Continued mitigation needed to minimise the high health burden from COVID-19 in Aotearoa New Zealand

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ABSTRACT

In this article we review the COVID-19 pandemic experience in Aotearoa New Zealand and consider the optimal ongoing response strategy. We note that this pandemic virus looks likely to result in future waves of infection that diminish in size over time, depending on such factors as viral evolution and population immunity. However, the burden of disease remains high with thousands of infections, hundreds of hospitalisations and tens of deaths each week, and an unknown burden of long-term illness (long COVID). Alongside this there is a considerable burden from other important respiratory illnesses, including influenza and RSV, that needs more attention. Given this impact and the associated health inequities, particularly for Māori and Pacific Peoples, we consider that an ongoing respiratory disease mitigation strategy is appropriate for New Zealand. As such, the previously described "vaccines plus" approach (involving vaccination and public health and social measures), should now be integrated with the surveillance and control of other important respiratory infections. Now is also a time for New Zealand to build on the lessons from the COVID-19 pandemic to enhance preparedness nationally and internationally. New Zealand's experience suggests elimination (or ideally exclusion) should be the default first choice for future pandemics of sufficient severity.

This viewpoint article reviews the past, current and potential continuing health impact of COVID-19 in Aotearoa New Zealand. It aims to identify the optimal response to this pandemic as it transitions to being an endemic infectious disease. It also considers how we can build pandemic preparedness nationally and internationally based on lessons from COVID-19, particularly as it is experienced by the most affected groups. In addition, it addresses questions about the relative effectiveness of the New Zealand response to date, the stringency of control measures and the factors associated with excess mortality during the pandemic.

Epidemiology and impact of the COVID-19 pandemic in New Zealand

The World Health Organization (WHO) removed the designation of the COVID-19 pandemic as a public health emergency of international concern (PHEIC) on 5 May 2023.[1] This change signified its shift from requiring emergency control measures but did not refer to its global pandemic status or continuing health impact. And on 15 August the New Zealand Government removed the remaining COVID-19 mandates covering self-isolation and wearing of face masks for visitors to healthcare facilities.[2] Consequently, this is a suitable time to review the current status of the pandemic in New Zealand and the associated response measures.

The broad features of the surveillance and epidemiology of COVID-19 in New Zealand are described in Appendix 1 and summarised below:

- Disease surveillance and wastewater testing data suggest COVID-19 infection since January 2022 has occurred as a series of four pandemic waves of diminishing size (though there were small waves of infection in 2020 and 2021, these are better described as outbreaks that were either eliminated or well controlled). These waves were associated with a succession of Omicron subvariants.[3] There were 2.1 million cases reported in 2022.
- COVID-19 is a major cause of hospitalisation in New Zealand, resulting in 22,426 hospitalisations in 2022.[4]
- COVID-19 has become a leading cause of death in New Zealand. It resulted in 2,448

deaths (attributed to COVID-19 as the underlying or contributory cause) in 2022 (6.3% of 38,574 total reported deaths that year).[4,5]

- COVID-19 remains an important source of inequities, with Māori and Pacific Peoples markedly more likely than Asian, European and other New Zealanders to be admitted to hospital and die from this infection.[6] In addition, high case rates have been observed in occupations relating to education, retail and hospitality.[7]
- It is common to experience new health problems following a COVID-19 infection,[8,9] and the high baseline of infections and reinfections during 2022–2023 has led to the emergence of long COVID, particularly among population groups with high infection rates.[10,11]
- New Zealand managed to sustain relatively low excess mortality during widespread Omicron infections,[12] and cumulative excess mortality in New Zealand from January 2020 to June 2023 remains close to zero (Figure 7, Appendix 1).

Future course of the pandemic

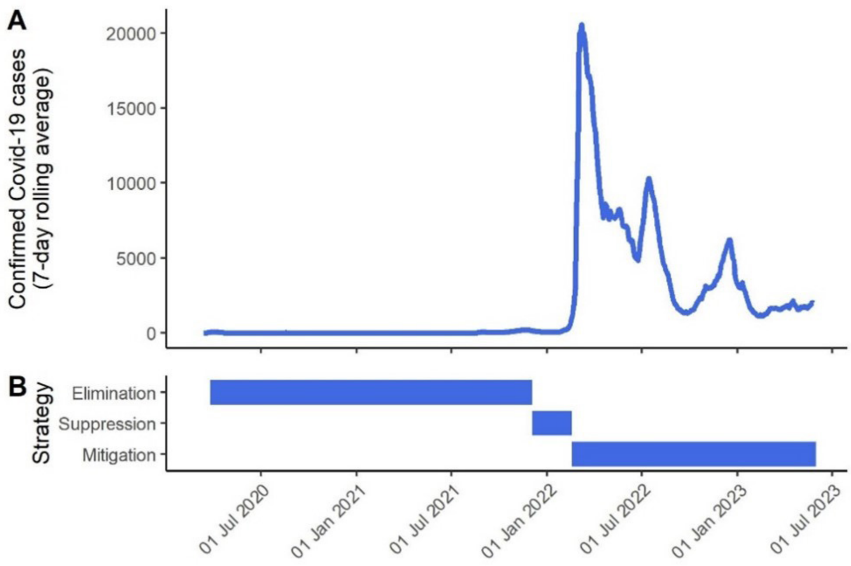
The future course of the pandemic is difficult to estimate. It depends on the interaction of organism factors (such as ongoing viral evolution), host factors (such as waning natural and post-vaccination immunity, which also reflects vaccine improvements) and environmental factors (such as greater mixing indoors in winter and fewer pandemic controls). The net effect of these changes is likely to continue to generate a succession of pandemic waves. These waves will probably decline in size, unless we see major new SARS-CoV-2 variants or sub-variants emerging.[13]

At a certain point, it will be more appropriate to describe COVID-19 as having moved from a pandemic to an endemic disease. A pandemic is "*an epidemic occurring worldwide, or over a very wide area, crossing international boundaries and usually affecting a large number of people*".[14] COVID-19 is arguably still at that stage, partly because it is displaying unpredictable epidemic waves that have not become season-specific, as with influenza. Assuming it settles into a more stable and predictable pattern, then it would be best described as endemic, which is "*the constant occurrence of a disease, disorder, or noxious infectious agent in a geographic area or population group*".[14] Continuing, unexpectedly large jumps in SARS-CoV-2 virus evolution remind us to be cautious about considering the pandemic over.[15]

It is important to estimate the future impact of COVID-19, even when it becomes endemic, to guide an effective and proportionate response. For example:

- COVID-19 could result in around 13,900 hospitalisations in 2023 (based on an average 268 hospitalisations per week for the first half of the year).
- COVID-19 could cause around 1,090 deaths in 2023 (based on an average of 21 COVID-attributed deaths per week for the first half of 2023). These measures may under-estimate mortality since those who have had a COVID-19 infection appear to be at increased risk of subsequent death for at least 2 years, particularly for people with a severe acute infection.[9,16,17]
- The future health and societal burden from longer-term impacts of COVID-19 may be substantial if ongoing levels of transmission are sustained. Incidence and prevalence estimates of long COVID vary depending on study design and case definitions (see Appendix 1 for examples). Health conditions associated with COVID-19 infection range from mild and transient to life limiting, including increased mortality risk in the years following infection, as above.
- An increasing proportion of COVID-19 infections are identified as reinfections (around half of new cases at the time of writing,[18] although this figure is likely an under-estimate). The ongoing emergence of new Omicron subvariants means that some people are reinfected after short intervals (sometimes just a few months)[19,20] compared with other common pathogens (e.g., seasonal influenza, which typically symptomatically infects adults once or twice a decade,[21] although asymptomatic infection is likely to be more frequent[22]). Each COVID-19 infection carries some risk of serious illness and death,[23] but it is currently hard to quantify the extent to which the protective effects of vaccination and prior exposure[24,25] will be offset by an increase in cumulative risk after multiple infections.[23]

Figure 1: Reported COVID-19 cases in New Zealand (A) and changing COVID-19 pandemic responses strategies (B) during the pandemic. Data source: Ministry of Health (MoH).[4] The key dates for these strategies are described in Appendix 2.



