Long-term COVID-19 control requires high vaccination and intermittent control measures

Whilst vaccines are critical to control the COVID-19 pandemic, the roll-out of an effective vaccine is the beginning, not the end of the pandemic. Both the AstraZeneca and Pfizer vaccines have demonstrated very high efficacy against severe disease and death, offering protection for most individuals who receive them. However, multiple models have shown that the combination of imperfect protection against infection (60-80%) and emerging more infectious variants means that Australia, and other countries globally, are unlikely to achieve herd immunity, even with high (80-90%) vaccine coverage [1-6].

Without herd immunity, if the virus were allowed to run without a public health response, thousands of deaths could occur in Victoria alone [4], despite many having individual-level protection from the vaccine. At the same time, Australia cannot keep its borders closed indefinitely. A key question is therefore what control strategies are proportionate, in a world with high vaccine coverage, no herd immunity, and an ongoing “leakage” of cases into the community from relaxed quarantine.

For this study, we used the Covasim model to simulate the Victorian population once a high-vaccine coverage is reached and considered the ongoing seeding of undiagnosed delta variant strains into the community. Specifically we assumed:

- 95%/70%/70% vaccine coverage for people aged 60+/12-59/<12 years
- Delta strain to be twice as infectious as the wild type from Victorian second wave
- Vaccine efficacy against the delta strain to be 80% protection against infection and 92% protection against death [7]
- New, undiagnosed infectious were introduced to the community at a rate of 5 incursions per day
- Testing, tracing and isolation of cases continues

As well as no response (i.e. “let it run”), we considered outcomes over a 12-month period for response scenarios triggered by either a 7-day average of 10, 20 or 50 diagnoses per day, or hospitals reaching 100 or 250 beds in use:
1. Light restrictions/density limits (masks, work from home where possible, 4sqm rule and outdoor gatherings <50)
2. Medium restrictions (additional limits on household gatherings)
3. Lockdown

Key findings

Even with high vaccination coverage, continually introducing cases through relaxed quarantine is likely to lead to outbreaks that require public health responses. However, greater vaccine coverage provides a variety of response and control options.

1. Even with high vaccine coverage, without any public health response to outbreaks thousands of deaths could occur

   If herd immunity has not been reached, an epidemic can still occur among the unprotected population, including infections among vaccinated people because of imperfect protection against infection. The proportion of overall deaths occurring for vaccinated individuals varies greatly depending on vaccine coverage and efficacy, but for the baseline scenario approximately 45% of deaths occur within the vaccinated population.

2. Light restrictions are likely to be sufficient to control outbreaks, whereas heavier restrictions would gain control faster

   - With 95%/70%/70% vaccine coverage among people aged 60+/12-59/<12 years, masks, optional working from home and density limits were sufficient to control of outbreaks of the delta strain if brought in sufficiently early.
   - However, additional restrictions on home visitors would be required if the vaccine was less effective at preventing infections (80% protection in the model), vaccine coverage was lower, or children under 12 were not eligible.
   - When harder responses were used, less time was spent on average under restrictions

3. If infections are continually introduced, then restrictions will either need to be maintained or periodically re-imposed

   Without herd immunity, the ongoing introduction of cases means that outbreaks will continue to occur. If international quarantine is eased, this creates a choice between living with some restrictions or frequently taking restrictions on/off.

4. These results hold when using either diagnoses or hospital utilization as trigger thresholds

   Without herd immunity if restrictions are lifted exponential growth resumes. However, using hospital usage as a trigger threshold for restrictions may lead to less overall time under restrictions while still achieving adequate health outcomes.

Further work is required to assess appropriate trigger thresholds for introducing restrictions, accounting for contact tracing capacity, to minimize both the time spent under restrictions and the frequency that restrictions need to be changed.

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**Background and aim**

Whilst vaccines are critical to control the COVID-19 pandemic, the roll-out of an effective vaccine is the beginning, not the end. Both the AstraZeneca and Pfizer vaccines have demonstrated very high efficacy against severe disease and death, offering protection for most individuals who receive them. However, multiple models have shown that the combination of imperfect protection against infection (60-80%) and emerging more infectious variants means that Australia is unlikely to achieve herd immunity, even with high (80-90%) vaccine coverage [1-6].

