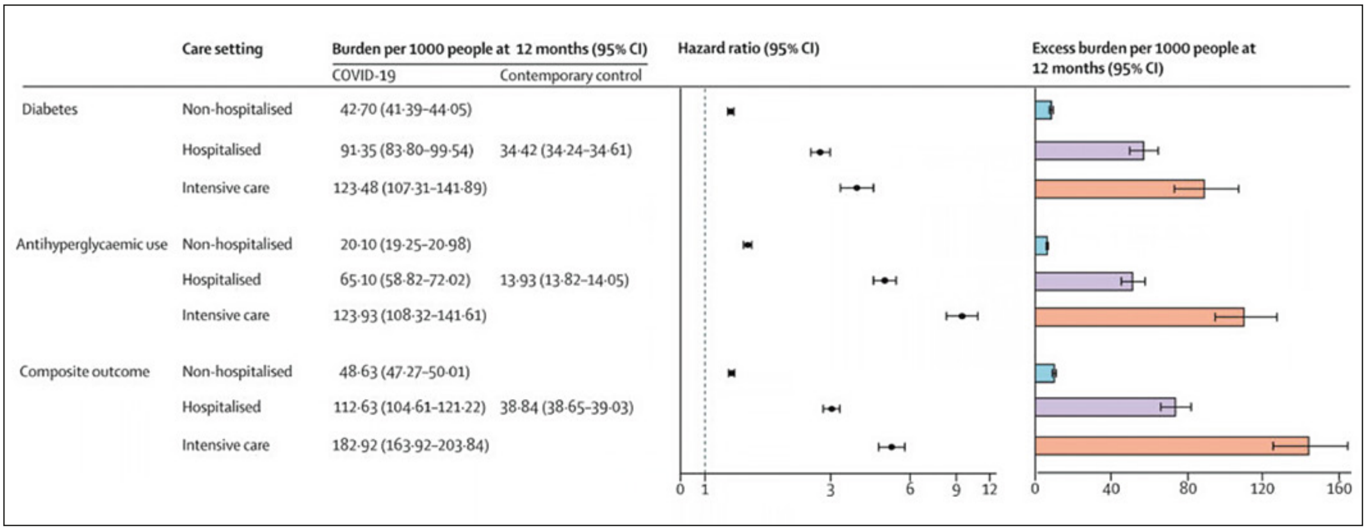
76 Long-term cardiovascular outcomes of COVID-19 | Nature Medicine.

77 RRisks and burdens of incident diabetes in long COVID: a cohort study in the Lancet, March 21, 2022 https://www.thelancet.com/journals/landia/article/PIIS2213-8587(22)00044-4/fulltext.

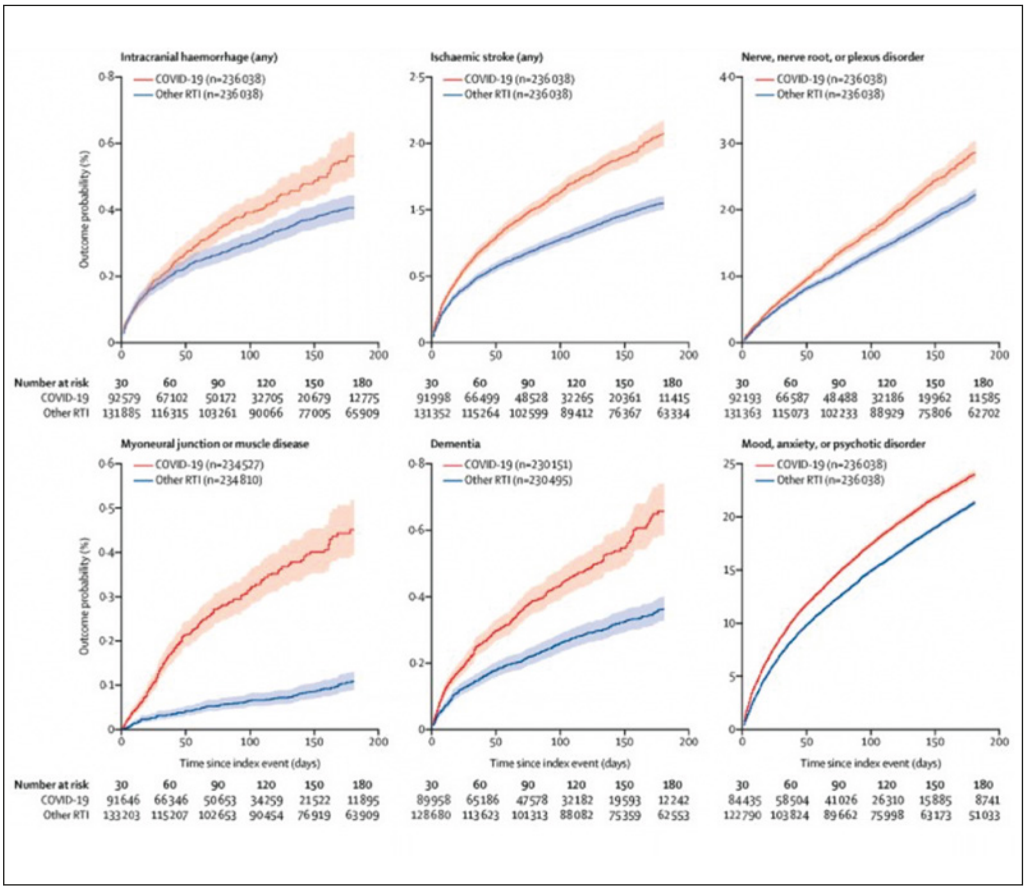
Figure 39 – Relative prevalence of post-COVID-19 diabetes, by severity of COVID-19 – US military veterans



Brain health

Finally, a 2021 US study in the Lancet Psychiatry journal[78] looks at the impact of COVID-19 on brain health in the six months following a COVID-19 diagnosis. They used health care records from various different health care organisations, comparing those diagnosed with COVID-19 with those diagnosed with flu or another respiratory disease.

Figure 40 – Comparison of prevalence of subsequent diagnoses of various conditions following COVID-19 and other respiratory diseases



78 6-month neurological and psychiatric outcomes in 236 379 survivors of COVID-19: a retrospective cohort study using electronic health records – The Lancet Psychiatry.

Most diagnostic categories were more common in patients who had COVID-19 than in those who had influenza (hazard ratio [HR] 1·44, 95% CI 1·40–1·47). Hazard Ratios were higher in patients who had more severe COVID-19 (e.g. those admitted to ICU compared with those who were not: 1·58, 1·50–1·67, for any diagnosis). The study concluded:

Our study provides evidence for substantial neurological and psychiatric morbidity in the 6 months after COVID-19 infection. Risks were greatest in, but not limited to, patients who had severe COVID-19. This information could help in service planning and identification of research priorities. Complementary study designs, including prospective cohorts, are needed to corroborate and explain these findings.

Other diseases/organs

It seems that studies that look at a particular subset of specific conditions generally find more long-term damage in those who have recovered from COVID-19, compared with those who have not, with worse COVID-19 illnesses generally leading to a more probable long-term outcome from almost any organ studied. As the medical profession continues to study post COVID-19 outcomes, it seems likely that further forms of long-term complications will be discovered.

3.2.5 In conclusion

In general, what we do seem to know about Long COVID is that:

- the chances of Long COVID are higher if the initial COVID-19 illness was worse – all the organ studies show this;
- Long COVID affects people of working age more than children and older people – as suggested by the UK study;
- women seem to be affected worse than men – most studies show this outcome;
- vaccination reduces the chances of long COVID – a wide variety of study outcomes, but settling on 50%;
- a wide variety of organs can be affected long term by an initial illness of COVID-19 – any study on an individual organ seems to show some effects;
- Long COVID outcomes have a wide range, from ongoing mild symptoms to serious limitations on day-to-day activity – there are over 200 symptoms identified; and
- overall, there is a non-trivial chance of being seriously disabled for a prolonged period by Long COVID for those who contract COVID-19 – at a population level, at least 0.4% of the UK population have identified this outcome, and the proportion of COVID-19 cases with a medium-term serious disability is likely to be higher than this.

Long COVID outcomes have a wide range, from ongoing mild symptoms to serious limitations on day-to-day activity.

3.2.6 Implications for Australia

Given low prevalence in 2020 and the first half of 2021, we haven't really seen deaths or long-term illness from Long COVID yet (the latest ABS statistics show that 42 of the 4876 deaths from COVID-19 are due to Long COVID[79]) – COVID-19 deaths have predominantly been from the acute stage of the illness.

By mid-April 2022, there have been over 20 notified cases of COVID-19 per 100 people in Australia. While there are now many people who have been infected more than once, this is likely to be an underestimate of the proportion of the population who have been infected to date. Around 90% of these people were infected in 2022, so it is too early to see truly long-term outcomes for these

79 The ABS *Australian COVID-19 Mortality* released 20 April 2022.

people. The vast majority of those cases were in vaccinated people, which reduces but does not eliminate the risk of Long COVID.

We can look to other countries to consider the implications for our population, our health care system, and our insurance sector. In the UK, 1 in 200 people now have serious limitations on daily activity from the long-term aftermath of a COVID-19 infection, and another 1 in 80 people have some limitations on daily activity. If that proportion occurred in Australia, that would be over 100,000 extra people compared with pre-COVID-19 with a serious disability, and another 300,000 with activity limiting disabilities. Australia's Long COVID cases are likely to be fewer, because more infections in Australia occurred post vaccination, and so far, there have been fewer notified infections, however, they will be significant. That will lead to:

- the need for better health care for long term illness – e.g. investment in more health care workers, Long COVID clinics, and other supports in the health care system;
- a requirement for income support to be available for those who are unable to work, or who have reduced ability to work, due to Long COVID outcomes;
- a requirement for support to be available in the workplace to enable workers with some activity limitations to continue working while suffering Long COVID symptoms; and
- higher insurance claims (and thus, perhaps, higher premiums) for all disability-related insurance – including income protection, workers compensation and Group Total and Permanent Disability (TPD).

There will be long-term implications for healthcare, income support, workplace support and insurance.'

Appendix A – COVID-19 and excess deaths in 37 countries

Table 8 – COVID-19 & excess deaths in 37 countries – 2020 & 2021 combined

Table 8 contains the data used in Figure 1 and Figure 3. It should be read in conjunction with descriptions of the data, methodology and caveats in Section 1.

Region	Country	Code	Covid-19 Deaths	Excess Deaths	Expected Deaths	Covid-19 %	Other Excess%	Total Excess%
Average	**37 Countries**	**AVE**	**102,222**	**153,874**	**905,745**	**11.3%**	**5.7%**	**17.0%**
Oceania	**Australia**	AUS	2,256	(10,824)	338,392	0.7%	-3.9%	-3.2%
Oceania	**New Zealand**	NZL	51	(2,797)	70,762	0.1%	-4.0%	-4.0%
SE & EAsia	**Japan**	JPN	18,389	(13,110)	2,849,943	0.6%	-1.1%	-0.5%
SE & EAsia	**Singapore**	SGP	828	1,767	44,507	1.9%	2.1%	4.0%
SE & EAsia	**South Korea**	KOR	5,625	7,551	618,247	0.9%	0.3%	1.2%
SE & EAsia	**Taiwan**	TWN	850	(3,423)	360,311	0.2%	-1.2%	-0.9%
SE & EAsia	**Thailand**	THA	21,700	63,124	1,001,964	2.2%	4.1%	6.3%
W Europe	**Belgium**	BEL	28,448	20,676	219,960	12.9%	-3.5%	9.4%
W Europe	**France**	FRA	124,192	79,467	1,226,338	10.1%	-3.6%	6.5%
W Europe	**Germany**	DEU	111,933	88,726	1,929,435	5.8%	-1.2%	4.6%
W Europe	**Netherlands**	NLD	21,022	28,574	312,721	6.7%	2.4%	9.1%
N Europe	**Denmark**	DNK	3,213	915	111,592	2.9%	-2.1%	0.8%
N Europe	**Latvia**	LVA	4,570	7,001	56,486	8.1%	4.3%	12.4%
N Europe	**Sweden**	SWE	15,566	9,958	181,203	8.6%	-3.1%	5.5%
N Europe	**United Kingdom**	GBR	148,737	137,044	1,225,323	12.1%	-1.0%	11.2%
S Europe	**Greece**	GRC	20,790	24,263	252,289	8.2%	1.4%	9.6%
S Europe	**Italy**	ITA	137,433	168,308	1,294,678	10.6%	2.4%	13.0%
S Europe	**Portugal**	PRT	18,955	20,770	229,505	8.3%	0.8%	9.1%
S Europe	**Spain**	ESP	90,146	103,319	849,262	10.6%	1.6%	12.2%
E Europe	**Czechia**	CZE	36,159	41,605	229,047	15.8%	2.4%	18.2%
E Europe	**Hungary**	HUN	39,186	35,949	262,291	14.9%	-1.2%	13.7%
E Europe	**Poland**	POL	97,054	157,846	846,422	11.5%	7.2%	18.6%
E Europe	**Romania**	ROU	58,752	108,448	526,007	11.2%	9.4%	20.6%
E Europe	**Russia**	RUS	302,671	1,080,774	3,503,321	8.6%	22.2%	30.9%
E Europe	**Ukraine**	UKR	102,088	178,931	1,152,167	8.9%	6.7%	15.5%
N America	**Mexico**	MEX	292,367	607,746	1,545,809	18.9%	20.4%	39.3%
N America	**United States**	USA	827,887	970,288	5,915,357	14.0%	2.4%	16.4%
S America	**Brazil**	BRA	619,334	698,574	2,745,967	22.6%	2.9%	25.4%
S America	**Chile**	CHL	39,328	38,997	225,546	17.4%	-0.1%	17.3%
S America	**Colombia**	COL	129,942	163,589	502,775	25.8%	6.7%	32.5%
S America	**Peru**	PER	203,399	217,626	259,052	78.5%	5.5%	84.0%
Other Asia	**Azerbaijan**	AZE	8,358	39,827	112,698	7.4%	27.9%	35.3%
Other Asia	**Iran**	IRN	131,606	251,859	788,784	16.7%	15.2%	31.9%
Other Asia	**Israel**	ISR	8,251	7,232	92,903	8.9%	-1.1%	7.8%
Other Asia	**Kazakhstan**	KAZ	18,492	80,696	265,274	7.0%	23.4%	30.4%
Other Asia	**Uzbekistan**	UZB	1,485	35,722	314,455	0.5%	10.9%	11.4%
Africa	**South Africa**	ZAF	91,145	246,337	1,051,757	8.7%	14.8%	23.4%

Table 9 – Excess and net excess mortality in 37 countries – 2020 v 2021

Table 9 contains data used in Figure 2 and Figure 4.

Region	Country	Code	Expected 2020	Expected 2021	Excess 2020	Excess 2021	Net Excess 2020	Net Excess 2021
Average	**37 Countries**	**AVE**	**454,450**	**451,294**	**13.6%**	**20.4%**	**5.2%**	**6.3%**
Oceania	**Australia**	AUS	169,627	168,765	-5.1%	-1.3%-	-5.7%	-2.1%
Oceania	**New Zealand**	NZL	35,391	35,371	-6.2%	-1.7%	-6.3%	-1.8%
SE & E Asia	**Japan**	JPN	1,412,512	1,437,431	-2.0%	1.0%-	-2.2%	0.0%
SE & E Asia	**Singapore**	SGP	22,032	22,475	0.1%	7.8%	0.0%	4.2%
SE & E Asia	**South Korea**	KOR	309,306	308,941	0.1%	2.4%	-0.2%	0.8%
SE & E Asia	**Taiwan**	TWN	178,899	181,412	-3.2%	1.3%	-3.2%	0.8%
SE & E Asia	**Thailand**	THA	498,051	503,913	0.7%	11.9%	0.7%	7.6%
N & W Europe	**Belgium**	BEL	111,093	108,867	15.6%	3.1%	-2.1%	-5.0%
N & W Europe	**France**	FRA	617,150	609,189	7.6%	5.3%	-2.9%	-4.4%
N & W Europe	**Germany**	DEU	972,727	956,707	2.9%	6.3%	0.5%	-2.0%
N & W Europe	**Netherlands**	NLD	157,462	155,260	8.8%	9.5%	1.5%	3.4%
N & W Europe	**Denmark**	DNK	56,133	55,459	-1.2%	2.8%	-3.5%	-0.6%
N & W Europe	**Latvia**	LVA	28,652	27,834	2.3%	22.8%	0.1%	8.6%
N & W Europe	**Sweden**	SWE	91,828	89,376	8.5%	2.4%	-1.3%	-5.0%
N & W Europe	**United Kingdom**	GBR	617,192	608,131	12.9%	9.5%	1.0%	-2.9%
S & E Europe	**Greece**	GRC	126,912	125,377	4.8%	14.5%	1.0%	1.8%
S & E Europe	**Italy**	ITA	654,935	639,743	15.6%	10.4%	4.2%	0.5%
S & E Europe	**Portugal**	PRT	115,780	113,724	8.6%	9.5%	2.6%	-1.1%
S & E Europe	**Spain**	ESP	428,311	420,951	16.4%	7.8%	4.4%	-1.3%
S & E Europe	**Czechia**	CZE	115,656	113,392	13.7%	22.7%	3.7%	1.0%
S & E Europe	**Hungary**	HUN	132,685	129,606	7.9%	19.6%	0.8%	-3.3%
S & E Europe	**Poland**	POL	425,281	421,141	14.2%	23.2%-	7.5%	6.9%-
S & E Europe	**Romania**	ROU	266,204	259,803	13.2%	28.2%	7.3%	11.6%
S & E Europe	**Russia**	RUS	1,765,821	1,737,499	21.1%	40.7%-	17.9%	26.6%-
S & E Europe	**Ukraine**	UKR	577,291	574,876	6.9%	24.2%	3.5%	9.8%
N America	**Mexico**	MEX	775,179	770,630	39.6%	39.1%	23.7%	17.1%
N America	**United States**	USA	2,974,092	2,941,266	15.6%	17.2%	3.8%	1.0%
S America	**Brazil**	BRA	1,364,075	1,381,892	16.0%	34.8%	1.6%	4.1%
S America	**Chile**	CHL	112,823	112,723	13.0%	21.6%-	-1.7%	1.5%-
S America	**Colombia**	COL	251,592	251,183	21.7%	43.4%	4.5%	8.9%
S America	**Peru**	PER	126,709	132,343	80.6%	87.2%	7.2%	3.9%-
Other Asia	**Azerbaijan**	AZE	56,449	56,249	34.0%	36.7%	29.3%	26.5%
Other Asia	**Iran**	IRN	395,093	393,691	29.3%	34.6%	15.3%	15.2%
Other Asia	**Israel**	ISR	46,773	46,130	5.9%	9.7%	-1.2%	-1.0%
Other Asia	**Kazakhstan**	KAZ	132,475	132,799	22.8%	38.1%	20.7%	26.2%
Other Asia	**Uzbekistan**	UZB	156,959	157,496	11.9%	10.8%-	11.5%	10.3%-
Africa South	**Africa**	ZAF	535,511	516,246	10.5%	36.8%	5.2%	24.7%

The countries in these tables and the associated figures were selected on the following basis:

First, we identified the 84 countries in the OWID database for which relevant data was available for all of 2020 and 2021.