Responding to the pandemic

The following are key areas where New Zealand can act to reduce the health impact of COVID-19 and other respiratory infections and increase its health security in the face of future pandemic threats (Table 1). We propose that the response should continue to be shaped by key principles, notably: science-informed strategic leadership; a Te Tiriti and equity focus; use of the precautionary principle; and the need to create legacy benefits for our health system and other essential infrastructure.[26] In addition, cost effectiveness needs to be a guiding consideration as resources applied to COVID-19 responses need to be justified in relation to other competing uses.[27]

Choosing an optimal and equitable response strategy

New Zealand has delivered one of the world's most strategic COVID-19 pandemic responses, taking an elimination strategy from March 2020[28] (closely related to an exclusion strategy, as practiced by many Pacific Island states, which is even more effective as it avoids the need for elimination measures[29]). It then transitioned to suppression in December 2021,[26] followed by mitigation from February 2022 onwards[30] (Figure 1 and Appendix 2). Elimination is currently not feasible with available and acceptable interventions, so the decision is about the optimal level of control, from suppression to mitigation to no strategic response.[29]

We consider the impact of COVID-19 justifies a continuing mitigation strategy to reduce its burden on health and the healthcare system. That means using a combination of vaccination and public health and social measures to reduce these impacts (described as "vaccines plus"[31]). This approach has been supported by both the Lancet COVID-19 Commission and a major global consensus paper on the pandemic.[32,33]

Equity needs to be at the heart of any response to endemic and pandemic infectious diseases, with strong Māori leadership at all levels in decision making and delivery. Providing such protection is a Te Tiriti obligation and is supported by the significantly higher burden of both disease and social consequences of the pandemic faced by Māori and Pacific Peoples. Fortunately, Te Aka Whai Ora (the Māori Health Authority) is well placed to provide leadership nationally. Similar engagement is needed at all levels of service delivery.[34]

Developing and implementing an integrated respiratory infection strategy to reduce disease burden

As COVID-19 transitions to becoming endemic, some argue that it should be treated more like other infectious diseases. We propose the converse approach of treating other serious respiratory infections such as influenza and respiratory syncytial virus (RSV) more like COVID-19. This is the argument for exploring an integrated respiratory infection control strategy that builds on the co-benefits and efficiencies of preventing multiple infections, along with a strong emphasis on equity.[35]

In the past, the annual toll from influenza of around 500 deaths and its substantive impact on our hospital system has been tolerated.[36,37] Yet influenza largely disappeared during the first 2 years of the pandemic.[38] This finding shows the disease burden of influenza is not inevitable and that public health measures can alter the annual epidemic patterns.[38] We need to identify the most effective and cost-effective mix of respiratory protections that lower the burden of multiple respiratory diseases.[39,40]

Elements of such a strategy could include: enabling self-isolation for those with respiratory infections;[41] good indoor ventilation and air filtration, which can reduce the risk of respiratory infection[42,43] as well as improve concentration at school and increase worker productivity;[44] mask use in high-risk indoor environments such as healthcare facilities and public transport, where ventilation is typically poor;[45,46,47] and systematic approaches to reducing transmission in key indoor environments such as schools.[48] However, the New Zealand Government has recently terminated the COVID-19 Leave Support Scheme and lifted the face mask requirement for visitors to healthcare settings.[2]

Achieving and maintaining high and equitable vaccine coverage for all at-risk groups

Vaccination has been a key intervention that has reduced the health impact of the COVID-19 pandemic in New Zealand and globally.[49] The elimination strategy delayed widespread transmission of COVID-19 in New Zealand for almost 2 years, providing time for international vaccine development and achieving high vaccination coverage, giving a beneficial level of population immunity before most people had been exposed to the virus.

Future vaccination policy needs to be considered across all vaccine-preventable respiratory illnesses and evolve as vaccine formulations and ability to deliver to populations continue to improve. Complicating factors for COVID-19 vaccines are continuing viral evolution and the short duration of protective immunity both post-infection and post-vaccination. Current COVID-19 vaccines have limited and short duration of immunity to asymptomatic infection and mild disease and therefore have little effect on reduction of community spread. Consequently, they are most effective as individual-level protection against severe disease, particularly for those at highest risk. The new bivalent booster containing an Omicron component has provided increased protection against serious illness and death during the current stage of the pandemic, compared with protection provided by the monovalent vaccine.[50,51]

Vaccine design is continuing to advance, to improve strain matching, duration of immunity and effectiveness. There is good progress towards universal pan-coronavirus[52,53] and influenza vaccines[54] to overcome the challenges of evolving strains. RSV is expected to be the next respiratory vaccine-preventable disease. The United States (US) FDA has recently approved an RSV vaccine for individuals 60 years and above.[55] Vaccines and long-acting passive immunisation approaches in pregnancy and infancy are also very close to international market approval.[56]

Technological advances in vaccinology are also likely to support vaccination uptake and equity. Combination vaccines for Covid-19 and influenza are expected on the market within the next 2 years, which should improve cost effectiveness, ease of delivery and uptake. Future combinations will probably include an RSV vaccine as well. Improved delivery mechanisms, such as intranasal and intradermal, have the potential to improve immunisation uptake and help manage the neglected barrier of needle phobia.[57]

Regardless of the optimal vaccine, there are still delivery challenges, with a relatively low uptake of boosters (with only 53% of the eligible 50+ age group having received a second booster, although rising to 70% for 65 years plus).[58] There are a range of factors that impact uptake, such as fatigue with the sustained COVID-19 response, the level of promotion by health authorities, accessibility of health services in the community, vaccine hesitancy and anti-vaccination views that are fuelled by mis/disinformation.[59]

It is important to acknowledge that serious adverse effects can occur following any vaccination but are rare (myocarditis and pericarditis are rare side effects of mRNA vaccines, for example[60]). At a population level, New Zealand surveillance data provide no evidence that COVID-19 vaccination is causing excess mortality.[61] The period of highest COVID-19 vaccination was in 2021 (Figure 8), which corresponded with low excess mortality (Figure 7). The period of increased excess mortality in 2022 corresponded with widespread COVID-19 infection, which appears to explain the majority of excess deaths.[62]

Enhancing health services to manage respiratory infections

The COVID-19 response has resulted in multiple changes to the operation of the healthcare system in New Zealand. These adaptations include increased use of telemedicine,[63] electronic prescribing,[64] separating respiratory illness from non-respiratory in primary care presentation, regular mask wearing for frontline services and delivery of testing and vaccination by a wider range of healthcare professionals including pharmacists. One area that needs particular focus is optimising effective and equitable delivery of key preventive care. A good example is antivirals such as Paxlovid, which can improve disease outcomes but only if delivered early in an infection.[65] Other therapeutics are likely to become increasingly useful in the future for managing viral respiratory infections.

Understanding of infection prevention and control measures has improved in all healthcare settings. These changes need systematic assessment and guideline development so that valuable and cost-effective changes are retained, e.g., prevention of airborne transmission.[66]

Improving effective public communication about respiratory infections

The pandemic has illustrated the value of effective communication during a public health crisis. But it also highlighted the challenges of effective risk communication and sustaining key behaviour changes. An important advance is to have consistent ways of communicating the risk of seasonal and pandemic respiratory infections. As such, an updated and more equitable version of an alert level system should be considered.[67]

This is also an opportunity to address wider communication goals of promoting pro-social behaviour[32] (which is particularly important for managing an infectious disease transmitted between people) and managing mis/disinformation.[68] Effective engagement with the multiple New Zealand communities is critical throughout the response.