Without herd immunity, if the virus were allowed to run without a public health response, modelling has shown that thousands of deaths could occur in Victoria alone [4], despite the individual-level protection of many. At the same time, Australia cannot keep its borders closed and the virus out indefinitely.

The aim of this study was to answer the key question: what control strategies would be proportionate, in a world with high vaccine coverage yet short of herd immunity, and an ongoing “leakage” of cases into the community through relaxed quarantine.

We used the Covasim model to simulate the Victorian population once a high-vaccine coverage is reached, and then considered the ongoing seeding of undiagnosed delta variant strains into the community and response options to control outbreaks.

**Method**

**Model overview**

We used an established agent-based microsimulation model, Covasim [8], developed by the Institute for Disease Modelling (USA) and previously adapted by the Burnet Institute to model the Victorian epidemic [9-11]. The model is available online [12] and reports are also available outlining its application to a number of other settings [13]. In brief, agents in the model are assigned an age (which affects their susceptibility to infection and also their likelihood of being symptomatic), a household, a school (for people age 5-17) or a workplace (for people over 18, up to 65), and they participate in a number of daily community activities including attending restaurants, pubs, places of worship, community sport, and small social gatherings. Details of included contact types, network structures, transmission probabilities, and contact tracing capability (which vary by setting) are provided in the appendix at the end of this report.

**Calibration**

The model was calibrated to data on daily new detected cases and hospitalisations from the COVID-19 outbreak in Victoria over the June-September period [14], and the associated policy changes and interventions that were implemented over that period (Table S2, with calibration and parameters associated with policy changes provided in the appendix). However, the model calibration was only used to determine and constrain parameters. For this analysis, each simulation was based on new cases being introduced and observing in the model whether those cases potentially led to a resurgence in cases, and policy options to prevent this outcome.

**Interventions**

The model includes testing, contact tracing and quarantine of close contacts and their household contacts, isolation of confirmed cases, masks, physical distancing policies in venues (e.g., the 4 square metre rule), and policy restrictions to prevent or reduce transmission in different settings (e.g., closing schools or venues).

**Symptomatic testing probability (COVID-19 cases)**

The general community will continue to test based on symptoms. In the absence of community transmission, an overall symptomatic testing probability of 11% per day of symptoms was estimated for Victoria. However, community uptake of symptomatic testing has been observed to radically increase after incursions were detected, amounting to a 45% relative increase.
in the daily symptomatic test probability in Victoria (see Appendix). We have assumed that this higher rate of symptomatic testing would be sustained in the event of ongoing incursions and community transmission, and therefore use an overall symptomatic testing probability of 1.6% per day for symptomatic individuals in all scenarios.

**Testing and contact tracing**
The model uses daily time steps and the testing/contact tracing system was approximated as follows:

1. Day 0: Test is taken by index case
2. Day 1 (24 hours following test): Positive test results are returned, index case is notified and enters isolation
3. Day 2 (48 hours following test being taken): Contact tracing completed, with contacts having a setting-specific probability of being detected (Table S1), reflecting differences in the level of difficult in identifying contacts in that network (e.g. households vs public transport contacts). Identified contacts are tested and quarantined for 14 days regardless of test results, along with their entire households. Contacts are additionally tested on day 11 of quarantine, regardless of symptoms.
4. Day 3 (72 hours following test): Test results for contacts become available, and any contacts who returned a positive initial test would then have their contacts traced within the next 24 hours, in the same manner as the index case.

It was assumed that contact tracing capacity was 250 cases per day. We also assumed no change to the tracing and isolation requirements – specifically, we assume no changes to QR code usage and a continued requirement for household and aged care secondary contacts to isolate as well as direct contacts. The contact tracing capacity does not apply to household contacts, which are assumed to be directly notified by newly diagnosed individuals.

**Policy options**
For this analysis, the scenarios were based on the policy packages defined in Table 1.

Table 1: Definition of different response levels in the model. Parameters for each policy are provided in the appendix.