Of these, we selected the 30 with the highest expected deaths, on the basis that these would give the greatest global coverage and relevance and the least spurious variation. These countries included Australia (20th on the list).

Then, we identified a further seven countries with special relevance. These were (in declining order of expected deaths):

- Sweden (33), because it adopted a COVID-19 strategy that differed greatly from the other Nordic nations;
- Azerbaijan (38), because of its very high mortality in late 2020;

- Denmark (39), because it represents the Nordic nations other than Sweden;
- Israel (44), because it was a leader in vaccine take-up;
- New Zealand (49), for direct comparison to Australia;
- Latvia (55), because it is representative of the Baltic states; and
- Singapore (58), because it always seemed to be a point of comparison for Australia, at least early in the pandemic.

Appendix B – Scaling of doctor-certified deaths

Table 10 shows the scaling factors applied to weekly doctor-certified deaths for each year 2015 to 2020. Note we have used the same definition of 'a year' as the ABS, namely ISO years. As such, 2015 and 2020 include exactly 53 weeks whereas the other years include exactly 52 weeks.

Table 10 – Population and other adjustments applied to actual deaths

Gender	Males					Females					
Yr/Ages	0-44	45-64	65-74	75-84	>85	0-44	45-64	65-74	75-84	>85	Total
Reported doctor certified deaths											
2015	1,706	8,889	12,741	20,854	24,162	1,501	6,482	8,562	17,229	37,276	139,402
2016	1,578	8,700	13,149	20,967	24,595	1,443	6,296	8,574	16,762	36,684	138,748
2017	1,617	8,688	13,660	21,528	25,841	1,460	6,383	9,124	17,387	38,101	143,789
2018	1,546	8,594	13,492	21,005	25,231	1,368	6,438	8,932	16,717	36,164	139,487
2019	1,615	8,771	13,582	21,808	26,025	1,385	6,356	9,357	17,314	37,595	143,808
2020	1,503	8,773	14,001	22,169	26,229	1,319	6,508	9,400	17,555	36,661	144,118
2021	1,568	8,466	13,976	23,361	27,636	1,321	6,294	9,732	18,301	38,542	149,197
Population (m)											
2015	7.29	2.88	0.99	0.50	0.17	7.12	2.97	1.02	0.58	0.30	23.82
2016	7.38	2.91	1.03	0.51	0.18	7.21	3.02	1.06	0.60	0.30	24.19
2017	7.48	2.95	1.06	0.53	0.19	7.31	3.07	1.09	0.61	0.31	24.60
2018	7.58	2.98	1.09	0.55	0.19	7.40	3.11	1.13	0.63	0.31	24.98
2019	7.68	3.01	1.12	0.58	0.20	7.49	3.14	1.17	0.66	0.32	25.37
2020	7.72	3.05	1.15	0.61	0.20	7.54	3.19	1.21	0.69	0.32	25.69
2021	7.82	3.09	1.16	0.62	0.21	7.64	3.23	1.23	0.70	0.33	26.03
Population adjusted deaths											
2015	1,829	9,537	14,998	26,014	29,109	1,611	7,041	10,355	20,718	41,278	152,333
2016	1,673	9,226	14,928	25,399	28,414	1,529	6,724	9,976	19,721	39,768	149,268
2017	1,691	9,088	15,052	25,051	28,913	1,526	6,709	10,254	19,821	40,712	152,108
2018	1,596	8,897	14,426	23,532	27,405	1,412	6,688	9,684	18,487	38,078	145,308
2019	1,646	8,986	14,183	23,299	27,347	1,412	6,530	9,836	18,371	38,901	147,547
2020	1,522	8,886	14,182	22,455	26,568	1,336	6,592	9,521	17,782	37,134	145,979
2021	1,568	8,466	13,976	23,361	27,636	1,321	6,294	9,732	18,301	38,542	149,197
Age Mix adjustments											
2015	100.3%	102.4%	103.7%	100.6%	106.6%	100.0%	102.8%	103.3%	100.0%	107.7%	111.0%
2016	100.8%	102.5%	103.6%	100.9%	105.8%	100.7%	102.9%	103.3%	100.5%	106.9%	109.5%
2017	101.3%	102.6%	102.8%	101.1%	105.1%	101.4%	103.0%	102.6%	100.9%	105.8%	108.0%
2018	101.7%	102.6%	102.3%	101.3%	104.3%	101.9%	102.9%	102.2%	101.0%	104.9%	106.5%
2019	102.0%	102.4%	102.1%	101.5%	103.6%	102.1%	102.7%	102.1%	101.3%	104.0%	104.8%
2020	102.0%	102.2%	102.1%	101.8%	102.8%	102.1%	102.4%	102.1%	101.7%	103.0%	102.4%
2021	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Age mix adjusted deaths											
2015	1,835	9,768	15,552	26,160	31,042	1,611	7,236	10,695	20,720	44,439	169,059
2016	1,687	9,460	15,466	25,621	30,072	1,540	6,919	10,309	19,827	42,497	163,396
2017	1,713	9,326	15,474	25,337	30,396	1,547	6,908	10,519	19,990	43,092	164,297
2018	1,623	9,128	14,758	23,829	28,580	1,438	6,882	9,895	18,675	39,947	154,756
2019	1,678	9,205	14,486	23,659	28,334	1,442	6,705	10,041	18,614	40,475	154,638
2020	1,553	9,084	14,476	22,855	27,315	1,364	6,747	9,717	18,079	38,259	149,446
2021	1,568	8,466	13,976	23,361	27,636	1,321	6,294	9,732	18,301	38,542	149,197
Delayed reporting allowance											
2020	1	6	10	15	18	1	5	7	12	26	104
2021	12	69	112	190	223	10	so	78	148	311	1,203
Total scaled deaths											
2015	1,835	9,769	15,552	26,160	31,040	1,611	7,236	10,695	20,720	44,439	169,059
2016	1,687	9,460	15,467	25,621	30,071	1,540	6,919	10,309	19,827	42,497	163,399
2017	1,713	9,327	15,474	25,337	30,394	1,547	6,908	10,520	19,990	43,091	164,301
2018	1,623	9,128	14,759	23,829	28,580	1,438	6,883	9,895	18,675	39,947	154,756
2019	1,678	9,205	14,486	23,659	28,334	1,442	6,706	10,041	18,614	40,474	154,638
2020	1,554	9,090	14,486	22,871	27,333	1,365	6,752	9,724	18,091	38,285	149,550
2021	1,580	8,535	14,088	23,551	27,859	1,331	6,344	9,810	18,449	38,853	150,400

Table 11 shows the calculation of the age mix adjustments applied to each cause, and in total.

Table 11 – Calculation of age mix adjustments

Age band	Population by Year (m) 2015	2016	2017	2018	2019	2020	Deaths by Year 2015	2016	2017	2018	2019	2020	Death rate 2015-2020	Proportion of Population within Each Age Band 2015	2016	2017	2018	2019	2020
0-4	1.553	1.574	1.579	1.572	1.568	1.552	1,201	1,161	1,209	1,146	1,192	1,104	0.07%	6.5%	6.5%	6.4%	6.3%	6.2%	6.0%
5-9	1.536	1.567	1.587	1.605	1.619	1.628	132	113	123	102	118	86	0.01%	6.5%	6.5%	6.5%	6.4%	6.4%	6.3%
10-14	1.411	1.432	1.473	1.516	1.556	1.596	147	133	140	136	146	139	0.01%	5.9%	5.9%	6.0%	6.1%	6.1%	6.2%
15-19	1.470	1.475	1.483	1.491	1.499	1.491	476	410	443	457	482	476	0.03%	6.2%	6.1%	6.0%	6.0%	5.9%	5.8%
20-24	1.676	1.694	1.719	1.740	1.750	1.711	678	728	679	677	834	730	0.04%	7.0%	7.0%	7.0%	7.0%	6.9%	6.7%
25-29	1.786	1.814	1.849	1.877	1.907	1.906	853	866	842	797	985	919	0.05%	7.5%	7.5%	7.5%	7.5%	7.5%	7.4%
30-34	1.752	1.794	1.833	1.863	1.893	1.923	1,106	1,135	1,089	1,043	1,148	1,121	0.06%	7.4%	7.4%	7.5%	7.5%	7.5%	7.5%
35-39	1.573	1.607	1.661	1.723	1.782	1.835	1,423	1,372	1,395	1,459	1,541	1,460	0.08%	6.6%	6.6%	6.8%	6.9%	7.0%	7.1%
40-44	1.655	1.627	1.604	1.594	1.596	1.620	2,138	2,070	1,958	1,822	2,062	1,812	0.12%	6.9%	6.7%	6.5%	6.4%	6.3%	6.3%
45-49	1.562	1.605	1.649	1.672	1.680	1.677	2,933	2,858	2,980	2,864	3,227	2,896	0.18%	6.6%	6.6%	6.7%	6.7%	6.6%	6.5%
50-54	1.560	1.548	1.536	1.529	1.536	1.564	4,381	4,174	4,008	3,979	4,104	3,975	0.27%	6.5%	6.4%	6.2%	6.1%	6.1%	6.1%
55-59	1.446	1.476	1.506	1.529	1.548	1.556	5,978	5,948	5,865	6,021	6,333	5,894	0.40%	6.1%	6.1%	6.1%	6.1%	6.1%	6.1%
60-64	1.282	1.305	1.332	1.359	1.392	1.437	7,923	7,839	7,806	8,075	8,742	8,190	0.60%	5.4%	5.4%	5.4%	5.4%	5.5%	5.6%
65-69	1.156	1.193	1.193	1.207	1.228	1.259	11,030	10,964	11,007	10,774	11,304	10,602	0.91%	4.9%	4.9%	4.9%	4.8%	4.8%	4.9%
70-74	0.850	0.890	0.958	1.017	1.058	1.105	13,482	13,753	14,535	14,837	15,772	15,523	1.50%	3.6%	3.7%	3.9%	4.1%	4.2%	4.3%
75-79	0.631	0.651	0.677	0.700	0.734	0.774	17,614	17,622	18,017	17,754	18,955	18,488	2.60%	2.6%	2.7%	2.8%	2.8%	2.9%	3.0%
80-84	0.448	0.455	0.469	0.486	0.505	0.529	23,359	23,166	23,029	22,688	24,206	23,413	4.84%	1.9%	1.9%	1.9%	1.9%	2.0%	2.1%
85-89	0.301	0.305	0.308	0.310	0.314	0.318	29,773	29,166	29,184	27,860	28,873	26,840	9.25%	1.3%	1.3%	1.3%	1.2%	1.2%	1.2%
90-94	0.135	0.140	0.145	0.149	0.153	0.159	23,813	23,974	24,683	24,265	25,978	24,621	16.74%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%
95-99	0.030	0.034	0.037	0.040	0.043	0.046	8,874	9,232	9,954	9,939	11,401	11,054	26.41%	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%
100+	0.004	0.004	0.004	0.004	0.005	0.006	1,736	1,816	1,958	1,797	1,897	1,950	41.67%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	23.816	24.191	24.602	24.983	25.366	25.693	159,050	158,500	160,904	158,492	169,300	161,293	0.65%						
Age standardised death rate														0.627%	0.635%	0.644%	0.653%	0.664%	0.679%
Age mix adjustment															1.38%	1.34%	1.42%	1.62%	2.37%

Table 12 shows the calculation of the age mix adjustments applied to the male age bands, while Table 13 shows the same information for females.

Table 12 – Calculation of age mix adjustments for male age bands

Age band	Population by Year (m) 2015	2016	2017	2018	2019	2020	Deaths by Year 2015	2016	2017	2018	2019	2020	Death Rate 2015-2020	Proportion of Population within Each Age Band 2015	2016	2017	2018	2019	2020
0-4	0.797	0.808	0.811	0.808	0.807	0.798	662	654	665	660	682	597	0.08%	10.9%	11.0%	10.8%	10.7%	10.5%	10.3%
5-9	0.789	0.804	0.814	0.823	0.830	0.836	75	69	66	51	72	55	0.01%	10.8%	10.9%	10.9%	10.9%	10.8%	10.8%
10-14	0.725	0.735	0.757	0.779	0.799	0.819	80	80	87	80	77	78	0.01%	9.9%	10.0%	10.1%	10.3%	10.4%	10.6%
15-19	0.752	0.756	0.760	0.765	0.771	0.767	311	283	291	304	342	329	0.04%	10.3%	10.2%	10.2%	10.1%	10.0%	9.9%
20-24	0.856	0.865	0.879	0.890	0.899	0.879	506	531	506	510	604	549	0.06%	11.7%	11.7%	11.7%	11.7%	11.7%	11.4%
25-29	0.896	0.908	0.925	0.940	0.958	0.961	612	596	601	580	702	660	0.07%	12.3%	12.3%	12.4%	12.4%	12.5%	12.4%
30-34	0.875	0.892	0.909	0.921	0.934	0.948	774	740	748	724	795	751	0.08%	12.0%	12.1%	12.1%	12.2%	12.2%	12.3%
35-39	0.785	0.802	0.828	0.858	0.885	0.909	907	895	919	966	1,018	940	0.11%	10.8%	10.9%	11.1%	11.3%	11.5%	11.8%
40-44	0.819	0.808	0.798	0.793	0.794	0.805	1,366	1,291	1,246	1,125	1,309	1,164	0.16%	11.2%	10.9%	10.7%	10.5%	10.3%	10.4%
Sub-total	**7.294**	**7.377**	**7.480**	**7.578**	**7.676**	**7.722**	**5,293**	**5,139**	**5,129**	**5,000**	**5,601**	**5,123**	**0.07%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Age standardised death rate														0.070%	0.070%	0.069%	0.069%	0.069%	0.069%
Age mix adjustment															-0.34%	-0.32%	-0.22%	-0.09%	0.16%
45-49	0.768	0.786	0.807	0.820	0.826	0.826	1,812	1,749	1,856	1,763	2,057	1,807	0.23%	26.7%	27.0%	27.4%	27.5%	27.4%	27.1%
50-54	0.770	0.763	0.755	0.750	0.751	0.763	2,691	2,561	2,398	2,391	2,561	2,444	0.33%	26.8%	26.2%	25.6%	25.2%	24.9%	25.0%
55-59	0.710	0.724	0.739	0.750	0.758	0.760	3,712	3,660	3,603	3,689	3,921	3,677	0.50%	24.7%	24.9%	25.0%	25.2%	25.2%	24.9%
60-64	0.628	0.638	0.649	0.661	0.677	0.697	4,925	4,872	4,834	4,955	5,452	5,033	0.76%	21.9%	21.9%	22.0%	22.2%	22.5%	22.9%
Sub-total	**2.876**	**2.910**	**2.950**	**2.981**	**3.012**	**3.046**	**13,140**	**12,842**	**12,691**	**12,798**	**13,991**	**12,961**	**0.44%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Age standardised death rate														0.440%	0.440%	0.440%	0.441%	0.442%	0.444%
Age mix adjustment															0.06%	0.08%	0.19%	0.31%	0.38%
65-69	0.573	0.589	0.587	0.590	0.596	0.609	6,834	6,764	6,768	6,612	6,954	6,518	1.14%	57.9%	57.4%	55.5%	54.1%	53.5%	53.0%
70-74	0.416	0.437	0.470	0.500	0.519	0.541	8,158	8,411	8,793	9,009	9,437	9,424	1.85%	42.1%	42.6%	44.5%	45.9%	46.5%	47.0%
Sub-total	**0.990**	**1.026**	**1.057**	**1.089**	**1.115**	**1.150**	**14,992**	**15,175**	**15,561**	**15,621**	**16,391**	**15,942**	**1.46%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Age standardised death rate														0.885%	0.886%	0.894%	0.899%	0.902%	0.904%
Age mix adjustment															0.11%	0.90%	0.56%	0.24%	0.21%
75-79	0.298	0.308	0.322	0.334	0.351	0.371	10,135	10,252	10,440	10,262	11,015	10,870	3.17%	60.1%	60.3%	60.5%	60.4%	60.6%	60.7%
80-84	0.198	0.203	0.210	0.218	0.228	0.240	12,399	12,513	12,340	12,330	13,151	12,692	5.82%	39.9%	39.7%	39.5%	39.6%	39.4%	39.3%
Sub-total	**0.496**	**0.511**	**0.532**	**0.552**	**0.579**	**0.611**	**22,534**	**22,765**	**22,780**	**22,592**	**24,166**	**23,562**	**4.22%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Age standardised death rate														4.229%	4.223%	4.218%	4.220%	4.215%	4.213%
Age mix adjustment															-0.15%	-0.11%	0.05%	-0.12%	-0.06%
85-89	0.119	0.122	0.125	0.126	0.129	0.132	13,883	13,878	13,879	13,457	13,946	13,063	10.89%	69.4%	68.3%	67.4%	66.3%	65.6%	64.5%
90-94	0.044	0.047	0.049	0.052	0.054	0.057	8,670	9,000	9,514	9,532	10,372	10,065	18.87%	25.5%	26.1%	26.5%	27.2%	27.4%	28.0%
95-99	0.008	0.009	0.010	0.011	0.012	0.013	2,477	2,678	2,920	2,947	3,514	3,446	27.84%	4.7%	5.1%	5.6%	5.9%	6.3%	6.5%
100+	0.001	0.001	0.001	0.001	0.001	0.002	340	387	381	372	364	420	32.99%	0.4%	0.4%	0.5%	0.6%	0.7%	0.9%
Sub-total	**0.172**	**0.179**	**0.185**	**0.191**	**0.197**	**0.204**	**25,370**	**25,943**	**26,694**	**26,308**	**28,196**	**26,994**	**14.14%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Age standardised death rate														13.811%	13.938%	14.055%	14.191%	14.306%	14.443%
Age mix adjustment															0.93%	0.83%	0.97%	0.81%	0.96%
Total	**11.828**	**12.003**	**12.204**	**12.391**	**12.579**	**12.733**	**81,329**	**81,864**	**82,855**	**82,319**	**88,345**	**84,582**	**0.68%**						