Improving surveillance and research to inform our response

COVID-19 has demonstrated the importance of high-quality, comprehensive disease surveillance for managing a pandemic. Emerging surveillance tools such as genomic surveillance havetransformed outbreak investigations and situational awareness,[69–74] as has wastewater testing.[75] However, there are important gaps in information. It is now time for a comprehensive, effective and sustainable surveillance system for COVID-19, influenza and other important respiratory pathogens.[35]

Point-of-care testing and self-reporting of illness are likely to remain useful ways of measuring disease rates in the community. The value of such surveillance could be enhanced by integrating it better with high-quality sentinel surveillance for respiratory infections.[76] This approach could build on successful community-based models such as the SHIVERS/WellKiwis cohort study.[77] This need has become more critical with the proposed COVID-19 infection prevalence surveys no longer going ahead.[78]

There are multiple important research questions where knowledge is critically important to guide the COVID-19 response. Key examples include the need to accurately monitor the prevalence of long COVID resulting from repeated infections, and the cost effectiveness of measures to improve indoor air quality. It will also be important to identify ways of sustaining high and equitable levels of vaccination coverage as well as public support for respiratory control measures. New Zealand clinical researchers should also be supported to continue their important contributions to international collaborative research programmes.[79]

Improving pandemic preparedness nationally and internationally

Preventing the next pandemic will need to be a major focus as there are multiple infectious agents with pandemic potential.[80] Avian influenza is an increasing concern at present.[81] A major focus of the Royal Commission of Inquiry into COVID-19 is to identify how New Zealand can better prepare for future pandemics.[82] This approach will require a far more adaptable response framework than the current pandemic plan that is still focussed on pandemic influenza.[83] It will be important to ensure this strategy is sustained, updated and resourced during inter-pandemic periods. The Government recently announced funding for a new Pandemic Research and Response Institute, which could increase local capacity.[84]

It is also crucial to support international initiatives (both regional and global) to strengthen capacity for early detection and control of pandemic threats, and more equitable delivery of key interventions such as vaccines.[85,86] The International Health Regulations are being amended at present, which should provide an opportunity to strengthen the response to emerging pandemic threats. In our view, the greatest lesson from COVID-19 is that elimination (or ideally exclusion) should be the default first choice for future pandemics of sufficient severity.[29,87] If rapid elimination at source or immediately after arrival in a new country is not possible, then at least suppression of spread may provide time to develop effective vaccines and optimise other prevention and control measures.

New Zealand data summarised here show that the elimination strategy not only resulted in low cumulative excess mortality (Figure 7), but also required less stringent controls during the pandemic compared with other high-income countries (Figures 9, 10). Although the 2020–2021 period with the strongest pandemic controls (greatest stringency) was very difficult for many New Zealanders, it was, reassuringly, a period of consistently low excess mortality.[62] Nevertheless, further research is needed to assess potential longer-term effects of both the pandemic and response.

Conclusions

The New Zealand COVID-19 pandemic response has been among the world's most effective, based on key public health metrics such as low cumulative excess mortality. During 2020 and 2021 when control measures were most stringent and vaccination was at its highest, excess mortality declined. Mortality only increased in 2022 in association with widespread circulation of COVID-19 for the first time. The elimination strategy meant that the stringency of control measures was also less than those used by other high-income countries that used suppression/mitigation approaches to COVID-19.

The high infection and reinfection rates in 2023 from this pandemic have ongoing substantial impacts on health and wellbeing and health equity in New Zealand. Because the disease burden remains large, a continuing mitigation strategy is justified. Adoption of an integrated respiratory infectious disease surveillance and control strategy covering influenza, RSV and other important respiratory pathogens would be a valuable legacy of the pandemic.

There is also an opportunity to improve New Zealand's health security by supporting the Royal Commission of Inquiry to identify a highly effective pandemic strategy for this country, and by contributing to global and regional efforts to improve pandemic preparedness. Implementing and sustaining these health security measures will be critically important given persisting concerns of future pandemics from either natural or engineered pathogens.[88]

Table 1: Summary of key measures to manage the ongoing threat from COVID-19 and other pandemic diseases, and to improve public health, equity and health security.

Broad area	Key measures
1. Choose and articulate an optimal and equitable response strategy.	Continue an explicit mitigation strategy to minimise the health impact of ongoing COVID-19 transmission. This strategic setting should be reviewed periodically based on new knowledge about the health impacts of COVID-19 and the availability of improved interventions (notably vaccines that can interrupt transmission, which could make suppression or even elimination of infection feasible).
	Ensure appropriate resourcing of Māori leadership (Te Aka Whai Ora) and service delivery by Māori providers. Also ensure continued Pacific community and provider engagement and participation.
2. Develop and implement an integrated respiratory infection strategy to reduce disease burden.	Maintain or improve clear self-isolation guidelines for COVID-19, with the support measures needed to make them effective (e.g., access to testing, sick leave entitlements and test-to-release guidelines). Consider extending these measures to other serious respiratory infections—albeit with further evaluation of the public acceptability and potential improvements in support from government agencies and the role of mandates for reinforcing such behaviours.
	Improve indoor air quality in public settings and evaluate the effectiveness and cost effectiveness of different options.
	Maintain mask use in high-risk indoor environments such as healthcare settings and explore the advantages and disadvantages of mandating masks in public transport settings, particularly over winter.
	Implement strategies to limit transmission in key shared environments like schools and ensure that resources are in place to protect students' access to education at times of expected high transmission.
3. Achieve and maintain high and equitable vaccine coverage for all at-risk groups.	Continue to refine the COVID-19 vaccination schedule based on best international evidence. Evolve the strategy depending on the type and action of each COVID-19 vaccine.
	Combine the focus on COVID-19 with other national schedule vaccines, particularly with influenza vaccination delivery strategies.
	Increase the focus on equitable vaccination uptake, and community trust and engagement. Continue measures to achieve high and equitable vaccination coverage and evaluate the most effective and cost-effective vaccination promotion interventions.

Table 1 (continued): Summary of key measures to manage the ongoing threat from COVID-19 and other pandemic diseases, and to improve public health, equity and health security.

Broad area	Key measures
4. Enhance health services capacity to manage respiratory infections.	Build on new models for primary healthcare delivery to improve access to essential care, such as telemedicine and provision of testing and vaccination by a wider range of healthcare professionals including pharmacists.
	Review and enhance delivery of essential respiratory infection management tools such as antivirals.
	Review services for optimal management in secondary/tertiary care, and in the community post-discharge to identify improved models of practice for pandemic and endemic respiratory infections.
	Continue to develop and enhance infection protection and control services and systems throughout the healthcare system, notably separating respiratory illness from non-respiratory in primary care presentation, ensuring adequate indoor ventilation and regular mask wearing for frontline services.
5. Improve public communication about respiratory infections.	Establish an effective alert system to communicate public health risk of endemic and pandemic respiratory infections.
	Address wider communication goals of managing mis/disinformation and promoting pro-sociality.
6. Improve surveillance and research to inform our response.	Build an effective national surveillance infrastructure to support management of endemic and pandemic respiratory infections using an optimal mix of integrated methods (including epidemiological, microbiological, genomics, informatics, mathematical modelling, social media information, multiple community narratives) with capacity to be quickly scaled up when needed to support a pandemic response.
	Develop a research agenda to fill key gaps in knowledge about COVID-19 and its management, including better estimates of the current and future health impact of long COVID, selection of cost-effective interventions and identifying ways of improving the equity and sustainability of the response to respiratory infections. It would also be useful to build on successful international collaborative clinical and other research that has accelerated in response to the pandemic.
7. Improve pandemic preparedness nationally and internationally.	Actively support the Royal Commission to identify a highly effective pandemic strategy for New Zealand that is flexible enough to respond to a range of potential pandemic threats beyond the current focus on pandemic influenza. Ongoing scrutiny will be needed to ensure this strategy is sustained, revised and resourced.
	Actively support international efforts to strengthen WHO to deliver a more proactive global response to prevent future pandemics and manage them effectively.
	Work with Australia, South Pacific Island nations and South East Asian nations to strengthen regional pandemic control measures and infectious disease surveillance in general.

Appendix 1: COVID-19 surveillance and epidemiology in New Zealand

Aotearoa New Zealand has a COVID-19 surveillance strategy, with multiple surveillance systems operated by Manatū Hauora – Ministry of Health (MoH), Te Whatu Ora – Health New Zealand and the Institute for Environmental Science and Research (ESR).[89] These systems provide data on different categories of COVID-19 infection and a range of other key measures such as vaccination coverage. Results are presented on the Te Whatu Ora – Health New Zealand website.[18]

Here we present an analysis of COVID-19 surveillance data starting from 2020 up to the time of writing in mid-2023. The data for this analysis were obtained from the MoH[4] and ESR.[90] All data were extracted on 3 July 2023.