<table>
<thead>
<tr>
<th>Policy</th>
<th>Level 0</th>
<th>Light Density restrictions</th>
<th>Medium Density + No gatherings</th>
<th>Lockdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor gatherings</td>
<td>Unrestricted</td>
<td>&lt;50</td>
<td>&lt;10</td>
<td>&lt;2 people</td>
</tr>
<tr>
<td>Small social gatherings</td>
<td>Allowed</td>
<td>Allowed</td>
<td>Stage 3</td>
<td>Stage 4</td>
</tr>
<tr>
<td>Childcare</td>
<td>Open</td>
<td>Precautions</td>
<td>Open</td>
<td></td>
</tr>
<tr>
<td>Schools</td>
<td>Open</td>
<td>Precautions</td>
<td>Precautions</td>
<td></td>
</tr>
<tr>
<td>Work</td>
<td>Unrestricted</td>
<td>Work from home if possible</td>
<td>Work from home if possible</td>
<td>Heavy restrictions</td>
</tr>
<tr>
<td>Community sports</td>
<td>Allowed</td>
<td>Allowed</td>
<td>Allowed</td>
<td>Cancelled</td>
</tr>
<tr>
<td>Places of worship</td>
<td>Open</td>
<td>4sqm</td>
<td>4sqm</td>
<td>Closed</td>
</tr>
<tr>
<td>Cafes/restaurants</td>
<td>Open</td>
<td>4sqm</td>
<td>4sqm</td>
<td>Take-away</td>
</tr>
<tr>
<td>Pubs/bars</td>
<td>Open</td>
<td>4sqm</td>
<td>4sqm</td>
<td>Closed</td>
</tr>
<tr>
<td>Masks</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Entertainment venues</td>
<td>Open</td>
<td>Open</td>
<td>Open</td>
<td>Closed</td>
</tr>
<tr>
<td>Mobility restrictions</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Virus strain**
The model parameters for the probability of transmission per contact with an infectious case have been calibrated to the dynamics of the second epidemic wave in Victoria. For this analysis, we model the delta variant by increasing the probability of transmission per contact by a factor of 2.0. The same disease prognoses are applied for people who become infected (e.g., incubation period, age-specific probability of being symptomatic).
**Vaccination**

In the model, vaccination acts to reduce the probability of acquiring an infection when a contact occurs with an infectious case, as well as the probability of developing symptoms (both mild and severe) for people who are vaccinated and become infected. The assumed efficacy values are below; they are, based on estimates of two dose Pfizer vaccine against the delta strain from Imperial College London, London School of Hygiene and Tropical Medicine and Warwick University [7].

<table>
<thead>
<tr>
<th>Vaccine impact</th>
<th>Infection</th>
<th>Symptoms</th>
<th>Hospitalization</th>
<th>ICU</th>
<th>Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall protection</td>
<td>80%</td>
<td>85%</td>
<td>87%</td>
<td>89%</td>
<td>92%</td>
</tr>
</tbody>
</table>

The vaccine’s prevention of infection is approximated as an all-or-nothing process, where a percentage of vaccinated people are assumed to have full protection and others no protection, based on the vaccine’s efficacy. This is as opposed to modelling partial protection for everyone, because it is difficult to parametrize reduction in transmission risk per contact from current data.

An independent behavioural factor was also modelled where people who are vaccinated had a 50% reduction in their probability of seeking testing if they had mild symptoms, compared to people who were not vaccinated. Vaccinated individuals were assumed to still test and quarantine the same as non-vaccinated people if they were identified as a close contact of a confirmed case.

Vaccination in the community was prioritized according to age, with vaccines allocated first to people aged >70 years, then 60-69, followed by 50-59, etc.

**Children under 12 were modelled as eligible for vaccination.** This assumes that they would have become eligible by the time high vaccination coverage is achieved (estimated 2022). This assumption is tested in a sensitivity analysis.

**Incursions**

The scenarios modelled here reflect a future in which border controls have been relaxed, such that there are a small number of incursions into the community occurring on a daily basis. We modelled 5 incursions per day, corresponding to 5 new cases being seeded in the population randomly each day. Sensitivity analyses were performed to test 1 or 10 incursions per day.