Table 13 – Calculation of age mix adjustments for female age bands

Age band	Population by Year (m)						Deaths by Year						Death Rate	Proportion of Population within Each Age Band					
	2015	2016	2017	2018	2019	2020	2015	2016	2017	2018	2019	2020	2015-2020	2015	2016	2017	2018	2019	2020
0-4	0.756	0.766	0.768	0.764	0.762	0.754	539	507	544	486	510	507	0.07%	10.6%	10.6%	10.5%	10.3%	10.2%	10.0%
5-9	0.748	0.763	0.773	0.781	0.788	0.793	57	44	57	51	46	31	0.01%	10.5%	10.6%	10.6%	10.6%	10.5%	10.5%
10-14	0.686	0.696	0.716	0.737	0.757	0.777	67	53	53	56	69	61	0.01%	9.6%	9.7%	9.8%	10.0%	10.1%	10.3%
15-19	0.717	0.720	0.723	0.726	0.728	0.724	165	127	152	153	140	147	0.02%	10.1%	10.0%	9.9%	9.8%	9.7%	9.6%
20-24	0.820	0.829	0.841	0.849	0.851	0.832	172	197	173	167	230	181	0.02%	11.5%	11.5%	11.5%	11.5%	11.4%	11.0%
25-29	0.890	0.907	0.924	0.937	0.949	0.946	241	270	241	217	283	259	0.03%	12.5%	12.6%	12.6%	12.7%	12.7%	12.5%
30-34	0.877	0.902	0.924	0.942	0.959	0.975	332	395	341	319	353	370	0.04%	12.3%	12.5%	12.6%	12.7%	12.8%	12.9%
35-39	0.788	0.806	0.833	0.865	0.897	0.926	516	477	476	493	523	520	0.06%	11.1%	11.2%	11.4%	11.7%	12.0%	12.3%
40-44	0.836	0.819	0.806	0.801	0.803	0.815	772	779	712	697	753	648	0.09%	11.7%	11.4%	11.0%	10.8%	10.7%	10.8%
Sub-total	**7.118**	**7.207**	**7.308**	**7.402**	**7.494**	**7.541**	**2,861**	**2,849**	**2,749**	**2,639**	**2,907**	**2,724**	**0.04%**	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Age standardised death rate														0.038%	0.038%	0.038%	0.038%	0.038%	0.038%
Age mix adjustment															-0.50%	-0.49%	-0.33%	-0.12%	0.24%
45-49	0.794	0.819	0.841	0.852	0.854	0.851	1,121	1,109	1,124	1,101	1,170	1,089	0.13%	26.7%	27.1%	27.4%	27.4%	27.2%	26.7%
50-54	0.790	0.786	0.781	0.779	0.785	0.801	1,690	1,613	1,610	1,588	1,543	1,531	0.20%	26.6%	26.0%	25.4%	25.1%	25.0%	25.1%
55-59	0.735	0.752	0.768	0.779	0.790	0.796	2,266	2,288	2,262	2,332	2,412	2,217	0.30%	24.7%	24.9%	25.0%	25.1%	25.1%	25.0%
60-64	0.654	0.667	0.683	0.698	0.715	0.740	2,998	2,967	2,972	3,120	3,290	3,157	0.45%	22.0%	22.1%	22.2%	22.4%	22.7%	23.2%
Sub-total	**2.973**	**3.024**	**3.073**	**3.109**	**3.144**	**3.189**	**8,075**	**7,977**	**7,968**	**8,141**	**8,415**	**7,994**	**0.26%**	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Age standardised death rate														0.261%	0.261%	0.262%	0.262%	0.263%	0.264%
Age mix adjustment															0.02%	0.11%	0.23%	0.36%	0.51%
65-69	0.583	0.604	0.607	0.617	0.631	0.650	4,196	4,200	4,239	4,162	4,350	4,084	0.68%	57.3%	57.1%	55.4%	54.4%	53.9%	53.5%
70-74	0.434	0.453	0.488	0.518	0.539	0.565	5,324	5,342	5,742	5,828	6,335	6,099	1.16%	42.7%	42.9%	44.6%	45.6%	46.1%	46.5%
Sub-total	**1.017**	**1.057**	**1.095**	**1.135**	**1.170**	**1.214**	**9,520**	**9,542**	**9,981**	**9,990**	**10,685**	**10,183**	**0.90%**	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Age standardised death rate														0.885%	0.886%	0.894%	0.899%	0.902%	0.904%
Age mix adjustment															0.11%	0.90%	0.56%	0.24%	0.21%
75-79	0.332	0.343	0.355	0.366	0.383	0.403	7,479	7,370	7,577	7,492	7,940	7,618	2.08%	57.0%	57.6%	57.8%	57.8%	58.0%	58.3%
80-84	0.250	0.253	0.259	0.267	0.277	0.289	10,960	10,653	10,689	10,358	11,055	10,721	4.04%	43.0%	42.4%	42.2%	42.2%	42.0%	41.7%
Sub-total	**0.583**	**0.596**	**0.615**	**0.634**	**0.660**	**0.692**	**18,439**	**18,023**	**18,266**	**17,850**	**18,995**	**18,339**	**2.91%**	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Age standardised death rate														2.923%	2.912%	2.908%	2.908%	2.904%	2.899%
Age mix adjustment															-0.37%	-0.15%	0.01%	-0.15%	-0.16%
85-89	0.182	0.183	0.183	0.183	0.185	0.186	15,890	15,288	15,305	14,403	14,927	13,777	8.13%	61.1%	60.3%	59.4%	58.7%	58.1%	57.4%
90-94	0.091	0.093	0.095	0.097	0.099	0.102	15,143	14,974	15,169	14,733	15,606	14,556	15.62%	30.5%	30.7%	31.0%	31.2%	31.1%	31.3%
95-99	0.022	0.024	0.027	0.028	0.031	0.032	6,397	6,554	7,034	6,992	7,887	7,608	25.85%	7.4%	8.0%	8.6%	9.1%	9.6%	10.0%
100+	0.003	0.003	0.003	0.003	0.004	0.004	1,396	1,429	1,577	1,425	1,533	1,530	44.66%	1.0%	0.9%	1.0%	1.0%	1.1%	1.3%
Sub-total	**0.297**	**0.303**	**0.308**	**0.312**	**0.318**	**0.325**	**38,826**	**38,245**	**39,085**	**37,553**	**39,953**	**37,471**	**12.40%**	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Age standardised death rate														12.083%	12.193%	12.330%	12.461%	12.584%	12.731%
Age mix adjustment															0.91%	1.12%	1.06%	0.98%	1.17%
Total	**11.988**	**12.188**	**12.398**	**12.592**	**12.786**	**12.960**	**77,721**	**76,636**	**78,049**	**76,173**	**80,955**	**76,711**	**0.62%**						

Table 14 shows the adjustments made for late reported deaths for 2021.

Table 14 – Adjustments for late-reported deaths

Week ending	Registered deaths	Late Reporting	Percent Loading	Adopted deaths
2021 (to 22 Aug)	94,488	560	0.6%	95,048
29-Aug-21	3,024	22	0.7%	3,046
05-Sep-21	3,081	20	0.6%	3,101
12-Sep-21	2,965	25	0.8%	2,990
19-Sep-21	3,061	25	0.8%	3,086
26-Sep-21	2,942	24	0.8%	2,966
03-Oct-21	3,050	22	0.7%	3,072
10-Oct-21	2,957	27	0.9%	2,984
17-Oct-21	2,907	26	0.9%	2,933
24-Oct-21	2,944	29	1.0%	2,973
31-Oct-21	2,852	26	0.9%	2,878
07-Nov-21	2,861	30	1.0%	2,891
14-Nov-21	2,683	33	1.2%	2,716
21-Nov-21	2,788	39	1.4%	2,827
28-Nov-21	2,791	36	1.3%	2,827
05-Dec-21	2,793	38	1.3%	2,831
12-Dec-21	2,725	48	1.7%	2,773
19-Dec-21	2,777	52	1.9%	2,829
26-Dec-21	2,824	55	2.0%	2,879
02-Jan-22	2,685	66	2.5%	2,751

Appendix C – Predicting deaths using a linear model

C.1 Simple linear regression

The weekly expected number of deaths for each cause of death (10 causes) and each age/gender combination (10 combinations), plus all causes combined is determined by simple linear regression. The linear model is fitted to the weekly deaths data (after scaling adjustments) from the first week of 2015 to the last week of 2019. We then use the estimated parameters to predict the expected number of deaths from the first week of 2020 onwards.

The explanatory variable in the regression is a time index that takes the value based on both year and week as shown in Table 15[80]. The response variable in the regression is the standardised death count where seasonality has been removed from the series.

Table 15 - The value of time index in the simple linear regression

Year	Week	Time index
2015	1	1
2015	2	2
2015	53	53
2016	1	54
2016	52	105
2017	1	106

C.2 Standardisation and smoothing

The standardised death counts are obtained by subtracting the means from the original series and then dividing by the smoothed standard deviations.

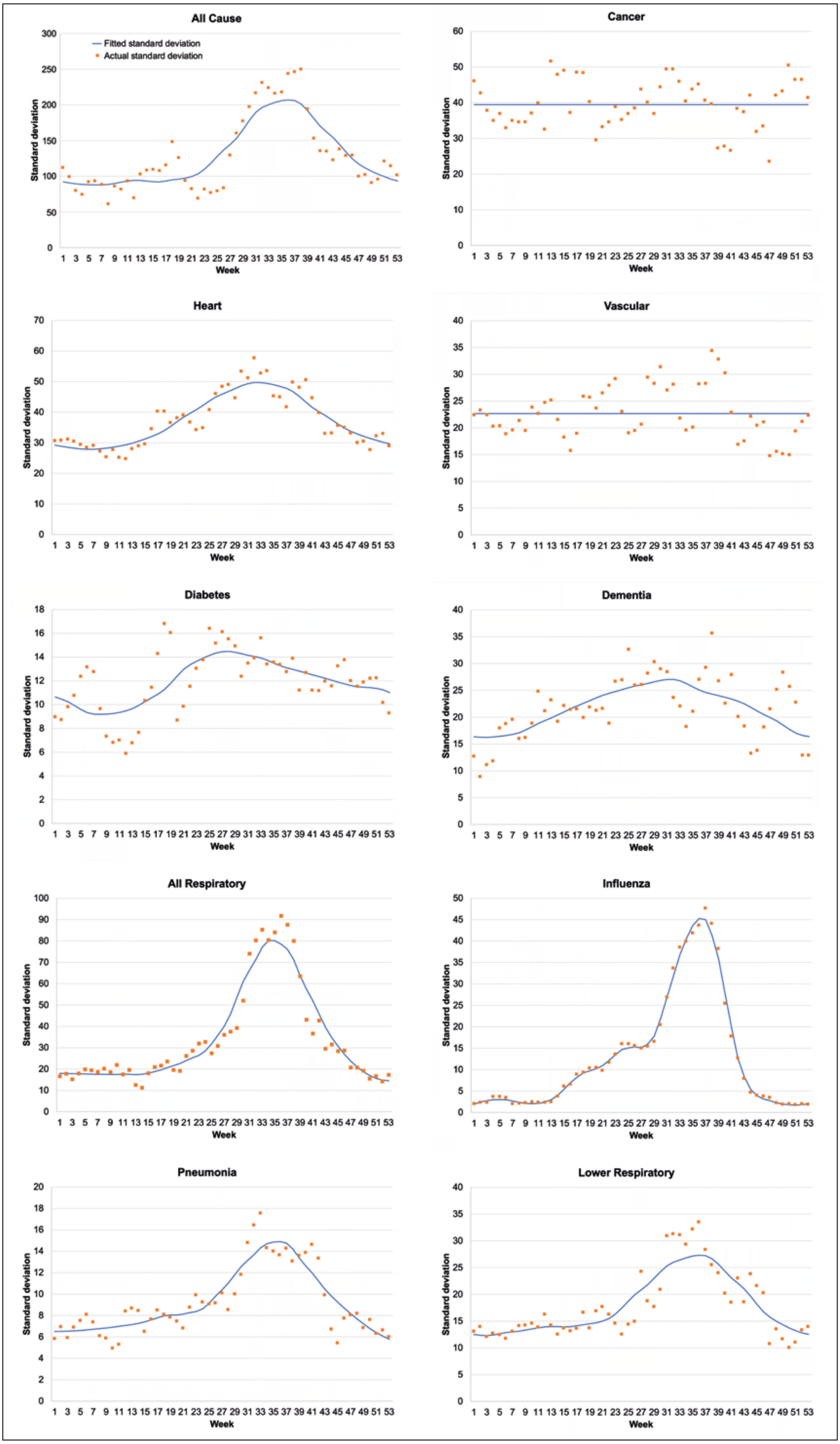
The mean (standard deviation) in Week x is calculated by taking the average (sample standard deviation) of deaths in Weeks $x - 1$, x, and $x + 1$ between 2015 and 2019. For the first week in each year, Week $x - 1$ refers to the last week of the previous year; for the last week in each year, Week $x + 1$ refers to the first week of the following year.

The standard deviation series are volatile, so we perform a local regression, namely LOESS (locally estimated scatterplot smoothing) to reduce the noise. When performing the LOESS, we also ensure a smooth transition from Week 52/53 to Week 1. For cancer and cardiovascular disease and the three age groups under age 75, the standard deviations are noisy and lack clear seasonality, so we have adopted the average over all weeks as the smoothed standard deviations.

Figure 41 shows the actual and adopted standard deviations for each cause of death, while Figure 42 shows the same information for each age/gender combination.

80 We fit a horizontal line with no time trend to the deaths due to flu because flu deaths are generally volatile, and Australia experienced a severe flu season in 2017. Fitting a linear model leads to an upward trend that predicts unrealistic figures in later years.