COVID-19 cases in the community

COVID-19 is a notifiable condition for diagnosing doctors, with cases confirmed by laboratory-based PCR testing or self-reported rapid antigen tests (RATs).[91] Since early 2022 members of the public have had widespread free access to RAT kits for testing themselves and people they are caring for. They have been required to report positive test results online.[92]

Case numbers remained relatively low during the elimination and suppression stages of the pandemic response but increased markedly following widespread transmission of the Omicron variant from February 2022 onwards (Figure 2). After January 2023, self-reported cases reached their lowest 7-day moving average of 1,132 per day on 11 February 2023. The numbers subsequently rose, reaching a moving average of 2,143 per day on 17 April 2023 before decreasing again as part of New Zealand's fourth pandemic wave.

COVID-19 hospitalisations and ICU admissions

Hospitals report diagnosed COVID-19 cases to the MoH, including admissions to intensive care units (ICUs). There is an international system for coding COVID-19 cases.[93]

During 2023, new weekly admissions increased from 132 for the week ending 19 February to a peak of 343 for the week ending 23 April 2023 before declining slowly (Figure 3).

COVID-19 deaths

Deaths linked to COVID-19 are reviewed by coding staff in the MoH who distinguish those that are attributed deaths (where COVID-19 was considered the underlying or contributing cause of death), and those that are unrelated cases, which are removed.[94] The MoH also reports all

Figure 2: COVID-19 cases in New Zealand, 7-day moving average of daily cases, from January 2020 to June 2023. Source: MoH.[4]

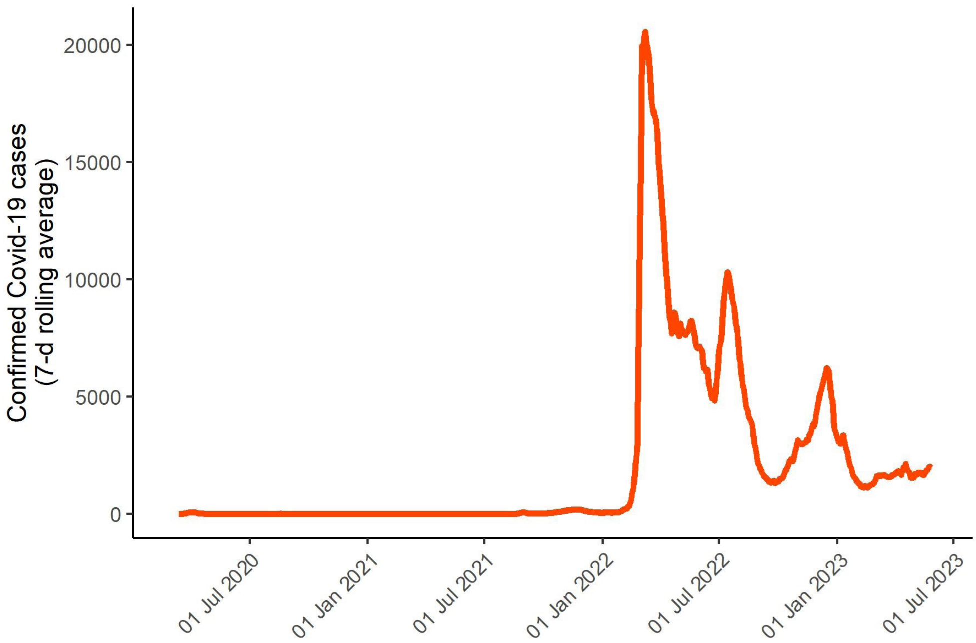


Figure 3: COVID-19 hospitalisations in New Zealand, weekly total, from January 2020 to June 2023. Source: MoH.[4]

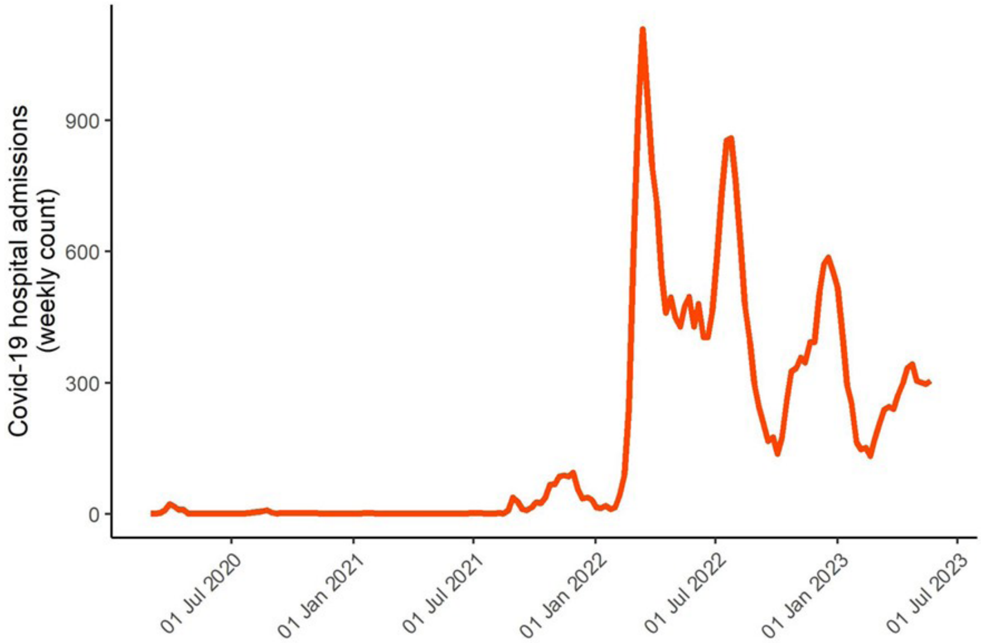
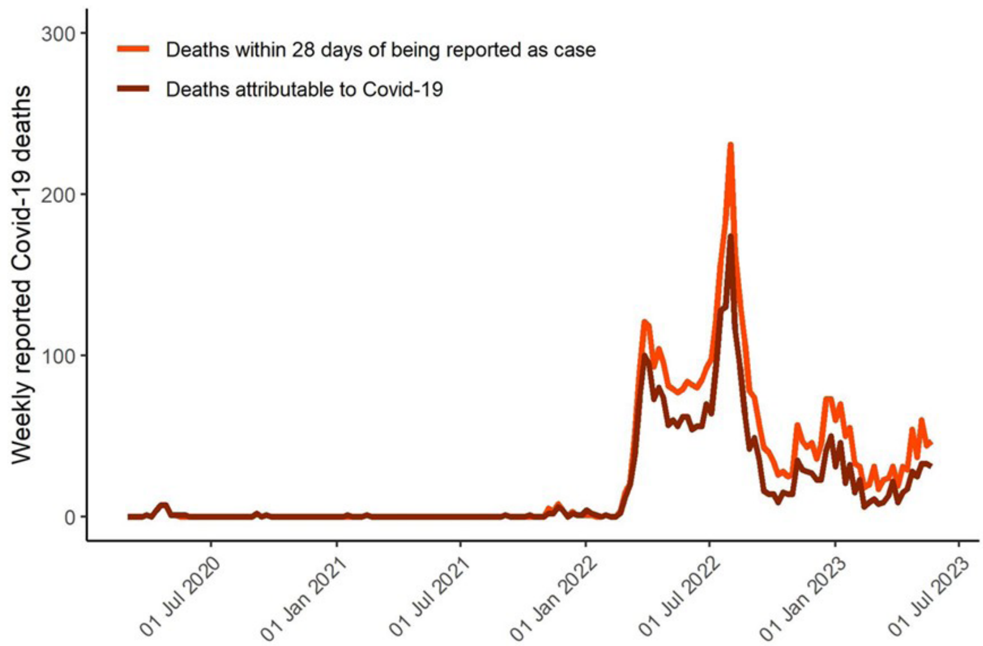


Figure 4: COVID-19 deaths in New Zealand, weekly total, from January 2020 to June 2023. Source: MoH.[4]



deaths within 28 days of COVID-19 infection as a separate category. The COVID-attributed measure may under-estimate mortality, which is substantially raised for at least 2 years following COVID-19 infection, particularly for people reporting long COVID.[9,16,17]

In the second quarter of 2023, deaths attributable to COVID-19 appeared to peak at 33 for the week ending 7 May 2023. Deaths within 28 days of being reported as a case appeared to reach a peak of 60 deaths that week (Figure 4).