**Part 1 scenarios: different responses to rising case numbers**

In a scenario where outbreaks are occurring daily, population level restrictions would likely be driven by population level metrics such as the number of new cases per day, rather than a response to individual incursion events. We therefore modelled a range of response strategies, in which restrictions are introduced or eased depending on the 7-day average diagnoses. The total time spent under restrictions, the frequency that restrictions change, and the effectiveness of the restrictions will vary depending on the chosen thresholds for introducing and easing restrictions. For this analysis, the policy responses in Table 2 were simulated, as a representative set of strategies.
A policy, health and implementation response to COVID-19

Table 2: Policy options based on case number trigger thresholds that were simulated for controlling outbreaks, alongside testing, contact tracing and isolation

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Scenario name</th>
<th>Threshold for introducing restrictions (7-day average diagnoses)</th>
<th>Threshold for easing restrictions (7-day average diagnoses)</th>
<th>Policy response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Let it run</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>Go early with light restrictions</td>
<td>10</td>
<td>5</td>
<td>Light restrictions; Masks, work from home, density limits</td>
</tr>
<tr>
<td>3</td>
<td>Go early with medium restrictions</td>
<td>10</td>
<td>5</td>
<td>Medium restrictions; Masks, work from home, density and social limits</td>
</tr>
<tr>
<td>4</td>
<td>Go early with lockdown</td>
<td>10</td>
<td>5</td>
<td>Lockdown; lockdown</td>
</tr>
<tr>
<td>5</td>
<td>Wait then add light restrictions</td>
<td>20</td>
<td>10</td>
<td>Light restrictions; Masks, work from home, density limits</td>
</tr>
<tr>
<td>6</td>
<td>Wait then add medium restrictions</td>
<td>30</td>
<td>10</td>
<td>Medium restrictions; Masks, work from home, density and social limits</td>
</tr>
<tr>
<td>7</td>
<td>Wait then lockdown</td>
<td>50</td>
<td>10</td>
<td>Lockdown; heavy restrictions</td>
</tr>
<tr>
<td>8</td>
<td>Gradually escalate restrictions</td>
<td>Staged: 10, 30, 50</td>
<td>Staged: 5, 10, 10</td>
<td>Light restrictions, Medium restrictions, Lockdown</td>
</tr>
<tr>
<td>9</td>
<td>Escalate with delayed backstop</td>
<td>Staged: 50, 100, 150</td>
<td>Staged: 20, 20, 75</td>
<td>Light restrictions; Medium restrictions; Lockdown</td>
</tr>
</tbody>
</table>

Part 2: scenarios: different responses to rising hospital utilization

We modelled a range of response strategies in which restrictions are introduced or eased depending on the number of hospital beds in use (Table 3), for example introducing restrictions when 100 or 250 beds are in use, and easing them again when hospital bed usage eases to 50 or 100 respectively.

Table 3: Policy options based on case hospital bed utilization thresholds that were simulated for controlling outbreaks, alongside testing, contact tracing and isolation

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Scenario name</th>
<th>Threshold for introducing restrictions (hospital usage)</th>
<th>Threshold for easing restrictions (hospital usage)</th>
<th>Policy response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Let it run</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>Go early with light restrictions</td>
<td>100</td>
<td>50</td>
<td>Light restrictions; Masks, work from home, density limits</td>
</tr>
<tr>
<td>3</td>
<td>Go early with medium restrictions</td>
<td>100</td>
<td>50</td>
<td>Medium restrictions; Masks, work from home, density and social limits</td>
</tr>
<tr>
<td>4</td>
<td>Go early with lockdown</td>
<td>100</td>
<td>50</td>
<td>Lockdown; lockdown</td>
</tr>
<tr>
<td>5</td>
<td>Wait then add light restrictions</td>
<td>250</td>
<td>200</td>
<td>Light restrictions; Masks, work from home, density limits</td>
</tr>
<tr>
<td>6</td>
<td>Wait then add medium restrictions</td>
<td>250</td>
<td>200</td>
<td>Medium restrictions; Masks, work from home, density and social limits</td>
</tr>
<tr>
<td>7</td>
<td>Wait then lockdown</td>
<td>250</td>
<td>200</td>
<td>Lockdown; lockdown</td>
</tr>
<tr>
<td>8</td>
<td>Wait then add light restrictions with delayed easing</td>
<td>250</td>
<td>50</td>
<td>Light restrictions; Masks, work from home, density limits</td>
</tr>
<tr>
<td>9</td>
<td>Wait then add medium restrictions with delayed easing</td>
<td>250</td>
<td>50</td>
<td>Medium restrictions; Masks, work from home, density and social limits</td>
</tr>
<tr>
<td>10</td>
<td>Wait then lockdown with delayed easing</td>
<td>250</td>
<td>50</td>
<td>Lockdown</td>
</tr>
</tbody>
</table>
Sensitivity analysis
The model scenarios were re-run with alternate assumptions for:

- **Lower vaccine efficacy**: Vaccine protection against infection of 65% instead of 80%, reflecting either lower efficacy of Pfizer or the population partly covered by AstraZeneca
- **Lower vaccine coverage**: Vaccine coverage of 85%/50%/50% among people aged 60+/12-50/<12 years (rather than 95%/70%/70%)
- **Higher vaccine coverage**: Vaccine coverage of 95%/90%/90% among people aged 60+/12-50/<12 years (rather than 95%/70%/70%)
- **Children remain ineligible for vaccination**: Children under 12 years not being included in the vaccine coverage (i.e. 95%/70%/0% among people aged 60+/12-50/<12 years).
- **Incursions per day**: Either 1, 5 or 10 incursions per day.

Results

Main results: case numbers as trigger thresholds
If a vaccine coverage of 95%/70%/70% among people aged 60+/12-59/<12 was achieved in Victoria, and the vaccine provided 80% protection against infection and 92% protection against death, then herd immunity is not reached against the delta virus strain, even if testing and contact tracing continue. Under these conditions, if cases are continually seeded into the community, then an outbreak eventually occurs.

Without any restrictions being imposed to control outbreaks, then over a 12-month period thousands of deaths could occur (Figure 1). In particular, around 45% of these deaths are expected among the portion of people who are vaccinated for whom the vaccine does not prevent infection (Figure 1). This is because if the vaccine has 80% protection against infection and an overall 92% protection against death, then most of the mortality impact comes from preventing infections in the first place, and for people who do become infected the vaccine only provides 60% protection against death (60% = [0.92 - 0.80]/[1 - 0.80]). The mortality risk profile for vaccinated and unvaccinated populations is shown in Figure 2 by age group; for example, an infected 80 year old who is vaccinated has the same risk of death as an infected 70 year old who is not vaccinated.

Light restrictions (i.e. masks, optional working from home and density limits; Table 1) are estimated to be sufficient to control the outbreak, and if implemented early would result in very few deaths (median across simulations = 31 deaths). However, they would need to be in place for the majority of the 12-month projection (>300 days). This is because once an outbreak is controlled, the continual seeding of infections meaning that outbreaks and exponential growth continues and responses are once again needed.

Using harder restrictions to control outbreaks requires them to be in place for shorter time periods, but this also requires restrictions to be changed more frequently, leading to greater policy uncertainty. Figure 3 shows an example of the time spent under restrictions in the scenario where the response is gradually escalated as cases increase.

The sensitivity analysis (Figure 4) suggests that additional restrictions on home visitors would be required if the vaccine was less effective at preventing infections, vaccine coverage was lower, or children under 12 were not eligible. Alternatively, vaccine coverage of 95%/90%/90% among people aged 60+/12-50/<12 years, with a vaccine that provided 80% protection against infection was sufficient to achieve herd immunity against the delta strain.
80% efficacy, 95/70/70% coverage, 5 incursions/day, cases strategy

Figure 1: Projected covid-19 deaths in Victoria over a 12-month period under different outbreak response scenarios, triggered by case numbers (left), and average time spent under restrictions (right). Grey bars show the projected number of deaths on a log scale, with the lighter shading indicating the proportion that are among the vaccinated population. Scenarios are based on 95%/70%/70% vaccine coverage being achieved among people aged 60+/12-59/<12 years, the vaccine having an assumed 80% protection against infection and 92% protection against death, and 5 cases per day were seeded into the community through reduced quarantine measures.

Figure 2: Probability of death given infection, for vaccinated vs unvaccinated. If the vaccine has 80% protection against infection and an overall 92% protection against death, then it only provides 60% protection against death for vaccinated people who become infected (60% = \([0.92-0.80]/[1-0.80]\)). This means an infected 80 year old who is vaccinated has the same risk of death as an infected 70 year old who is not vaccinated.
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Figure 3: Illustrative example of projected cases (7-day average daily diagnoses) and hospital bed usage in Victoria over a 12-month period under the ‘Escalate with delayed backstop’ scenario, with restrictions triggered by case numbers. Light, medium, or lockdown level restrictions are introduced progressively when the 7-day average diagnoses reach 50, 100, or 150, respectively (blue horizontal lines). In red, the top panel shows cases and bottom panel shows hospital bed usage. Note that this figure reflects restriction levels being triggered based on cases rather than hospitalisations (compared with Figure 6).