Figure 41 – Actual and adopted standard deviations by cause of death



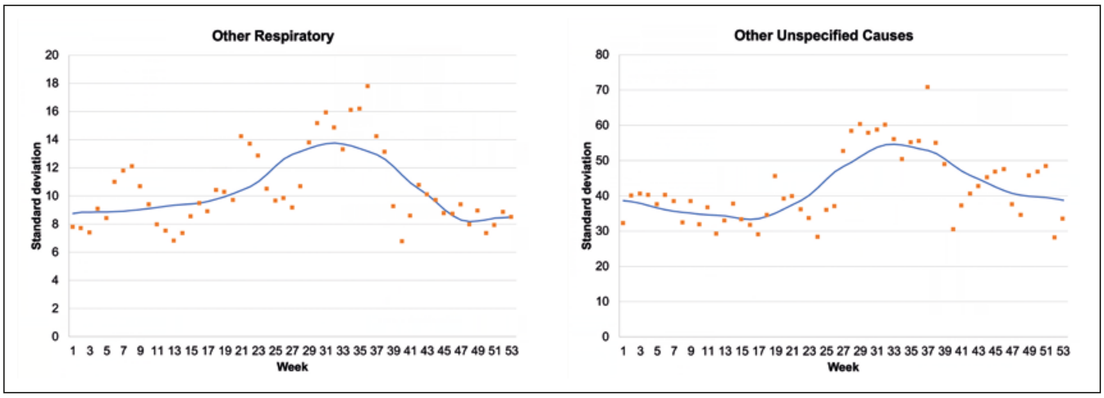
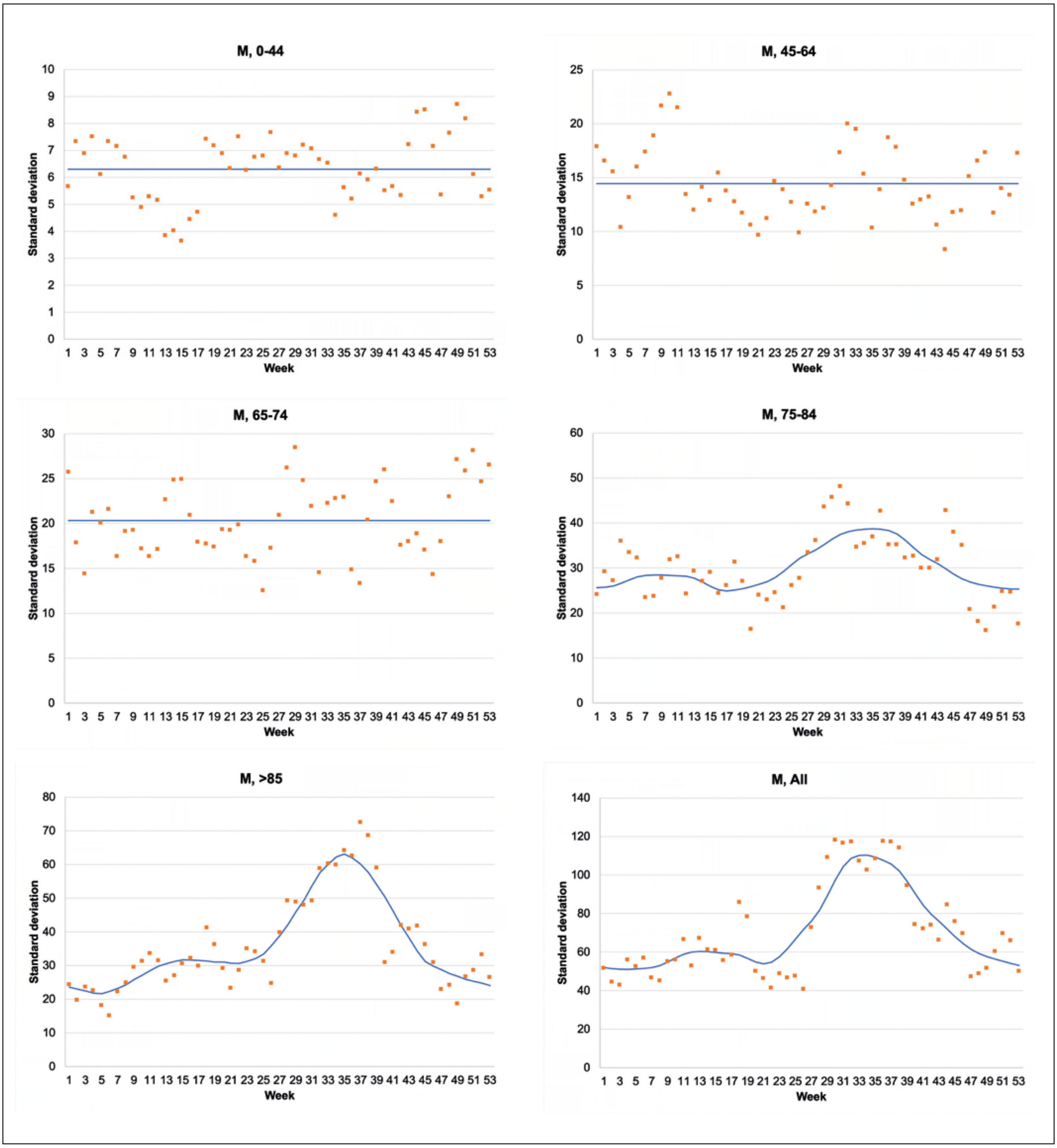
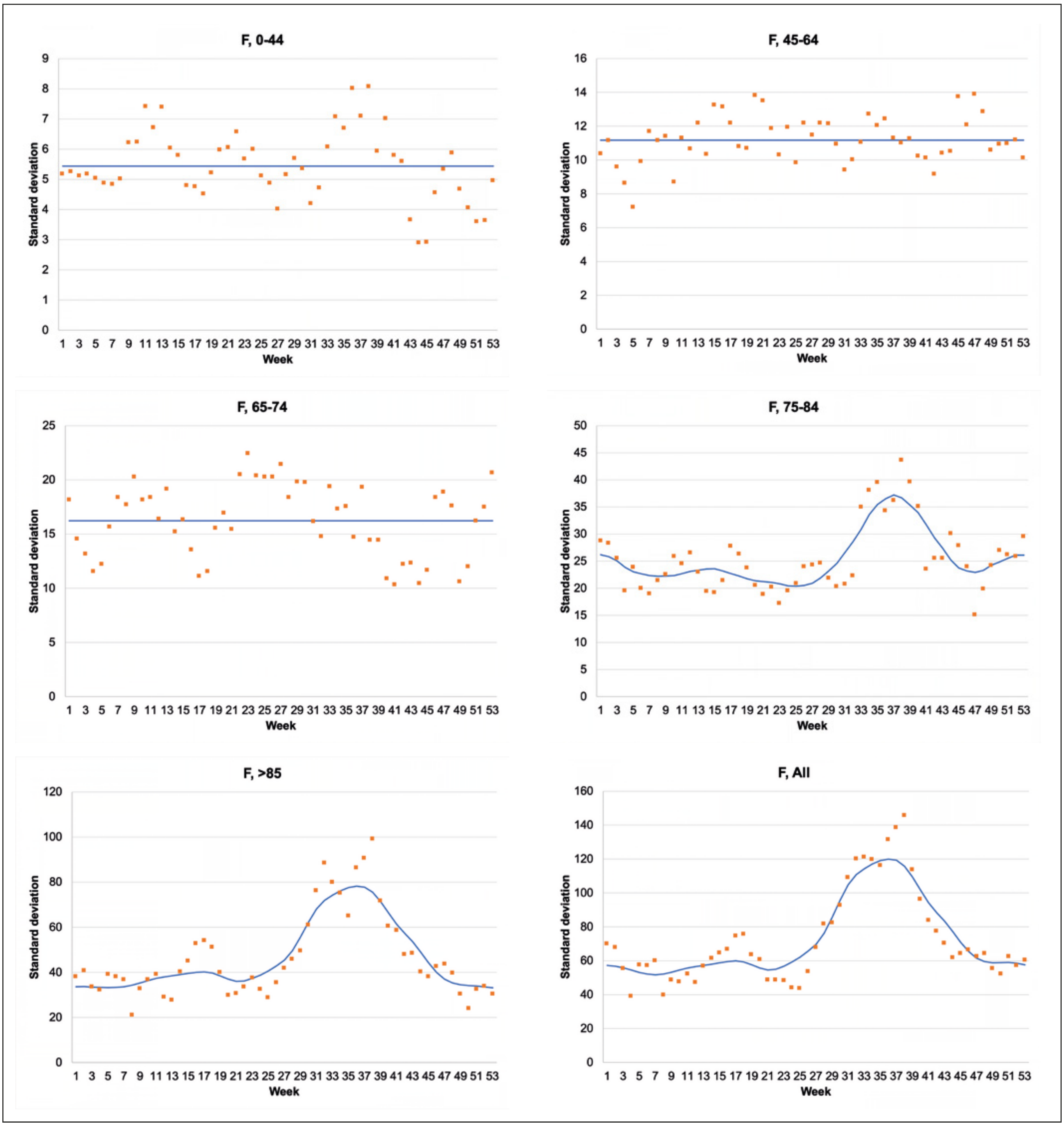


Figure 42 – Actual and adopted standard deviations by age/gender





C.3 Prediction intervals

We generate the prediction intervals for the weekly expected deaths using the simulation method. The residuals of the simple linear regression show strong serial correlation, so we fit a time series model to the residuals of each linear regression. We then simulate 100,000 paths based on the fitted time series model. Each of the 100,000 paths is then added to the weekly expected number of deaths, and the sum becomes one simulated path of weekly number of deaths. We use the 2.5% and 97.5% quantiles of the simulated weekly number of deaths as our prediction intervals. One week in 40 is expected to show deaths above this range and one week in 40 should be below the range.

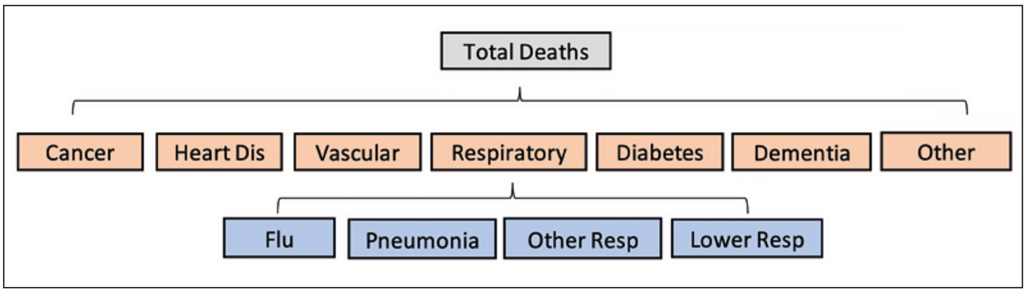
In addition to the weekly figures, we are also interested in the cumulative number of deaths in a year. The cumulative expected number of deaths is the sum of the weekly expected number of deaths. To generate the prediction intervals, we first calculate the cumulative number of deaths in each simulated path of weekly number of deaths, and then use the 2.5% and 97.5% quantiles as our prediction intervals.

C.4 Forecast reconciliation

Once predictions on death counts are generated via the linear models described in Section B, we implement a forecast reconciliation approach to ensure coherence of forecasts across different causes.[81] Forecast reconciliation is a useful tool that eliminates the discrepancy resulting from conflicting forecasts. Essentially, this technique ensures that the individual predictions for each cause and age/gender combination add up to the total. By incorporating information from all levels, reconciliation methods also improve overall forecast accuracy.

The cause-specific death counts follow a hierarchical setting illustrated in Figure 43. For each time series in the hierarchy, we model and forecast the death counts using separate models. However, it is very unlikely that these forecasts will add up in the same way as specified in the underlying hierarchy structure. Therefore, we need to reconcile these forecasts so that they fulfil certain aggregation constraints.

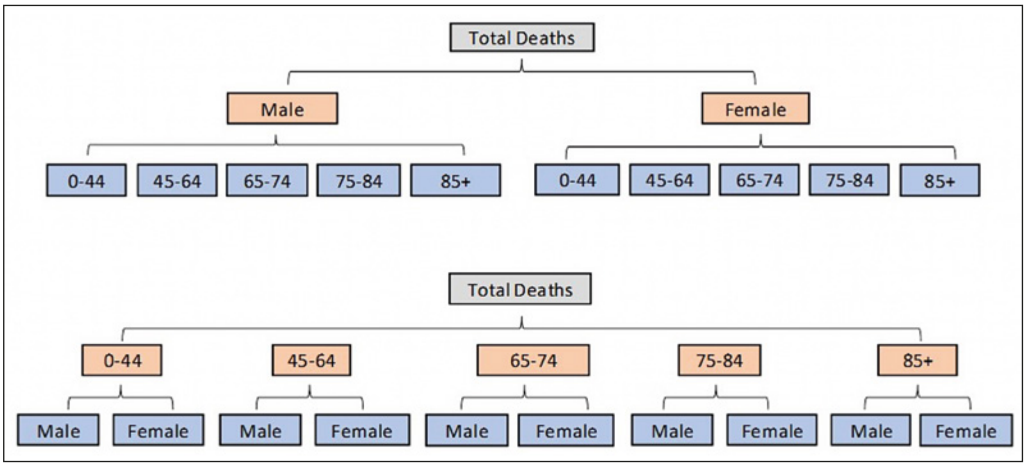
Figure 43 – Hierarchy of causes of death



For the hierarchical structure of death counts, we need to ensure that forecast of deaths from individual causes add up to forecast of total deaths. Since we further disaggregate respiratory illness into flu, pneumonia, lower respiratory diseases, and other respiratory diseases, we also need to ensure that these subclasses add up to total respiratory deaths.

For the age/gender combinations, there are two hierarchies as shown in Figure 44. We perform forecast reconciliation on the two hierarchies simultaneously.

Figure 44 – Hierarchies of age/gender



The following sets out how the forecast reconciliation process is implemented for the cause of death models. A similar process is followed for the age/gender models.Following the trace

81 For more details of this approach, please refer to:

1. Li, H., Li, H., Lu, Y., and Panagiotelis, A. (2019). A forecast reconciliation approach to cause-of-death mortality modeling. *Insurance: Mathematics and Economics*, 86, 122-133; and
2. Wickramasuriya, S. L., Athanasopoulos, G., and Hyndman, R. J. (2019). Optimal forecast reconciliation for hierarchical and grouped time series through trace minimization. *Journal of the American Statistical Association*, 114(526), 804-819.

minimization (MinT) reconciliation method proposed by Wickramasuriya et al. (2019), we define the following notation

- Let y = *(Total deaths, Respiratory, Cancer, Diabetes, Dementia, Flu, Pne, Lower Resp, Other Resp, Vascular, HeartDis, Other)* be a vector that contains observations of all series in the hierarchy.
- Let x = *(Cancer, Diabetes, Dementia, Flu, Pne, Lower Resp, Other Resp, Vascular, HeartDis ,Other)* be a vector that contains observations at the bottom level only.

We can then link these two vectors by the equation

$$y = Sx,$$

where S is a summing matrix of dimension 12 (representing all series, including the respiratory total and the overall total) ×10 (representing the bottom level only), which aggregates cause-specific death counts to the total level, and it is given by

$$S = \begin{pmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 \\ & & & & I_{10} & & & & & \end{pmatrix},$$

where I_{10} denotes a 10×10 identity matrix. The aggregation constraints in the hierarchy are reflected by the first two rows of the matrix.

Let $\hat{y}_h$ be a vector of independently obtained h-step-ahead forecasts of all series in the hierarchy, and $\hat{b}_h$ be a vector of independently obtained h-step-ahead forecasts of bottom-level series only. According to Wickramasuriya et al. (2019), the MinT reconciliation methods can be expressed as

$$\tilde{y}_h = SP\hat{y}_h.$$

$\tilde{y}_h$ is the reconciled forecasts, and P is a matrix of dimension 10×12, and it is given by

$$P=(S'W_h^{-1}S)^{-1}S'W_h^{-1},$$

where W_h is a variance-covariance matrix of the h-step-ahead in-sample forecast errors.

As proved by Wickramasuriya et al. (2019) and the references therein, the linear reconciliation produces unbiased forecasts and leads to improved overall forecast accuracy.

C.5 Limitations

Our analysis of doctor-certified deaths is based on the ABS mortality statistics up to 31 December 2021. We have made actuarial adjustments to allow for changes in population numbers and age profile and to reflect the likely emergence of more reported deaths for the period as time passes. These adjustments are quite simple. In particular:

- the same allowance for late reported deaths was applied to each cause of death and age/gender combination. Examination of late reporting by cause of death indicates that there is no discernible difference, however for some causes of death the number of deaths is small hence variable;
- we used total death rates to make the age mix adjustments (not doctor-certified deaths only). The available data on doctor-certified deaths is not supplied in granular enough age bands to allow the age mix adjustment to be carried out on these deaths only; and
- the same age mix adjustment was applied to each cause of death due to limitations in the available data.

Appendix D – Excess deaths by cause

D.1 Deaths from respiratory disease

The following figures present a breakdown of respiratory disease into influenza, pneumonia, lower respiratory disease, and other respiratory disease.