Wastewater testing for COVID-19

Specimens are collected from sewerage systems at sites across New Zealand and tested for SARS-CoV-2 RNA.[75] These data are presented on the ESR Wastewater Surveillance Dashboard.[95] Wastewater sites are selected based on several factors including population and geographic coverage. New sites may be added over time and/or sampling may reduce in frequency or cease for other sites.

Results of wastewater testing showed a similar series of four pandemic waves during the 2022–2023 period that corresponded to waves of infection detected through other forms of surveillance. These testing results are likely to provide a relatively consistent indicator of COVID-19 infection levels in the community as they do not depend on levels of testing and reporting by members of the public.

During 2023, this testing showed a rise in SARS-CoV-2 RNA levels in wastewater from a low point of 1.5 million genome copies per person per day on 5 February 2023 to 4.4 million genome copies per person per day on 16 April 2023 before a decline in detections (Figure 5).

Genomic surveillance of COVID-19

Specimens obtained from cases and from wastewater undergo whole genome sequencing and analysis.[69] Results are regularly updated on the ESR COVID-19 Genomics Insights Dashboard (CGID) (Figure 6).[3]

These data show that initially there was a series of dominant Omicron subvariants associated with each wave of infection—notably BA.1/BA.2 with the first wave in 2022, and BA.4/BA.5 with the second wave. More recently the pattern has been characterised as a "swarm" or "soup" of multiple subvariants.[96] New Zealand had a mix of BA.2.75, BA.5, CH.1.1 and BQ.1.1 subvariants associated with the third wave in late 2022. The most recent (fourth) wave in 2023 coincided with a rise in XBB subvariants, which became dominant in human cases and wastewater samples.[3,97] These subvariants had also been associated with waves of infection overseas, notably in Singapore.[98]

Excess mortality

New Zealand sustained low excess mortality through the first 2 years of the pandemic until

Figure 5: COVID-19 wastewater detections and new cases in New Zealand, by day, from January 2020 (cases) and June 2021 (wastewater) to June 2023. Sources: ESR,[90] MoH.[4]

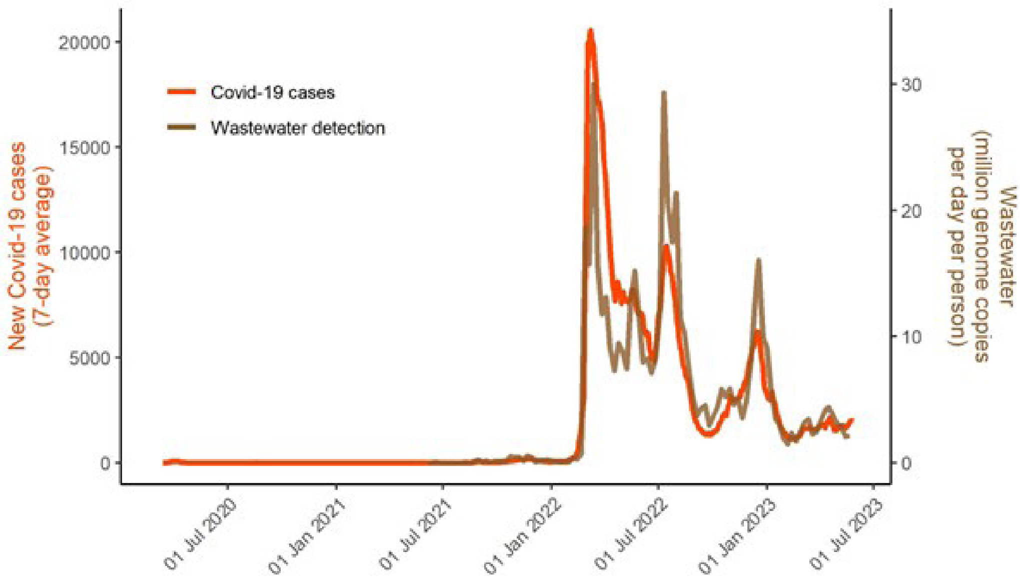


Figure 6: COVID-19 variants and subvariants isolated in New Zealand (including from Managed Isolation and Quarantine at the border), by day, February 2020 to June 2023. Source: ESR.[99]

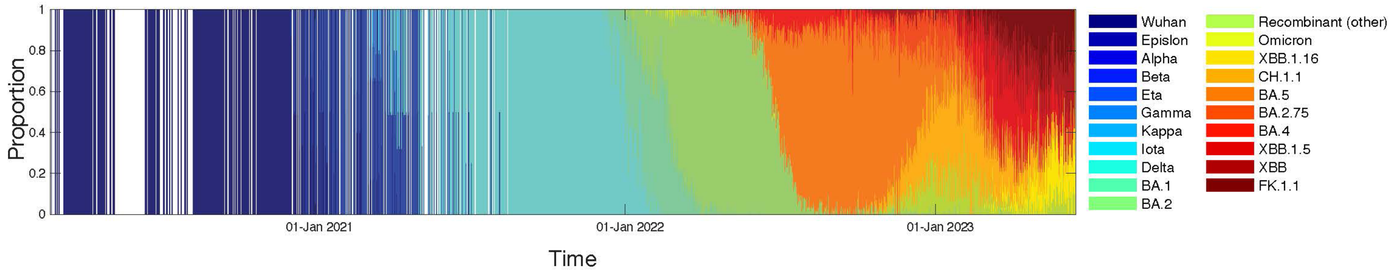
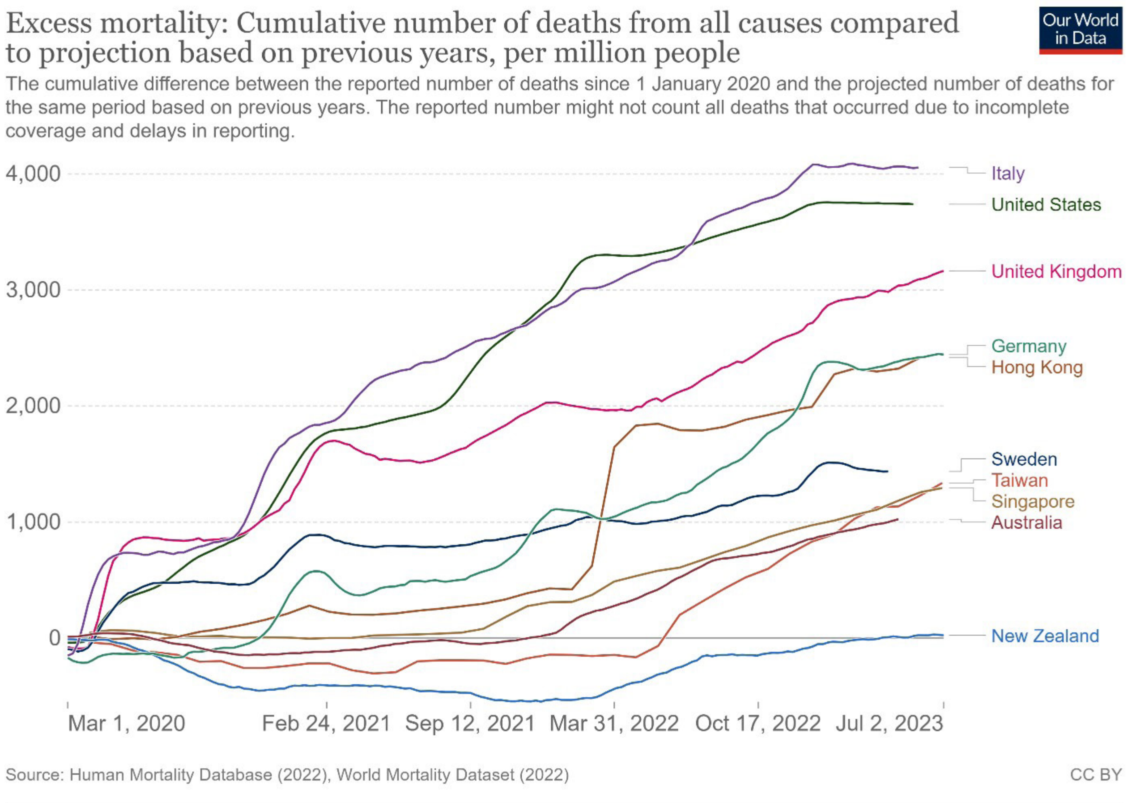