Figure 4: Sensitivity analysis for different vaccine protection against infection, vaccine coverage among different age groups, and incursions per day. Column with black border reflects scenario shown in Figure 1.
Main results: hospital bed usage as trigger thresholds

Qualitatively similar results were observed when hospital bed usage was used to trigger the introduction or release of restrictions, rather than diagnoses. Namely, light restrictions (i.e. masks, optional working from home and density limits) were sufficient to stop the exponential growth of cases and reduce bed usage when there was high levels of vaccine coverage and vaccine efficacy was 80%, but once restrictions were eased the exponential growth continued and restrictions needed to be introduced (Figure 5).

Compared to when case numbers are used to trigger restrictions, the ‘go early with light restrictions’ options using hospital beds as a trigger threshold maintains an acceptable number of deaths with much less time spent in restrictions. However, if restrictions are introduced too late (e.g. “Wait then add light restrictions” scenario; Figure 5) then deaths may escalate quickly. In the model, a contact tracing capacity of 250 diagnoses per day is assumed, and if restrictions are not introduced until 250 hospital beds are in use, this is likely to have been exceeded, and therefore harder restrictions are required to compensate the loss of contact tracing efficacy.

The harder the restrictions used to control outbreaks, the shorter the duration under restrictions was required.

The time between restrictions being eased and reintroduced was dependent on the gap between the restriction introduction and release thresholds.

Figure 5: Projected covid-19 deaths in Victoria over a 12-month period under different outbreak response scenarios, triggered by hospital bed usage (left), and average time spent under restrictions (right). Grey bars show the projected number of deaths on a log scale, with the lighter shading indicating the proportion that are among the vaccinated population. Scenarios are based on 95%/70%/70% vaccine coverage being achieved among people aged 60+/12-59/<12 years, the vaccine having an assumed 80% protection against infection, 87% overall protection against hospitalization and 92% protection against death, and 5 cases per day were seeded into the community through reduced quarantine measures.
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Figure 6: Illustrative example of projected cases (7-day average daily diagnoses) and hospital bed usage in Victoria over a 12-month period under the ‘Go early with light restrictions’ scenario, with restrictions triggered by hospital bed usage. Restrictions are introduced when 100 hospital beds are in use (blue horizontal lines). In red, the top panel shows cases and bottom panel shows hospital bed usage. Note that this figure reflects restriction levels being triggered based on hospital bed usage, rather than cases (compared with Figure 3).

Figure 7: Sensitivity analysis for different vaccine protection against infection, vaccine coverage among different age groups, and incursions per day. Column with black border reflects scenario shown in Figure 5.
Conclusions and recommendations

Even with a high vaccination coverage, if cases are continually introduced to the community through relaxed quarantine, outbreaks will inevitably occur that require public health responses to control them. Fortunately, greater vaccine coverage provides more margin for error and a greater variety of response options and control configurations.

1. **Even with high vaccine coverage, without any public health response to outbreaks thousands of deaths could occur**
   
   If herd immunity has not been reached, an epidemic can still occur among the unprotected population, including infections among vaccinated people because of imperfect protection against infection.

2. **The need for an ongoing public health response is as a whole of population issue, rather than an issue for people who are not vaccinated.** In a number of scenarios a high proportion of deaths occur in people who have been vaccinated.
   
   - The proportion of overall deaths occurring for vaccinated individuals varies greatly depending on vaccine coverage and efficacy, but for the baseline scenario approximately 45% of deaths occur within the vaccinated population.
   
   - For example, if the vaccine has 80% protection against infection and 92% overall protection against death then an infected 80 year old who is vaccinated has the same risk of death as an infected 70 year old who is not vaccinated.

3. **Light restrictions are likely to be sufficient to control outbreaks, whereas heavier restrictions would gain control faster**
   
   - With 95%/70%/70% vaccine coverage among people aged 60+/12-59/<12 years, masks, optional working from home and density limits were sufficient to control of outbreaks of the delta strain if brought in sufficiently early.
   
   - However, additional restrictions on home visitors would be required if the vaccine was less effective at preventing infections than the 80% protection in the model, vaccine coverage was lower, or children under 12 were not eligible.
   