Figure 45 – Doctor-certified influenza deaths

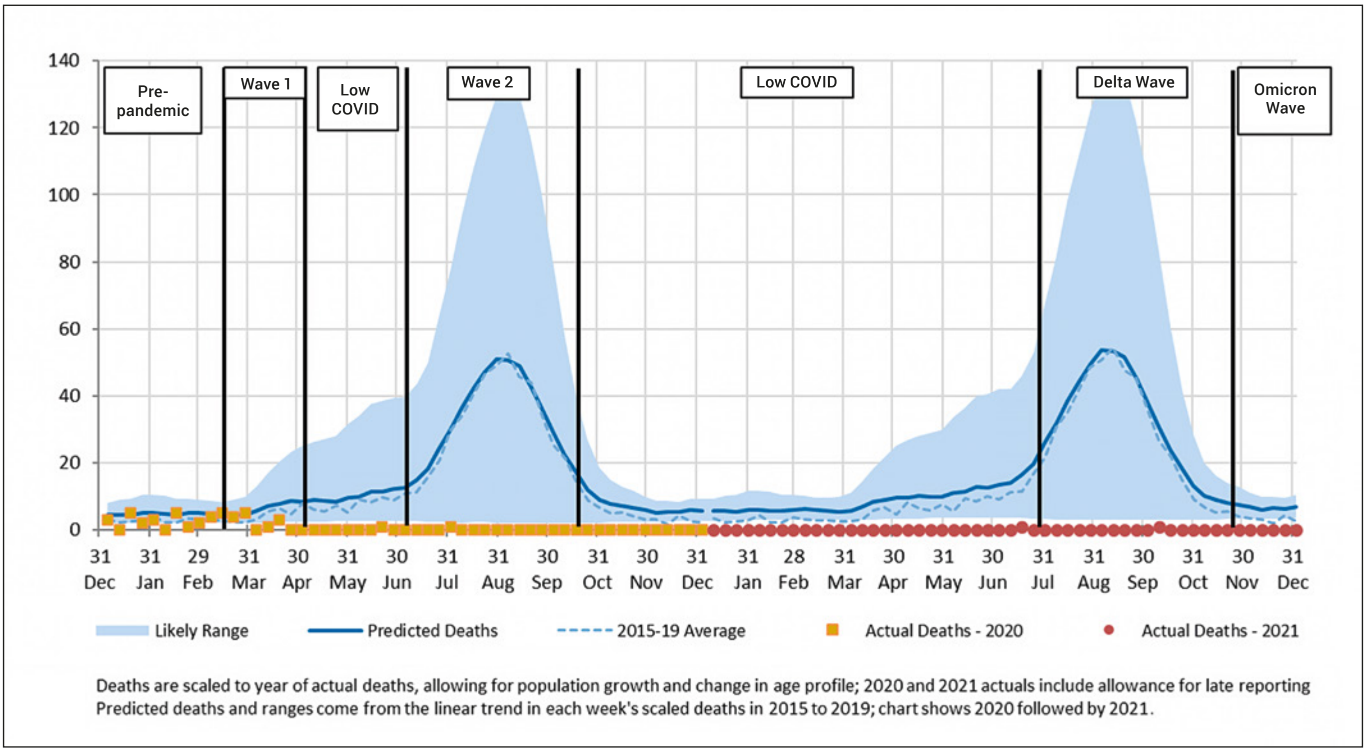
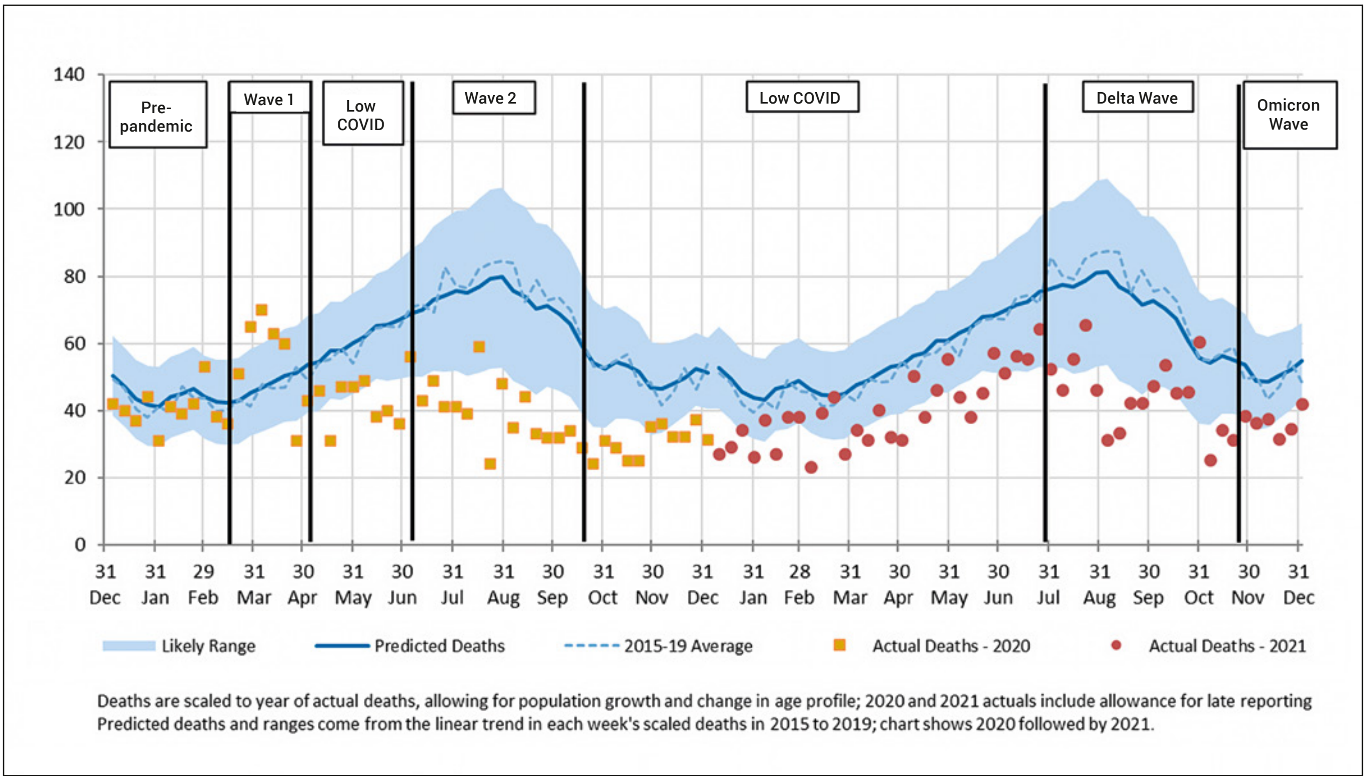
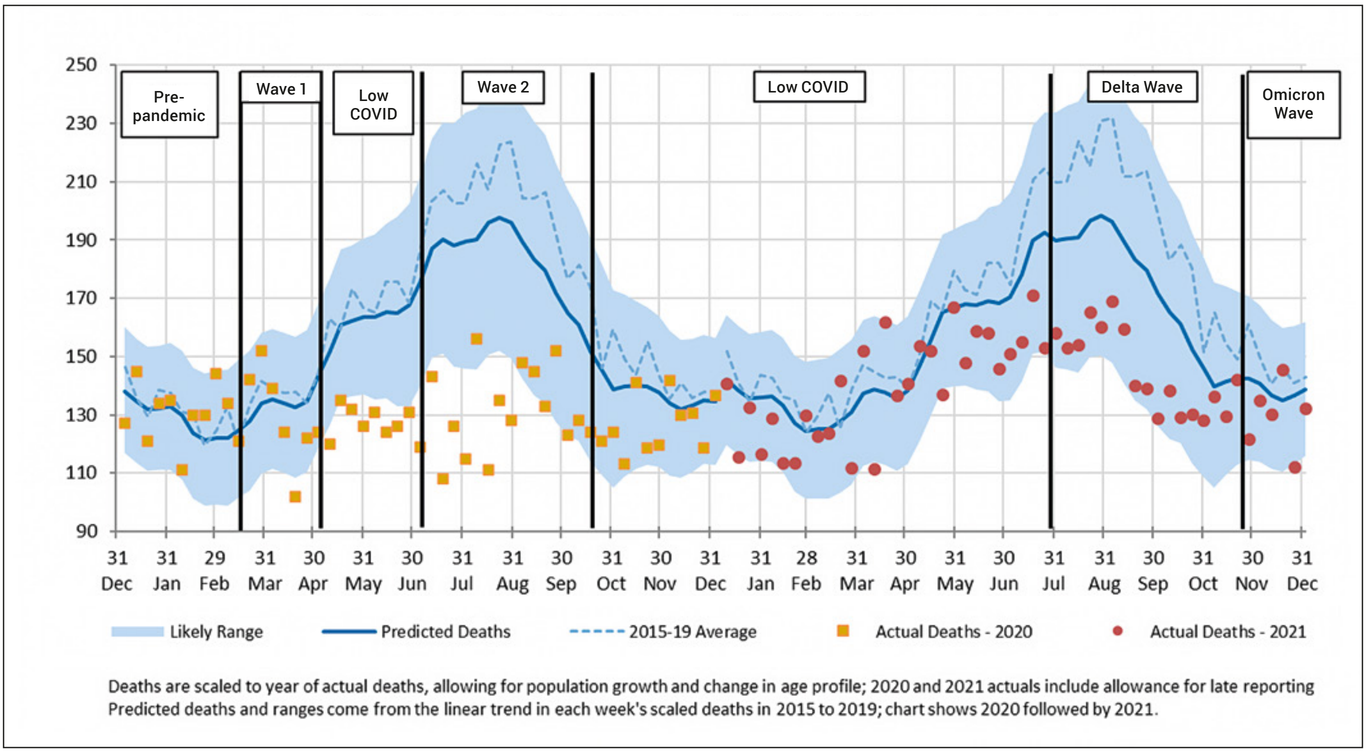


Figure 46 – Doctor-certified pneumonia deaths



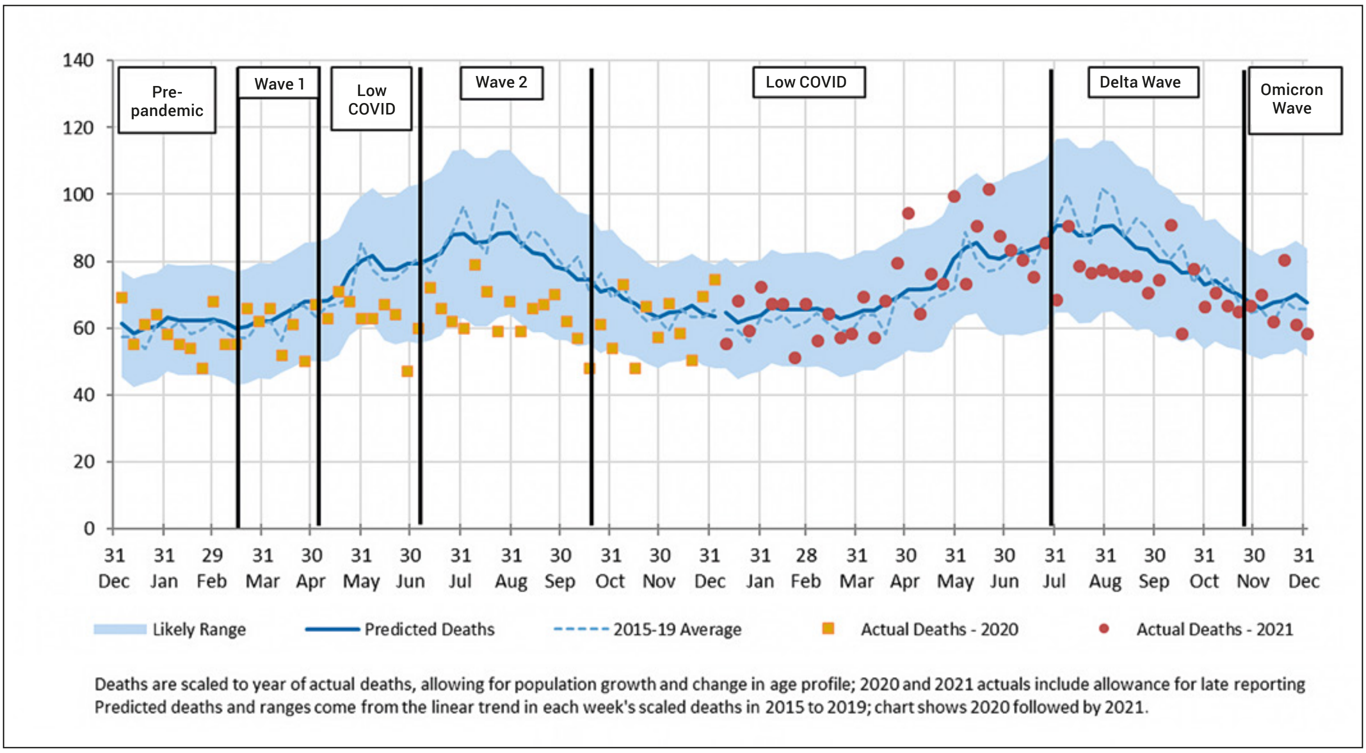
Pneumonia deaths were well below the predicted deaths throughout 2021, although the gap between actual and predicted has narrowed in 2021 compared with 2020.

Figure 47 – Doctor-certified lower respiratory disease deaths



Deaths from lower respiratory disease were much lower than predicted during the winter months of June to October 2021, but again the gap has narrowed relative to 2020.

Figure 48 – Doctor-certified deaths from other respiratory diseases

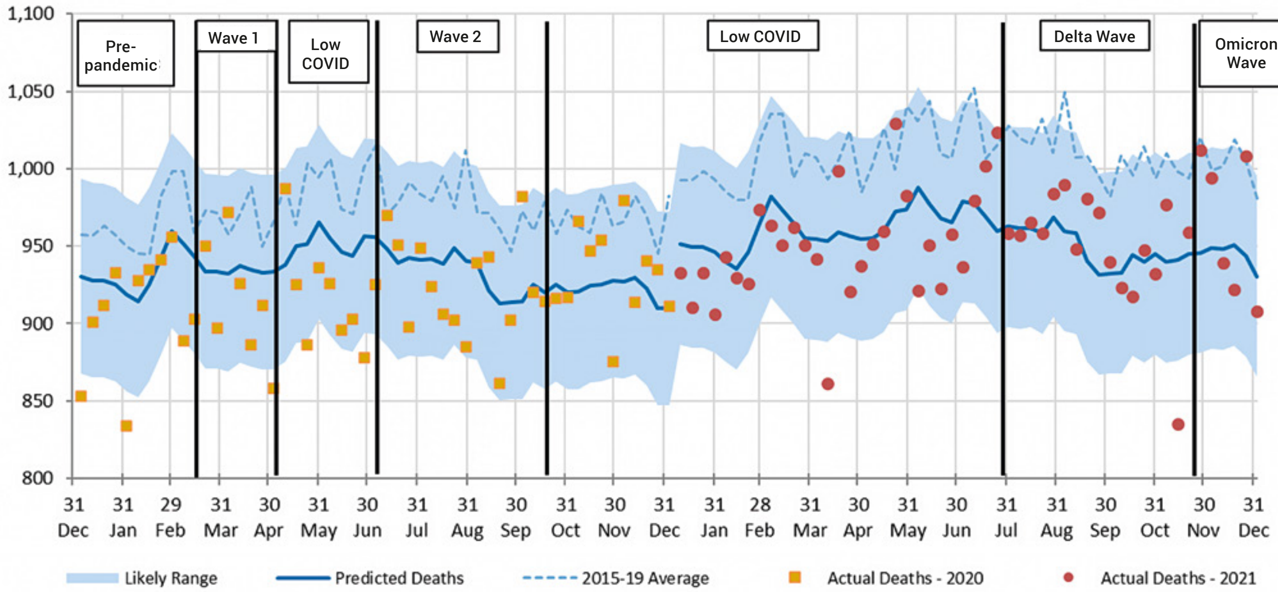


Deaths from other respiratory diseases in 2021 were close to our predictions with some highs and lows throughout the year.

D.2 Non-COVID-19 and non-respiratory deaths

The following figures show a breakdown of non-respiratory/non-COVID-19 deaths into cancer, heart disease, cerebrovascular disease, diabetes, dementia, and all other causes.

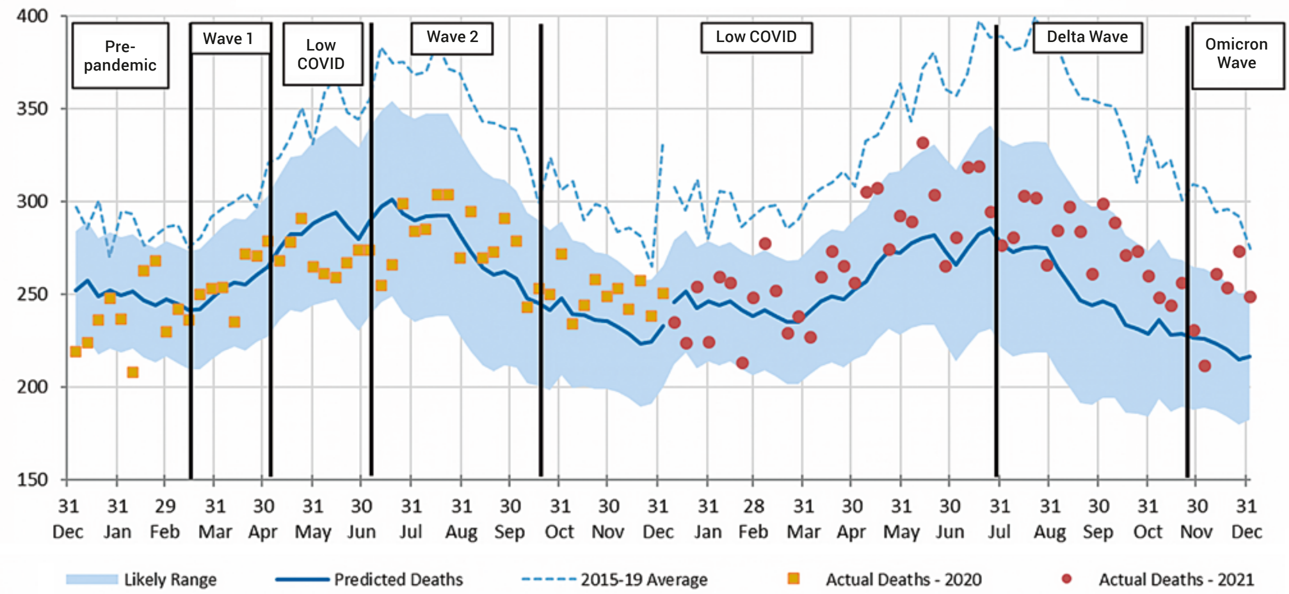
Figure 49 – Doctor-certified cancer deaths



Deaths are scaled to year of actual deaths, allowing for population growth and change in age profile; 2020 and 2021 actuals include allowance for late reporting
Predicted deaths and ranges come from the linear trend in each week's scaled deaths in 2015 to 2019; chart shows 2020 followed by 2021.

Cancer deaths continue to be close to the predicted values for most weeks. With diagnostic testing down in 2020, there were concerns that there would be a spike in cancer deaths in 2021 and beyond. While it is still early days, we are not yet seeing any evidence of this.