Figure 7: Cumulative excess mortality, expressed as deaths per million people from all causes compared to projected numbers based on previous years, for New Zealand and a selection of other high-income jurisdictions up to June 2023. Source: OWD.[102]



COVID-19 circulated widely in 2022.[62] Several organisations including WHO,[100] The Economist magazine[101] and Our World in Data (OWD)[102] have generated excess mortality estimates. These estimates use similar approaches of comparing total mortality since the start of the pandemic (January 2020) with "expected mortality" based on the pattern of the preceding years (OWD uses the preceding 5 years, 2015–2019[103]). The OWD site shows New Zealand is one of only four remaining countries globally that are estimated to have excess mortality close to zero at the time of writing (Figure 7). The other jurisdictions (Luxembourg, Antigua and Barbuda, and Seychelles) all have small populations (<0.7 million). The COVID-19 pandemic appears to be driving an increase in overall mortality in many countries, including in younger age groups,[104] but these totals do not distinguish between impacts of the infection itself and other factors such as reduced access to healthcare or suppression of other infectious diseases such as influenza.

If New Zealand (resident population 5.185 million in 2022) had experienced the cumulative excess mortality of the US (3,739.3 per million) then we would have had around 19,390 excess deaths up to the end of June 2023. With the United Kingdom (UK) excess mortality (3,164.8 per million), we would have had around 16,410 excess deaths, or using the experience of Sweden (1,436.3 per million) we would have had 7,450 excess deaths. New Zealand's excess was varying around zero in mid-2023 (122 at the time of writing).

Globally, COVID-19 is likely to have been the third leading cause of death in the world for the last 3 years (2020–2022).[105]

Longer-term effects of COVID-19 on population health

COVID-19 is a multi-organ disease with mechanisms of effect that include immune dysregulation, autoimmunity, abnormal neurological signalling and damage to small blood vessels (endothelial dysfunction) causing microclots.[106,107,108] Endothelial dysfunction is considered to be the central underlying mechanism of acute- and post-acute COVID-19 disease.[109]

These cell- and tissue-level impacts may manifest as a post-acute viral syndrome (syndromic long COVID)[110] similar to that caused by a range of other infections.[107,111] Alternatively, health impacts may follow a more organ-specific pattern, presenting as heart attacks, new-onset diabetes including type 1 diabetes in children, decreased lung function, cognitive dysfunction and others.[106,112–115] These types of health conditions do not appear to differ markedly from variant to variant, but the risk is lower in Omicron infections compared with earlier variants and there is evidence of a protective effect of vaccination.[116] Robust evidence of the effect of multiple Omicron reinfections is not yet available.

There appears to be a wide overlap between syndromic and non-syndromic presentations, with over 200 symptoms described to date. Because only a little over 3 years of observation time of this virus is possible, we can expect that different types of longer-term impacts may resolve or emerge in future. For example, there are arguments both for and against a role for COVID-19 in causing or exacerbating cancers.[117]

In this paper we use the term "long COVID" to cover all sequelae of COVID-19 infection. This term includes the alternative names of post-COVID conditions, long-haul COVID, post-acute COVID-19, long-term effects of COVID, chronic COVID and post-acute sequelae of SARS CoV-2 infection (PASC).

Estimating the incidence and prevalence of long COVID in populations is challenging. Studies of syndromic long COVID (i.e., reported symptoms) following infection include the following recent examples that show the wide range of findings from different study designs and measurement approaches. Each of the following cohort designs has potential to both under- and over-estimate the incidence.

- The WHO's current (2023) estimate is that 10–20% of people experience health effects that persist or manifest themselves more than 3 months after recovery from the initial episode; this estimate has not been updated for more recent variants.[8]
- The UK's Office for National Statistics (ONS) estimates that 2.4–4% of adults and 0.6–1% of children report having long COVID 12–20 weeks after infection (and 1.6–2.8% of adults and 0.4–0.6% of children reported having "limited daily activities").[118] The ONS survey is high quality, and the sampling frame and design are extremely robust. There are some measurement aspects (e.g., the timing and questionnaire) in the above estimate that may under-count long COVID.
- The Long COVID in Children and Young People (CloCK) study's most recent estimate for 11–17-year-olds (Omicron; prospective test-negative design; n=886; 5.9% survey response rate) was 12.1% of respondents (first positives), 16.1% (reinfected) and 4.8% (always tested negative) at both 3- and 6-months post-test. The analysis did not show a significant difference in prevalence of long COVID symptoms between first infections and reinfections.[119]
- The most recent estimate for adults from the National Institutes of Health's Researching COVID to Enhance Recovery (RECOVER) Initiative was that 10% (95% confidence interval [CI], 8.8–11%) of study participants were PASC-positive at 6 months (prospectively measured) based on a composite score of a small number of selected symptoms that aimed to optimise sensitivity and specificity. The authors reported that "*among participants with a first infection during the Omicron era, PASC*

frequency was higher among those with recurrent infections" and they reported a "modest reduction" in PASC among vaccinated participants compared with unvaccinated.[120]
- The US Census Bureau (Household Pulse Survey; April/May 2023) estimates that 5.6% (95% CI, 5.3–5.9) of all adults are currently experiencing long COVID.[121]
- In a 2021 New Zealand survey, 22% of respondents who had had a confirmed COVID-19 infection reported symptoms of long COVID.[11] This study had a 12% response rate and recruited participants who tested positive before December 2021, so these results reflect pre-Omicron variants and, in some cases, pre-vaccination infections.

Even at the lowest end of the prevalence range listed here, the impact of COVID-19 on long-term public health is highly concerning. A major reason is that population exposure is high, and continuing, resulting in infections and reinfections that will ultimately be experienced by most people. The long-term trajectory of this disease burden is very hard to predict given the multiple unknown factors. But the precautionary principle suggests we should take a cautious approach and assume the long-term health impact is at least as high as the mid-range estimates are suggesting and respond accordingly, at least until we have high-quality evidence to the contrary.

Therapeutic strategies to prevent and treat long COVID are an active area of research. A recently reported randomised controlled trial tested outpatient treatment options in a cohort of adults with overweight or obesity.[122] Randomisation took place between 30 December 2020 and 28 January 2022 with a 10-month follow-up. Only one treatment, metformin, showed a significant improvement over placebo in cumulative incidence of long COVID at day 300. The incidence of long COVID was 6.3% (95% CI, 4.2–8.2) in participants who received metformin and 10.4% (7.8–12.9) in those who received identical metformin placebo (hazard ratio [HR], 0.59; 95% CI, 0.39–0.89; p=0.012). Among the vaccinated subgroup, incidence was 6.1% and 7.2% respectively in the treatment and control groups (HR, 0.85; 95% CI, 0.46–1.57). This finding also provides additional therapeutic validation of long COVID as a clinical condition to add to the symptom data reported by those living with long COVID[123] and the large literature reporting radiological and immuno-pathological evidence of end-organ damage.[108]

Vaccination surveillance

The systems for surveillance of key aspects of vaccination include vaccine coverage surveillance conducted by the MoH[58] and vaccine adverse event surveillance conducted by MedSafe.[61]

Vaccination coverage data provide multiple measures of the time distribution of vaccination doses (Figure 8) and who is receiving vaccines, including breakdowns by place and person (age, ethnicity).[58]