   - When harder responses were used, less time was spent on average under restrictions

4. **If infections are continually introduced, then restrictions will either need to be maintained or periodically re-imposed**
   
   Without herd immunity, the ongoing seeding of cases in the community means that outbreaks will continue to occur. If international quarantine is eased, this creates a choice between living with some restrictions or ongoing policy changes.

5. **These results hold when using either diagnoses or hospital utilization as trigger thresholds**
   
   Without herd immunity if restrictions are lifted exponential growth resumes. Using hospital usage as a trigger threshold for restrictions may lead to less overall time under restrictions while still achieving adequate health outcomes. However, delaying the introduction of restrictions until high a high number of restrictions may lead to the need for harder restrictions to control growth due to the impact on the contact tracing system (see below).

6. **Trigger thresholds for introducing restrictions must factor in contact tracing capacity**
   
   Once contact tracing capacity is exceeded, harder restrictions may be required to achieve the same results as lighter restrictions + contact tracing.

Further work is required to assess appropriate trigger thresholds for introducing restrictions, accounting for contact tracing capacity, to minimize both the time spent under restrictions and the frequency that restrictions need to be changed.

Where applicable, these results are consistent with other modelling studies being conducted on the long-term solutions for COVID-19 in Australia [1-6], and highlight the need for further national conversations on what might be acceptable to the community, business and other sectors.
Limitations

The findings presented are derived from an individual-based model, which is an imperfect representation of the real world.

- This analysis is based on the delta variant and the effectiveness of the Pfizer vaccine against it. These vaccine efficacy parameters are difficult to measure and may change over time as further studies are conducted.
- In the future other strains may emerge with different properties to the delta variant, and this would change the results.
- There is emerging evidence that disease prognosis following infection with the delta variant may be worse than the original variant, and these effects are not included. Therefore hospitalizations and deaths may be higher than we have estimated.
- There is also emerging evidence that the incubation period for the delta strain may be shorter than the original variant. This may make contact tracing less effective, and outbreaks more difficulty to control than we have estimated.
- We have assumed no change to effectiveness of testing, contact tracing and quarantine with increased vaccination coverage, which may overestimate effectiveness if people are less compliant with QR sign in and other measures once they are vaccinated.
- It is not clear how testing and contact tracing capacity will fare as outbreak size increases. For these projections, we have assumed an unvalidated maximum of 250 contacts being traced each day.
- This model currently only attributes basic properties to individuals, specifically age, household structure and participation in different contact networks. The model does not account for any other demographic and health characteristics such as socioeconomic status, comorbidities (e.g. non-communicable diseases) and risk factors (e.g. smoking) and so cannot account for differences in transmission risks, testing, quarantine adherence or disease outcomes for different population subgroups.
- The model does not include a geospatial component and so cannot capture geographic clustering of vaccination or infection.
- The model simulates symptomatic testing by having a parameter for the per day probability of being tested if symptoms are present. This means that the distribution of time from symptom development to testing is binomial, which may differ from the true distribution of time from symptom onset to testing.
- Model parameters are based on best-available data at the time of writing. However, studies are underway to obtain improved data to inform these parameters, including estimates of social mixing, contact networks, adherence to policies and quarantine advice, and disease characteristics (e.g. asymptomatic cases).
References


Appendix: Additional methodological details

The agent-based model Covasim models the spread of COVID-19 by simulating a collection of agents representing people. Each agent in the model is characterised by a set of demographic and disease properties:

- **Demographics:**
  - Age (one-year brackets)
  - Household size, and uniquely identified household members
  - Uniquely identified school contacts (for people aged 5-18)
  - Uniquely identified work contacts (for people aged 18-65)
  - Average number of daily community contacts (multiple settings / contact networks modelled, described below)

- **Disease properties:**
  - Infection status (susceptible, exposed, recovered or dead)
  - Whether they are infectious (no, yes)
  - Whether they are symptomatic (no, mild, severe, critical; with probability of being symptomatic increasing with age, and the probability of symptoms being more severe increasing with age)
  - Diagnostic status (untested vs tested)

Transmission is modelled to occur when a susceptible individual is in contact with an infectious individual through one of their contact networks. The probability of transmission per contact is calibrated to match the epidemic dynamics observed and is weighted according to whether the infectious individual has symptoms, and the type of contact (e.g. household contacts are more likely to result in transmission than community contacts). Transmission dynamics depend on the structure of these contact networks, which are randomly generated but statistically resemble the specific setting being modelled. The layers included are described below, and the model parameters values are provided for each layer that was included.