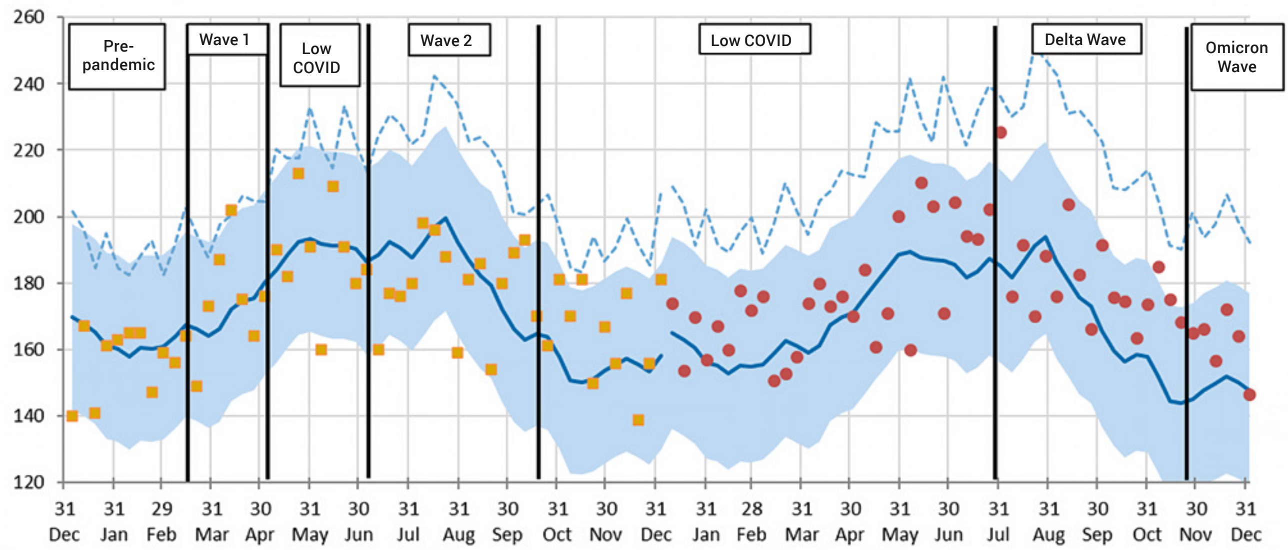
Figure 50 – Doctor-certified deaths from ischaemic heart disease (about 60-65% of all deaths from heart disease)



Deaths are scaled to year of actual deaths, allowing for population growth and change in age profile; 2020 and 2021 actuals include allowance for late reporting
Predicted deaths and ranges come from the linear trend in each week's scaled deaths in 2015 to 2019; chart shows 2020 followed by 2021.

There were very few weeks in 2021 where deaths from ischaemic heart disease were lower than predicted, and only 3 such weeks after mid-April 2021. We note that the predicted values allow for continued strong mortality improvement in 2021 in this cause.

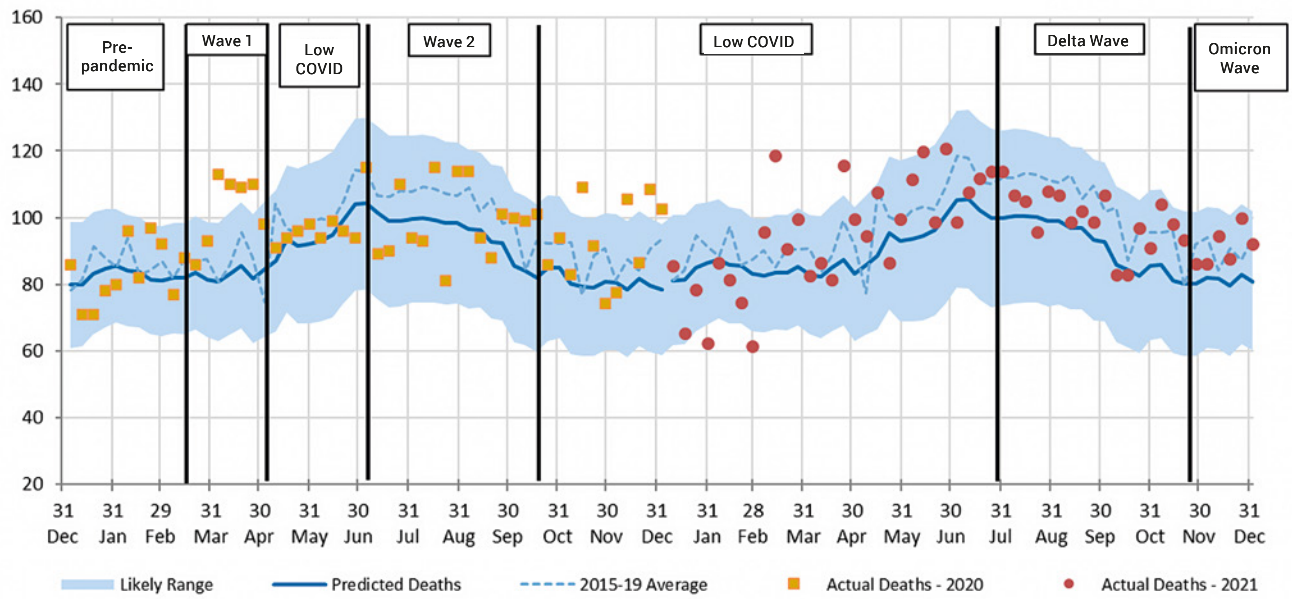
Figure 51 – Doctor-certified deaths from cerebrovascular disease (stroke, etc)



Deaths are scaled to year of actual deaths, allowing for population growth and change in age profile; 2020 and 2021 actuals include allowance for late reporting
Predicted deaths and ranges come from the linear trend in each week's scaled deaths in 2015 to 2019; chart shows 2020 followed by 2021.

For cerebrovascular disease, actual deaths are 5% higher than predicted across 2021. Most weeks are higher than predicted but are within the 97.5th percentile. Note that predicted values incorporate a continuation of strong mortality improvement.

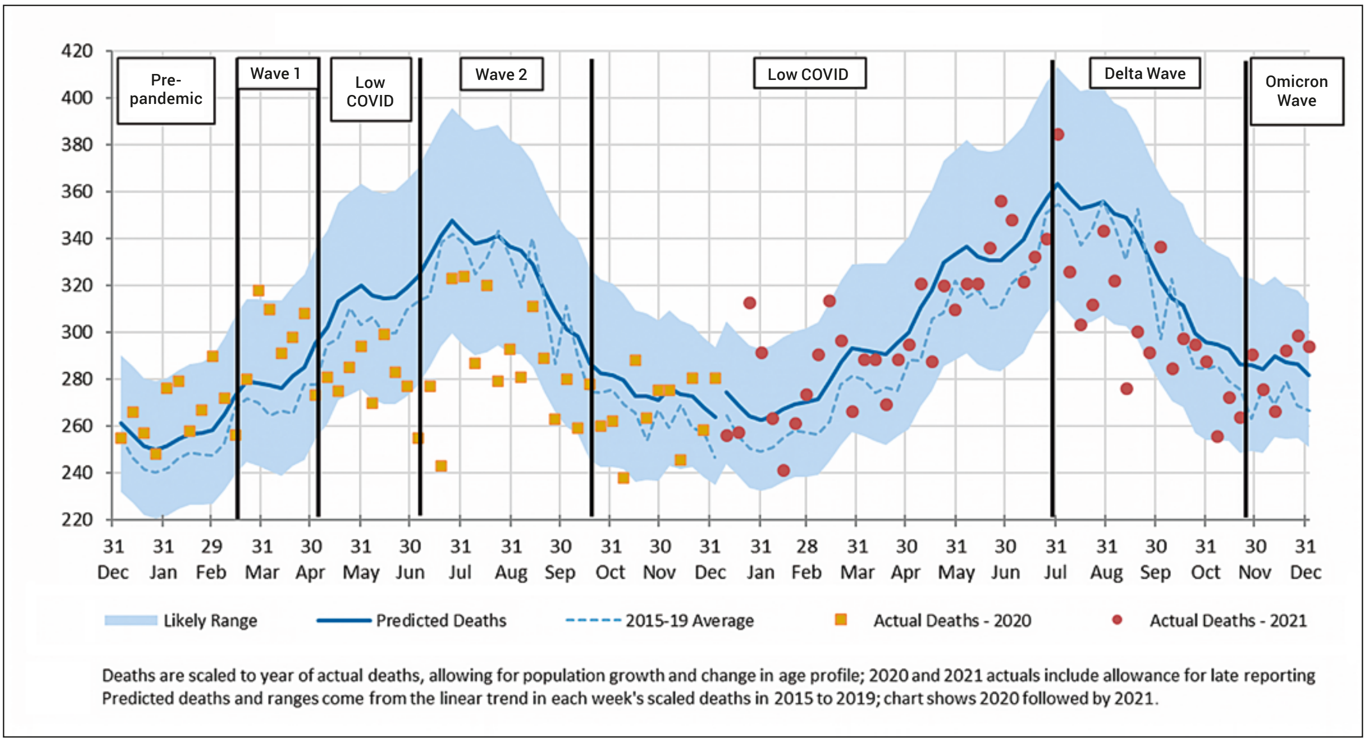
Figure 52 – Doctor-certified diabetes deaths



Deaths are scaled to year of actual deaths, allowing for population growth and change in age profile; 2020 and 2021 actuals include allowance for late reporting
Predicted deaths and ranges come from the linear trend in each week's scaled deaths in 2015 to 2019; chart shows 2020 followed by 2021.

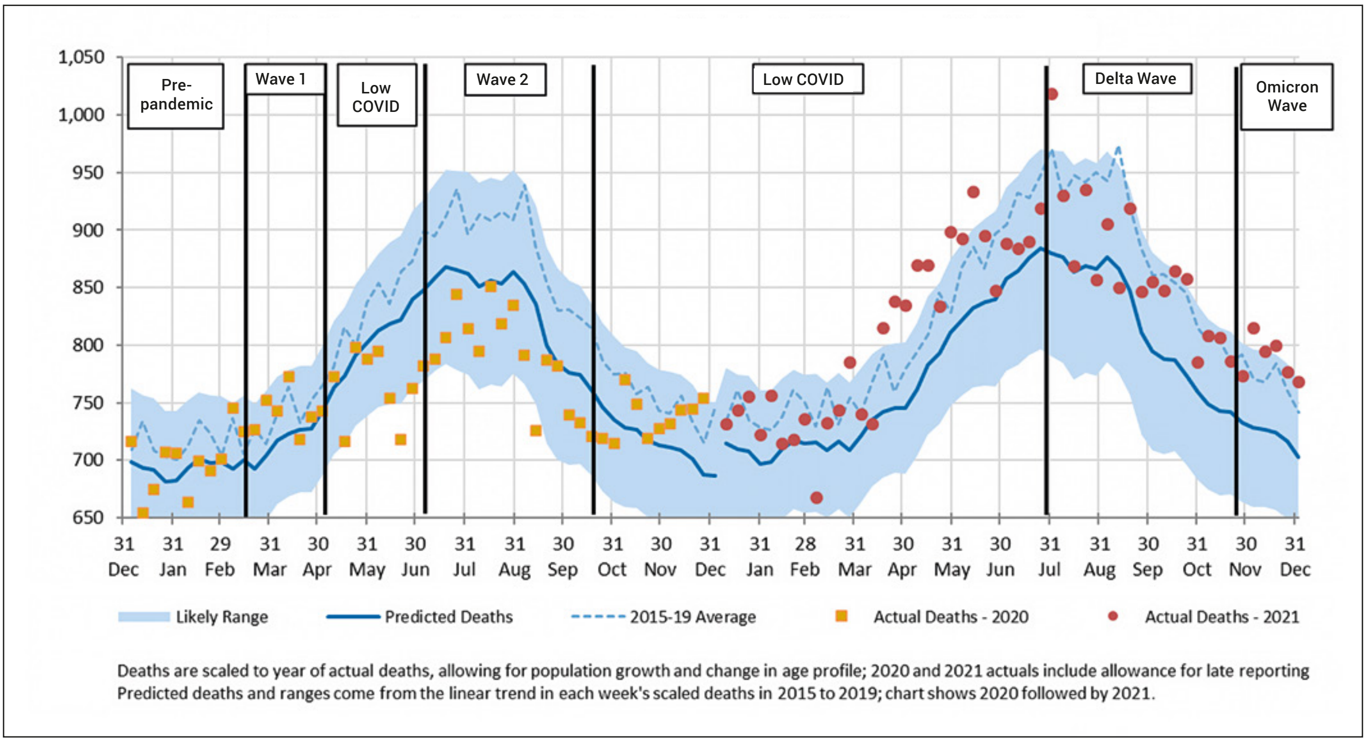
Deaths from diabetes were 7% higher than expected over the whole of 2021. Deaths from diabetes only make up a small proportion of all deaths, which leads to a somewhat higher volatility, however most weeks are above the mean prediction.

Figure 53 – Doctor-certified dementia deaths



Deaths from dementia were lower than expected during July-November, which is possibly related to lower than usual levels of respiratory disease in the community.

Figure 54 – Doctor-certified deaths from other causes, not explicitly identified in the ABS report



Deaths from other causes, i.e. those not explicitly reported on by the ABS, were much higher than expected across most of 2021, and above the upper limit of the prediction interval for many weeks.

Appendix E – Excess deaths by gender and age Bband

E.1 COVID-19 Deaths by gender and age band

Table 16 – Doctor-certified COVID-19 deaths by gender and age band, compared with total doctor-certified deaths – 2020 & 2021

Doctor-certified COVID-19 deaths

Gender	Year	Age band					
		0-44	45-64	65-74	75-84	85+	All
Persons	2020	2	27	78	237	510	854
	2021	20	162	258	364	408	1,212
Males	2020	2	17	52	129	214	414
	2021	12	110	160	231	202	715
Females	2020	0	10	26	108	296	440
	2021	8	52	98	133	206	497

Source: Australian Bureau of Statistics, bespoke data request

All Doctor-certified deaths

Gender	Year	Age band					
		0-44	45-64	65-74	75-84	85+	All
Persons	2020	2,822	15,281	23,401	39,724	62,890	144,118
	2021	2,889	14,760	23,708	41,662	66,178	149,197
Males	2020	1,503	8,773	14,001	22,169	26,229	72,675
	2021	1,568	8,466	13,976	23,361	27,636	75,007
Females	2020	1,319	6,508	9,400	17,555	36,661	71,443
	2021	1,321	6,294	9,732	18,301	38,542	74,190

Source: Australian Bureau of Statistics, Provisional Mortality Statistics

COVID-19 as percentage of all deaths

Gender	Year	Age band					
		0-44	45-64	65-74	75-84	85+	All
Persons	2020	0.1%	0.2%	0.3%	0.6%	0.8%	0.6%
	2021	0.7%	1.1%	1.1%	0.9%	0.6%	0.8%
Males	2020	0.1%	0.2%	0.4%	0.6%	0.8%	0.6%
	2021	0.8%	1.3%	1.1%	1.0%	0.7%	1.0%
Females	2020	0.0%	0.2%	0.3%	0.6%	0.8%	0.6%
	2021	0.6%	0.8%	1.0%	0.7%	0.5%	0.7%

Table 16 sets out the COVID-19 data used in Table 3. It is interesting to note that COVID-19 accounted for a similar proportion of deaths in all age groups in 2021. By comparison, the proportion of all deaths that were from COVID-19 increased by age in 2020.

We note that the mortality risk for the unvaccinated who are infected by COVID-19 increases faster by age than does the general mortality risk. However, the proportion of people vaccinated also generally increases by age. Perhaps, for 2021, these two effects largely cancel each other out, while there was effectively no vaccination in 2020.