Adverse event surveillance also includes multiple measures of vaccine safety. For example, it shows that the risk of sudden death in the 21 days following receipt of the main COVID-19 vaccine used in New Zealand (the Pfizer/BioNTech mRNA vaccine Comirnaty) is reduced to about half of the expected background rate.[61] This reduction is likely due to a *healthy vaccinee effect* where healthy people are preferentially vaccinated compared with those who are unwell with comorbidities. Serious adverse events are rare following vaccination. Of the deaths that occurred following administration of the Pfizer vaccine up to 30 November 2022, two were determined by the coroner to be due to myocarditis, of which one was likely vaccine-induced myocarditis and for one a link to the vaccine could not be excluded.[61] A total of around 11.9 million doses were given during this time.[61]

Other forms of COVID-19 surveillance

There are multiple additional forms of surveillance that have been used to better understand the COVID-19 pandemic and response. Some surveillance makes use of existing data gathering processes such as use of Google Global Mobility data.[124] Other surveillance is specifically designed to gather data on COVID-19. An example is behavioural risk factor surveillance conducted by the MoH.[125]

Stringency of COVID-19 restrictions in New Zealand

The OWD site also reports the level of COVID-19 restrictions for jurisdiction across the globe. They use the Oxford Stringency Index, a composite based on nine measures (school closures; workplace closures; cancellation of public events; restrictions on public gatherings; closures of public transport; stay-at-home requirements; public information campaigns; restrictions on internal movements; and international travel controls). The index is

Figure 8: Count of vaccinations administered by week from the COVID-19 Immunisation Register. Source: MoH.[58]

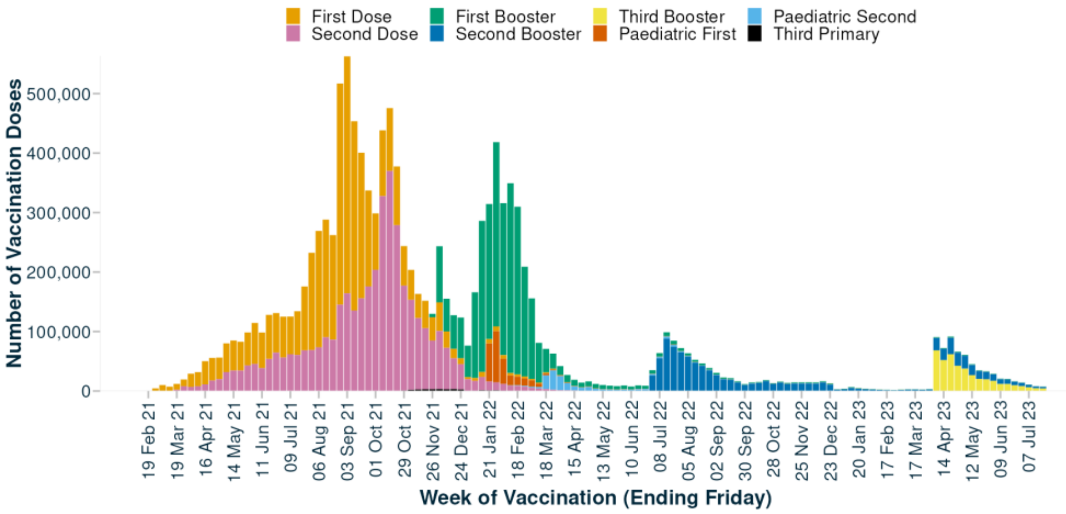
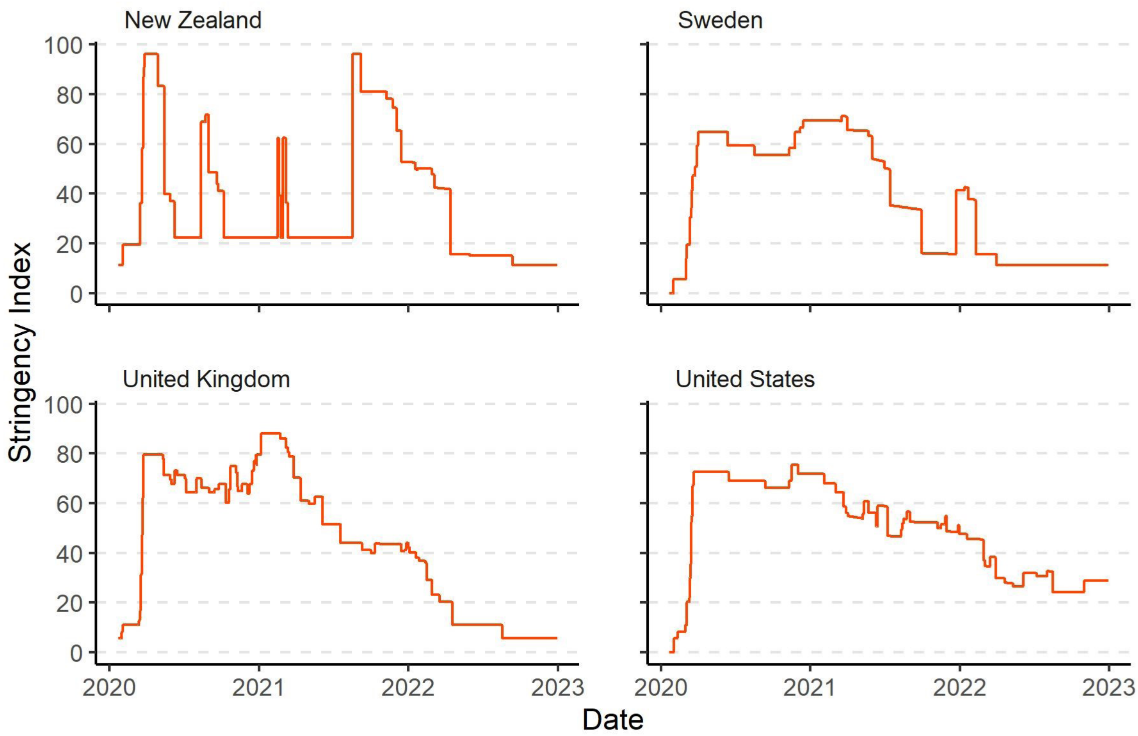


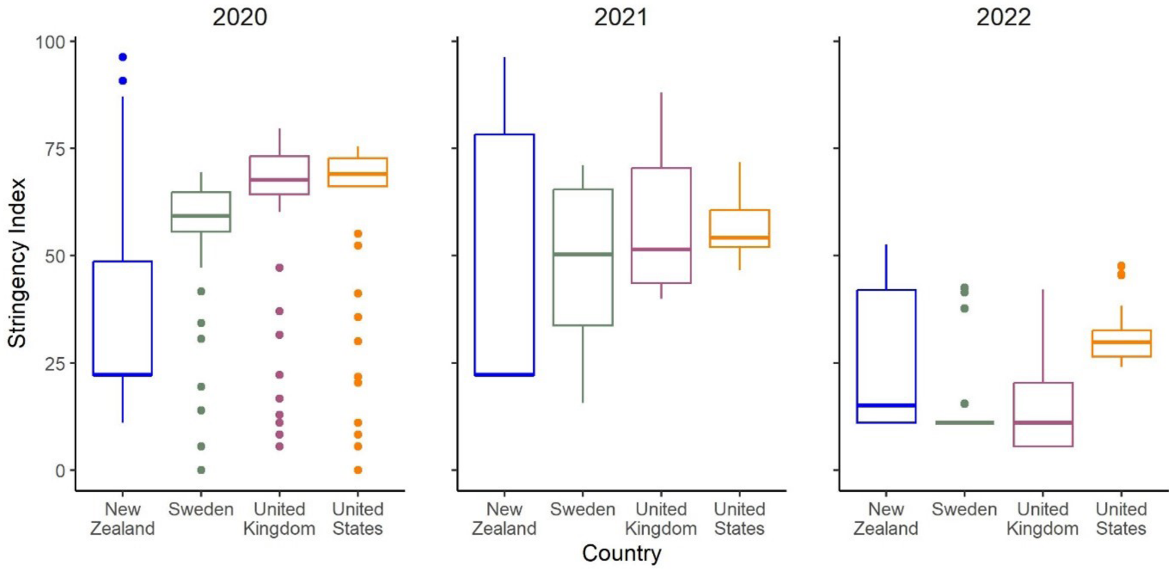
Figure 9: Level of COVID-19 restrictive policies during the pandemic in selected countries (22 January 2020 to 31 December 2022). The Stringency Index is based on nine response indicators including school and workplace closures and travel bans. Source: OWD.[102]