E.2 Deaths for males by age band

Figure 55 – Doctor-certified deaths of males aged 0-44

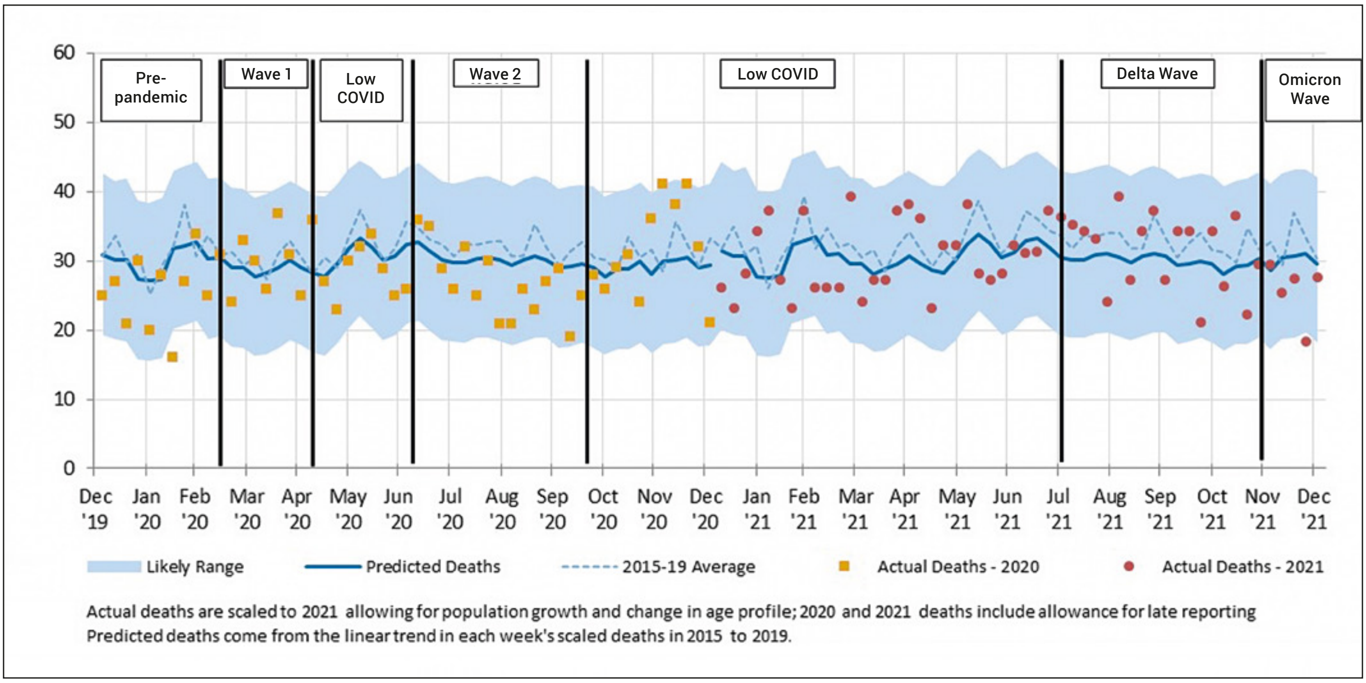


Figure 56 – Doctor-certified deaths of males aged 45-64

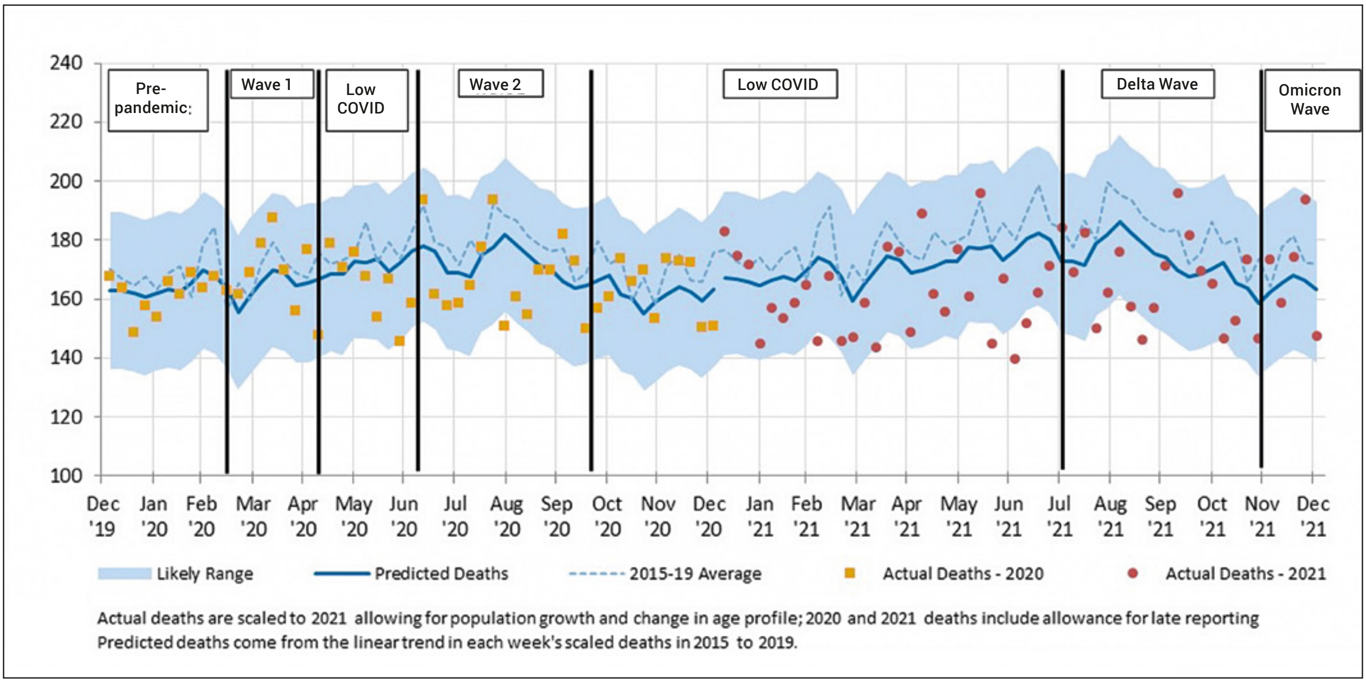


Figure 57 – Doctor-certified deaths of males aged 65-74

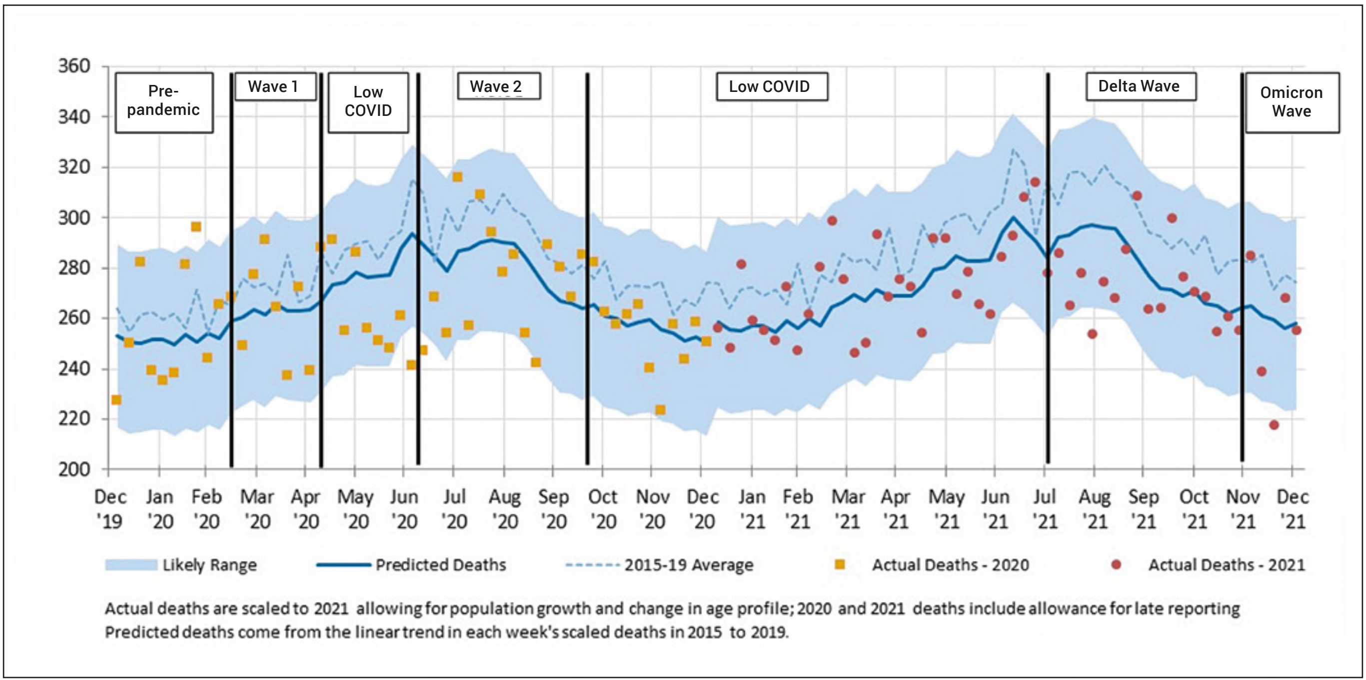


Figure 58 – Doctor-certified deaths of males aged 75-84

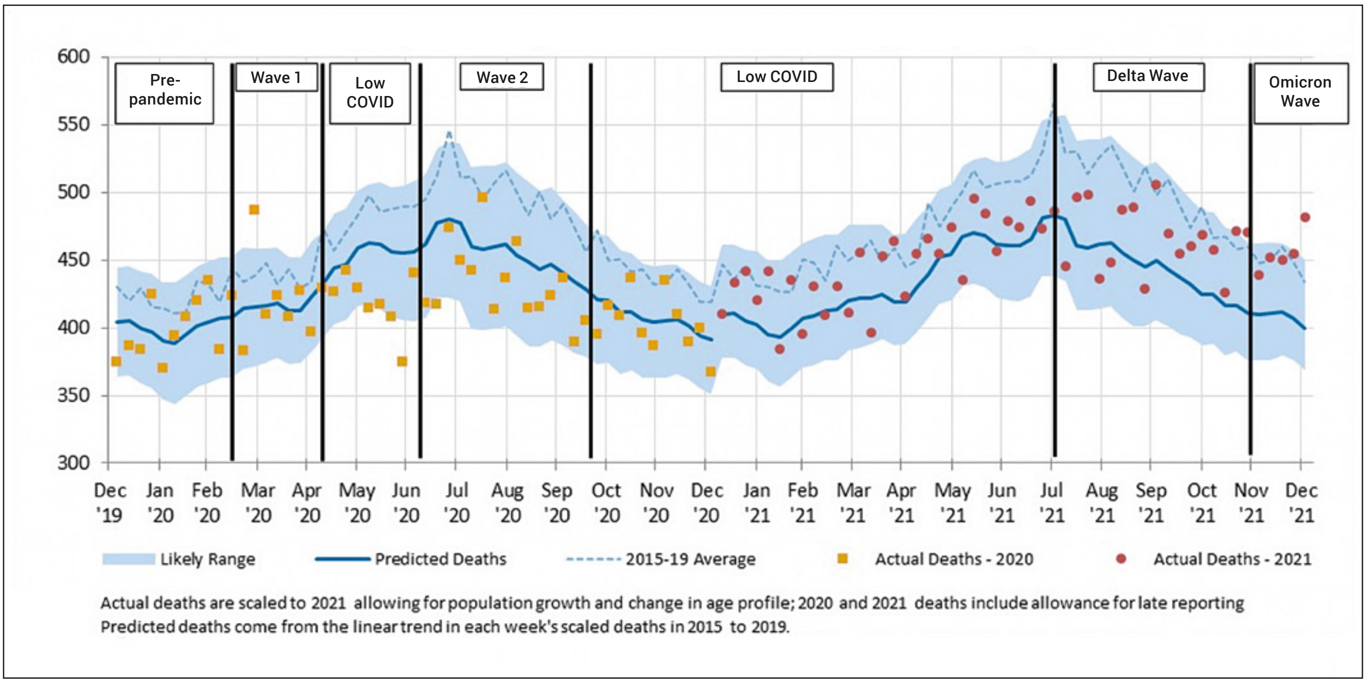


Figure 59 – Doctor-certified deaths of males aged 85+

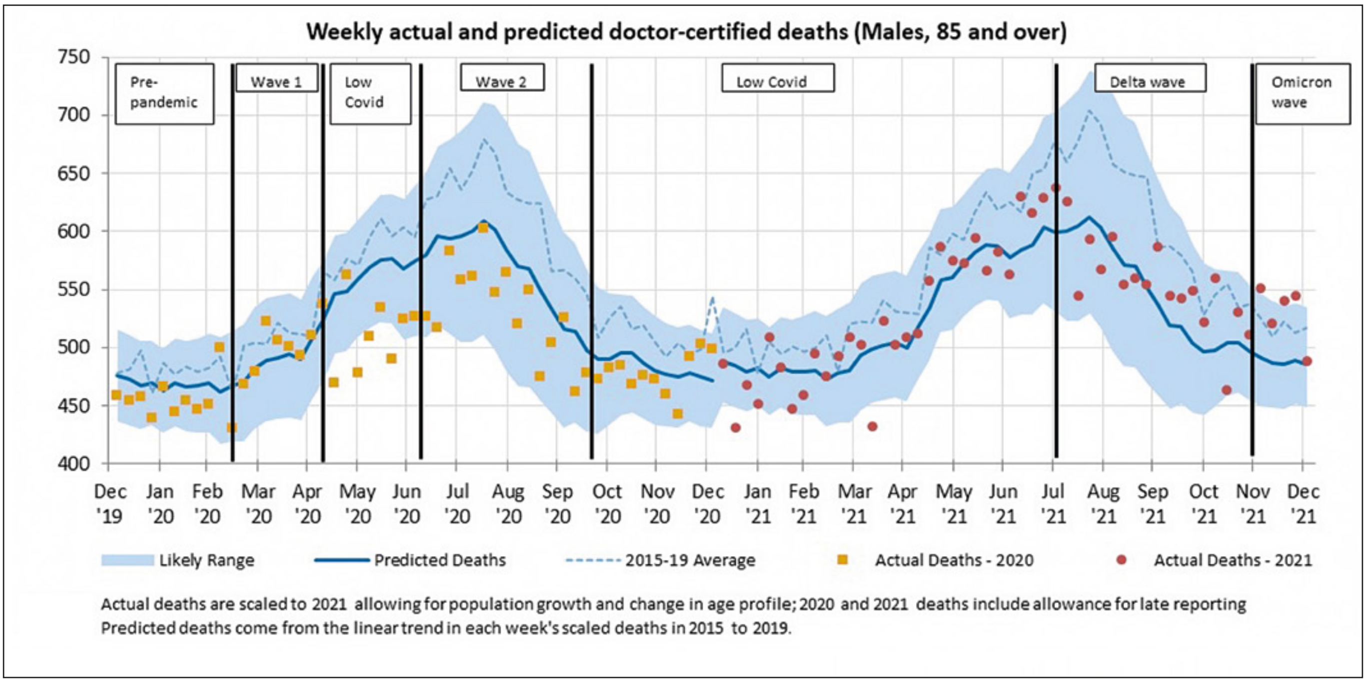
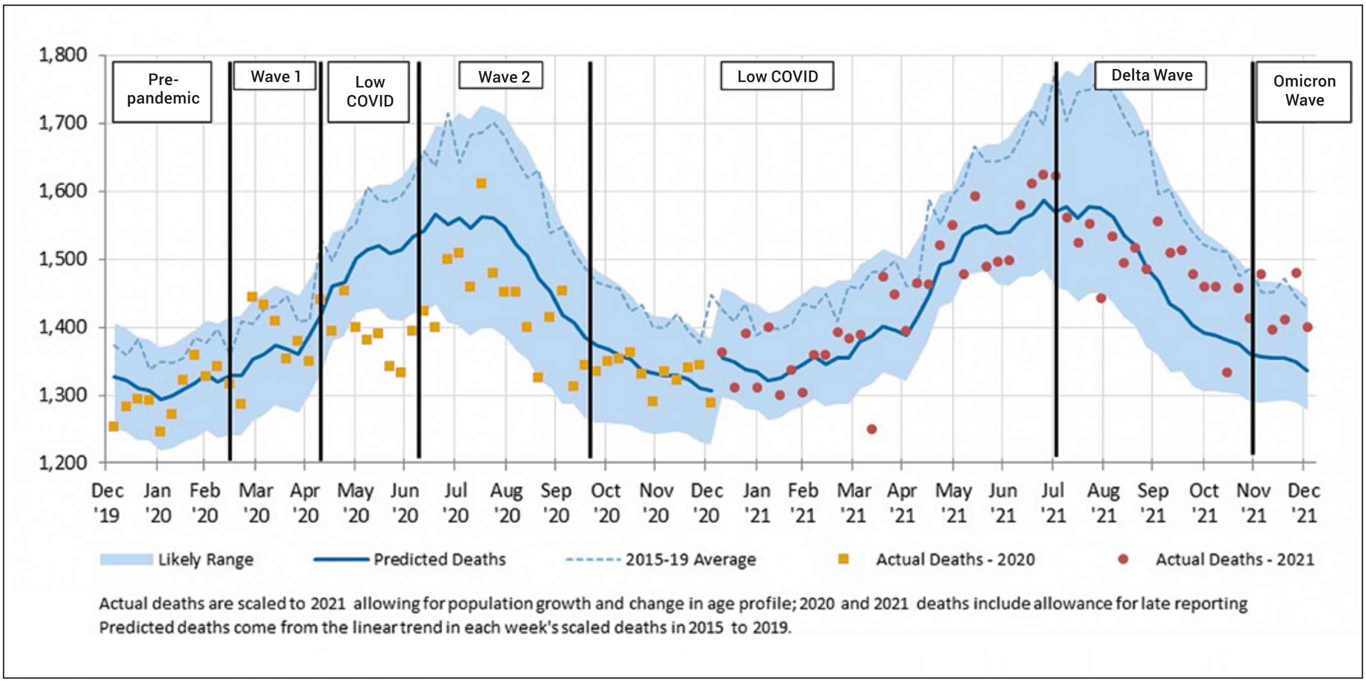