Appendix Table 1: Proportion of days per year spent above policy restriction thresholds (22 January 2020 to 31 December 2022; 1,075 days total). Source: OWD.[102]

Country	Percentage of days each year spent below/above Stringency Index thresholds (%)											
	2020				2021				2022			
	<30	≥30	≥50	≥70	<30	≥30	≥50	≥70	<30	≥30	≥50	≥70
New Zealand	59.4	40.6	21.2	17.4	57.0	43.0	40.3	29.6	72.1	27.9	14.2	0.0
Sweden	14.5	85.5	81.7	0.0	23.3	76.7	52.3	3.8	89.3	10.7	0.0	0.0
United Kingdom	16.2	83.8	82.6	37.1	0.0	100.0	54.5	27.7	87.7	12.3	0.0	0.0
United States	14.5	85.5	84.3	38.3	0.0	100.0	80.3	9.0	55.9	44.1	0.0	0.0

Figure 10: Median COVID-19 policy stringency for selected countries. Boxplots detail median, inter-quartile range, range and outliers (based on daily data, 22 January 2020 to 31 December 2022; 1,075 days total). Source: OWD.[102]



scaled from 0–100, with higher values indicating a greater level of restrictions.[126]

Figures 9 and 10 and Appendix Table 1 show a comparison of New Zealand with three other countries (a full range of country comparisons can be generated on the OWD website). This comparison shows how New Zealand used restrictions, such as stay-at-home orders (lockdowns), for relatively short periods during the elimination phase to "stamp out" COVID-19 outbreaks before returning to periods with few restrictions except at borders. Then during the suppression phase, it used them for a sustained period at a less intense level to minimise the transmission of COVID-19, before using them at a lower intensity during the mitigation phase.

By comparison, countries such as the US, UK and Sweden used moderate to high levels of restrictions continuously for much of the first 18 months of the pandemic to suppress transmission to minimise the health burden and avoid overwhelming health services. The net effect was markedly less time living with restrictions (≥50 stringency) in New Zealand during the first 2

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years of the pandemic, particularly in 2020. All countries greatly reduced controls following arrival and spread of the Omicron variant in late 2021 or early 2022.

Reassuringly for New Zealand, periods of relatively high stringency of pandemic controls in 2000 and 2001 were associated with negative excess mortality, i.e., low and decreasing mortality (Figure 7). Excess mortality increased in 2022 corresponding to less stringent controls and high COVID-19 infection. This evidence suggests COVID-19 infection has been the main cause of an increase in excess mortality in 2022 rather than the effects of pandemic control measures and vaccination.[62]

Limitations of surveillance data

All of the data presented here have important limitations. In general, disease surveillance systems have sensitivity that is less than 100%, so under-count cases. This is particularly the situation with systems that require an active reporting process, such testing and reporting of positive RAT results by members of the public. Systems based on well-recorded events, such as hospitalisations and deaths, are likely to be far more sensitive to COVID-19 but still have limitations because of requirements for clinical judgement, testing and accurate recording. Active surveillance based on wastewater testing is also likely to provide consistent measurement of the presence of COVID-19 infections in a community.

Similarly, it is difficult to estimate the future course of the pandemic as it transitions to being an endemic infection. As noted (under *Future course of the pandemic*), there are multiple contributing factors to these future epidemiological scenarios. The limitations of current surveillance data add further uncertainties.

International assessments depend on countries having at least a moderate degree of comparability of data collection and reporting. Measures like excess mortality may be more valid in some situations than routine reporting of specific outcomes, such as COVID-19 mortality. However, excess mortality is also an imperfect measure because it is sensitive to the estimated baseline, which is becoming increasingly difficult to reliably extrapolate from pre-pandemic trends, and it cannot distinguish between deaths that are directly related, indirectly related and unrelated to the pandemic. Composite indexes, such as the Oxford Stringency Index, inevitably involve simplification of the policy responses in different countries (particularly for countries with very heterogeneous response across jurisdictions such as the US) to provide a single measure that can be used for comparison purposes.

Appendix 2: Timing of transitions through different COVID-19 response strategies

Here we summarise when New Zealand transitioned through different pandemic response strategies, from elimination to mitigation. We provide a rationale for assigning a date for each transition based on when the strategy was implemented.

It is important to note the limitations of this process. Government officials did not necessarily use standard terms for describing disease control strategies, so we have to infer them from the description of the measures being used and their aims. Suppression and mitigation strategies are on a spectrum rather than having a precise definition. Also, the implementation of specific strategies often included multiple incremental steps. For these reasons, the transition dates are indicative rather than being precise.

Elimination strategy

The elimination strategy aims to reduce transmission of an infectious disease to zero for a defined geographic area and time period.[28,87]

The elimination strategy was effectively announced on 23 March 2020, with New Zealand placed on Alert Level 3 immediately and a proposal to move to Alert Level 4 at 11:59 pm on 25 March. Government leaders and officials did not use the term elimination until several weeks later, but there was a strong implication that the intent was to eliminate COVID-19 from New Zealand.

We have therefore set the start day of the elimination strategy as **26 March 2020.**

The strategy achieved its aim of eliminating COVID-19 infection with the last case identified in early May and a move to Alert Level 1 on 8 June 2020, effectively declaring the end of person-to-person transmission within New Zealand.[127] Elimination continued successfully across New Zealand, with occasional small outbreaks, until the Delta variant outbreak was detected in Auckland on 17 August 2021, with New Zealand being placed back on Alert Level 4. This outbreak proved difficult to eliminate in Auckland, necessitating a change in strategy.

Suppression strategy

The suppression strategy aims to reduce the transmission of an infectious disease and the consequences of infection to minimise its health burden.[26,87]

The transition from elimination to suppression was signalled on 4 October 2021 when the Government announced that the elimination strategy would be phased out.[128] It would be replaced with the COVID-19 Protection Framework or "traffic lights" system.[129] Implementation happened at 11:59 pm on 2 December 2021, when the Alert Level System was retired and the COVID-19 Protection Framework was introduced.[129]

We have therefore set the start day for the suppression strategy as **3 December 2021**.

The strategy achieved its aim of suppressing the Delta variant wave of infection in both size and geographic spread.[30]

Mitigation strategy

The mitigation strategy provides a lower level of disease reduction than suppression, with a particular aim of protecting the health system from being overwhelmed.[87]

The transition from suppression to mitigation was signalled on 26 January 2022 with the Government announcing its three-phase public health response to Omicron.[130] The first phase articulated a suppression approach: "*Phase One is where we are now, and we are doing what we have successfully done with Delta—taking a 'stamp it out' approach … Our objective is to keep cases as low as possible for as long as possible to allow people to be boosted and children to be vaccinated without Omicron being widespread*." This phase retained PCR testing and a 14-day isolation period for cases. Phases Two and Three signalled a shift away from identifying all cases and attempting to interrupt transmission. Implementation of this shift in strategy occurred with the move to Phase Two of the Omicron response at 11:59 pm on 16 February 2022.

We have therefore set the start day for the mitigation strategy as **17 February 2022.** Other measures associated with elimination and suppression were removed after this date, notably a phased reduction in border controls.[131]

This change to mitigation was also a pragmatic response to the introduction and rapid spread of Omicron cases. The first case of community transmission of Omicron in New Zealand was reported on 18 January 2022. Cases accelerated from 28 January and steeply during February, with a peak of almost 24,000 reported cases on 8 March. Arguably, the mitigation strategy achieved its aim, as the New Zealand healthcare system was stressed but not overwhelmed.

COMPETING INTERESTS

Nil.

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