Figure 60 – Doctor-certified deaths of all males



E.3 Deaths for females by age band

Figure 61 – Doctor-certified deaths of females aged 0-44

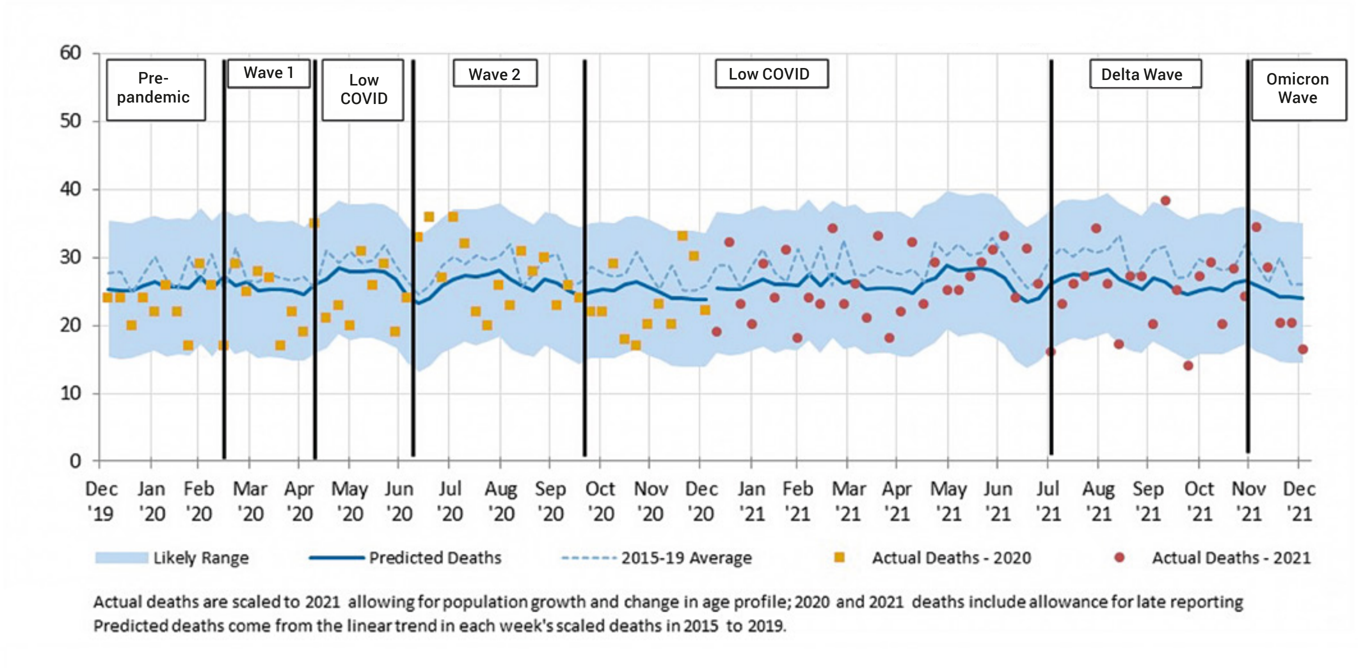


Figure 62 – Doctor-certified deaths of females aged 45-64

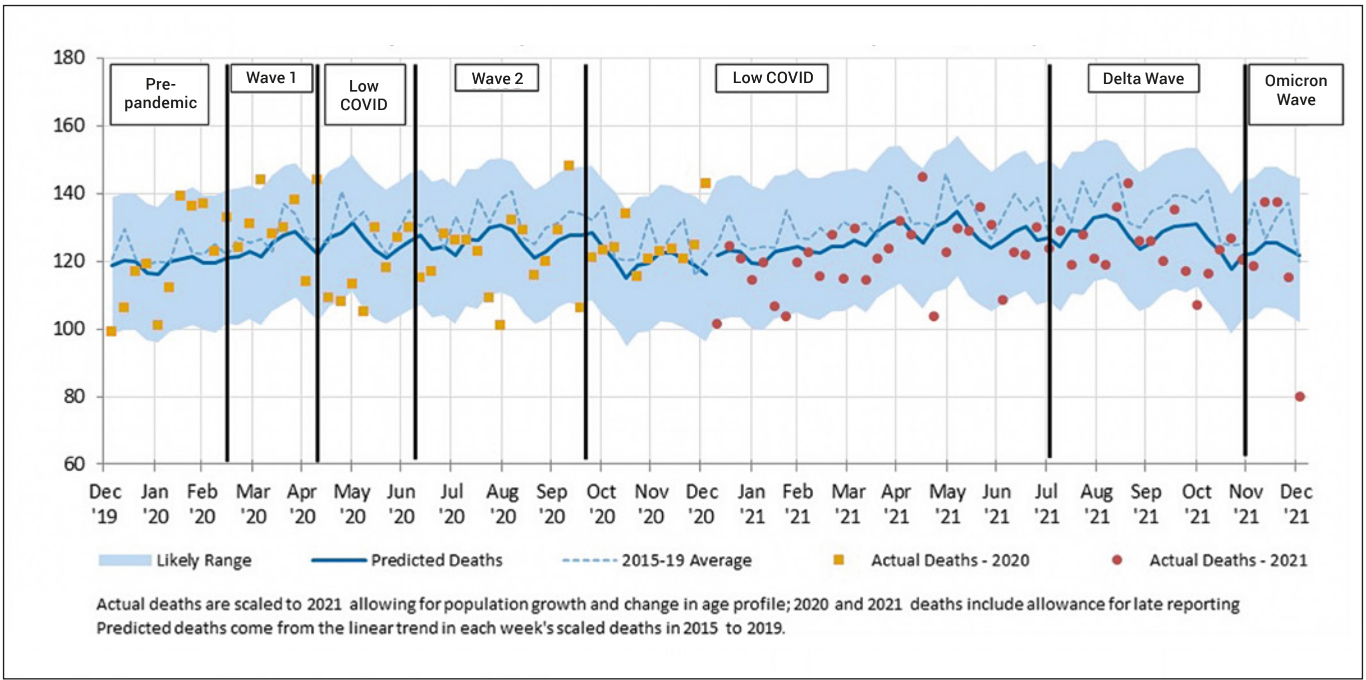


Figure 63 – Doctor-certified deaths of females aged 65-74

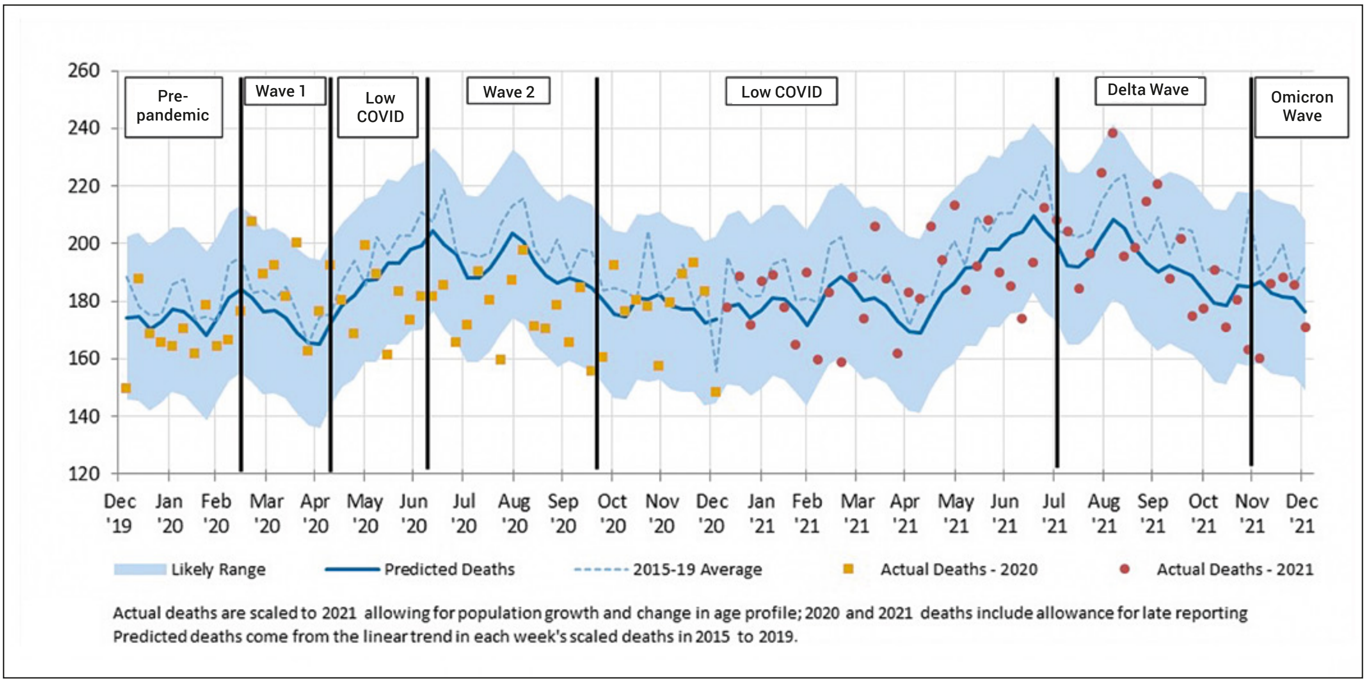


Figure 64 – Doctor-certified deaths of females aged 75-84

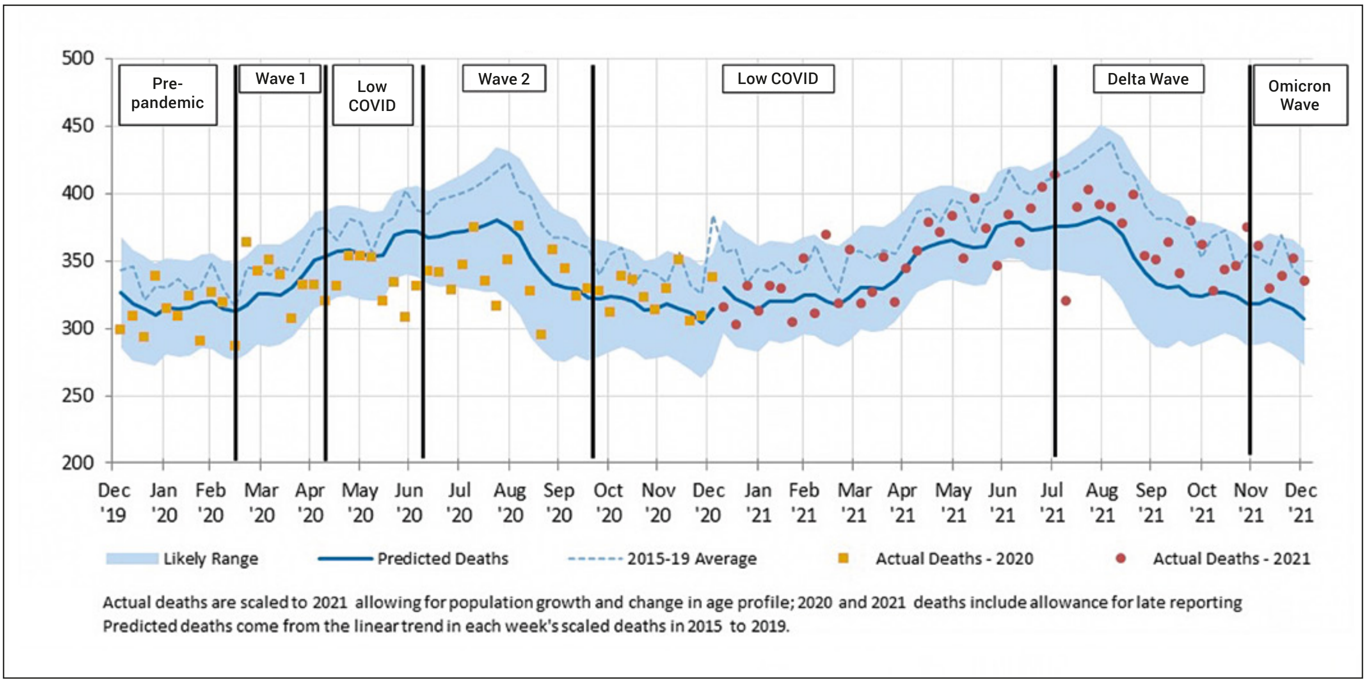


Figure 65 – Doctor-certified deaths of females aged 85+

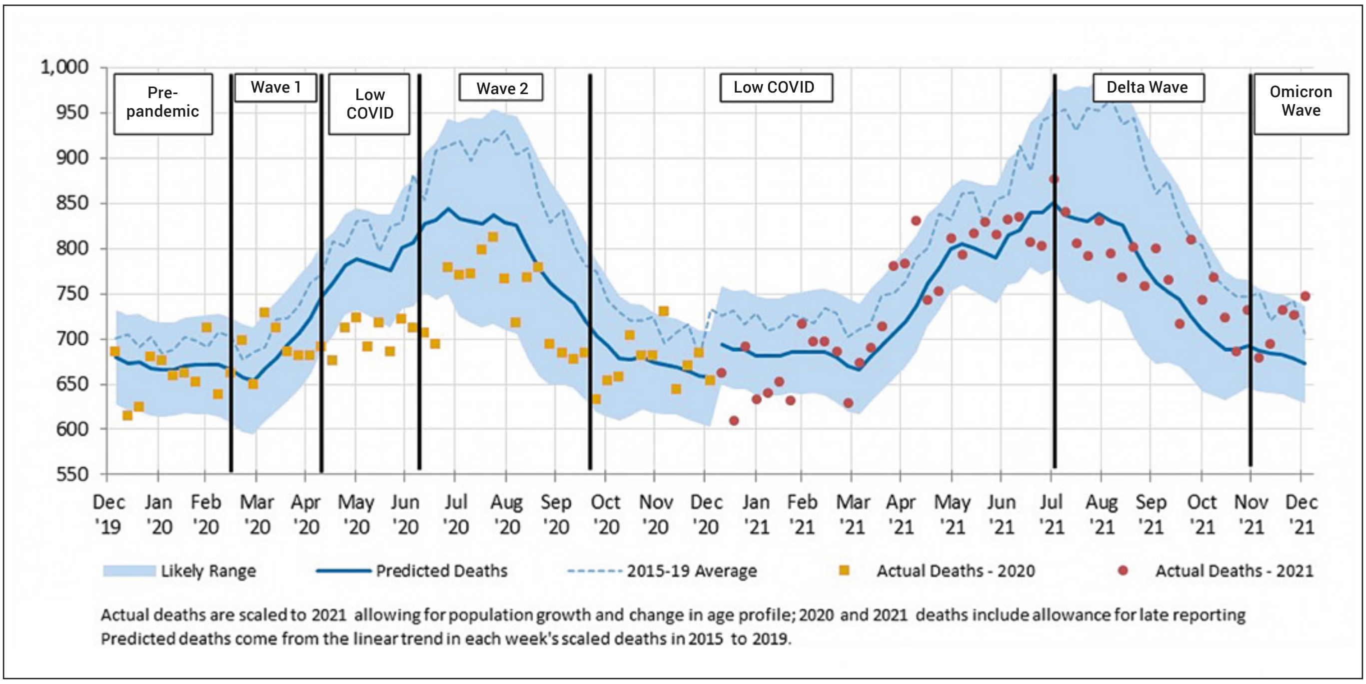
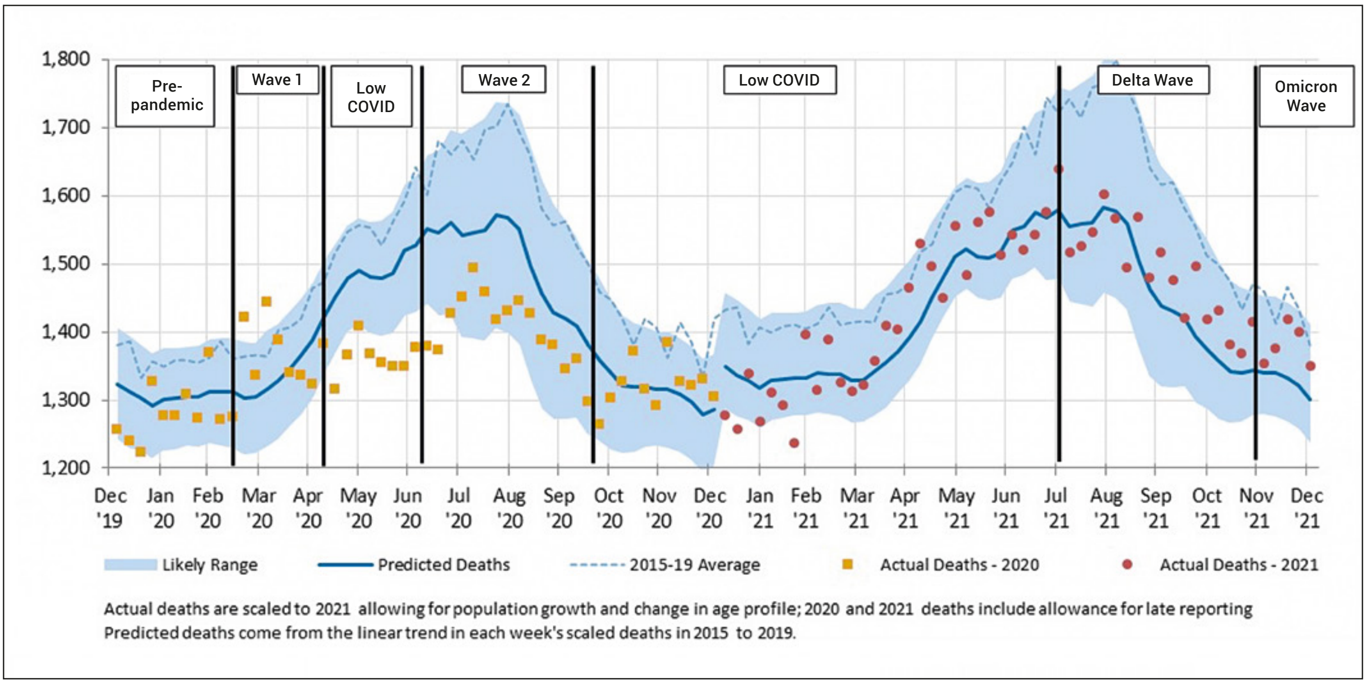


Figure 66 – Doctor-certified deaths of all females



Institute of Actuaries of Australia
ABN 69 000 423 656
Level 2, 50 Carrington Street,
Sydney NSW Australia 2000
t +61 (0) 2 9239 6100
actuaries@actuaries.asn.au
www.actuaries.asn.au