**Household contact network: household size and age structure**

The household contact network was set up by explicitly modelling households. The households size distribution for Australia [5] was scaled to the number required for the number of agents in the simulation. Each person in the model was uniquely allocated to a household. To assign ages, a single person was selected from each household as an index, whose age was randomly sampled from the distribution of ages of the Household Reference Person Indicator in the 2016 Census for Greater Melbourne [15]. The age of additional household members were then assigned according to Australian age-specific household contact estimates from Prem et al. [16], by drawing the age of the remaining members from a probability distribution based on the row corresponding to the age of the index member.

**School and work contact networks**

The school contact network was set up by explicitly modelling classrooms. Classroom sizes were drawn randomly from a Poisson distribution with mean 21 [17]. People in the model aged 5-17 years were assigned to classrooms with people their same age. Each classroom had one randomly selected adult (>21 years) assigned to it as a teacher. The result was that the school contact network was approximated as a collection of disjoint, completely connected clusters (i.e. classrooms).

Transmission in schools is influenced by age-specific disease susceptibility, and the age-specific probability of being symptomatic, which influences symptomatic testing interventions. In the model, people under 14 years have an odds ratio of 0.34 for acquiring infection relative to adults [18], and we use Victorian data to determine age-specific probability of being symptomatic, based on the percentage of positive contacts of confirmed cases who were symptomatic when they were tested. For this analysis it was additionally assumed that transmission risks in schools would be reduced by 50% relative to pre-COVID-19

Similarly, a work contact network was created as a collection of disjoint, completely connected clusters of people aged 18-65. The mean size of each cluster was equal to the estimated average number of daily work contacts. Some workplaces are associated with a higher risk of infection, including healthcare settings, meat processing facilities, construction, warehousing and distribution, and are classified by the Department of Health and Human Services as high risk [19]. In the model, we classified 15% of workplaces as high risk, based on labour force data from the Australian Bureau of Statistics [20]. High risk workplaces were assigned a higher transmission probability, are less likely to be closed by restrictions (as many of these workplaces correspond to essential services.
Additional contact networks

An arbitrary number of additional networks can be added, but for this analysis we considered those most likely to be subject to policy change. Each network layer requires inputs for: the proportion of the population who undertake these activities; the average number of contacts per day associated with these activities; the risk of transmission relative to a household contact (scaled to account for (in)frequency of some activities such as pubs/bars once per week); relevant age range; type of network structure (random, cluster [as per schools/workplaces]); and effectiveness of quarantine and contact tracing interventions.

Parameter values for each contact network

Table S1 shows the parameters that define each contact network in the model. Unless otherwise noted, parameters are derived in [9] from a mix of published and grey literature and a Delphi parameter estimation process. The columns of Table S1 refer to:

- **Mean contacts:** The average number of contacts per person in each network. Each person in the model has their individual number of contacts draw at random from a Poisson distribution with these values as the mean. For the social network layer, a negative binomial distribution was used with dispersion parameter 2 to account for a longer tail to the distribution.

- **Transmission probability:** The transmission probability per contact is expressed relative to household contacts, and reflects the risk of transmission depending on behaviour. For example, a casual contact in a public park is less likely to result in a transmission event compared to a contact on public transport.

- **Quarantine effect:** If a person is quarantined, the transmission probability is reduced by this factor. For example, an individual on quarantine at home would likely not work or use public transport, but they may still maintain their household contacts.

- **Population proportion:** Each network will only include a subset of the population e.g. every person has a household, but not every person regularly uses public transport.

- **Lower age/upper age:** Each network will only include agents whose age is within this range.

- **Clustered:** Here, we refer to a clustered network as one that consists of small groups people who are all connected to each other (e.g. classrooms), and where contacts do not change over time. This is compared to non-clustered networks, where contacts are randomly allocated. Non-clustered networks can either remain constant over time (e.g. social network) or have new contacts sampled each day (e.g. public transport).

- **Contact tracing probability** – the probability that each contact can be notified in order to quarantine

### Table S1: Parameters for each of the networks in the model.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Mean contacts</th>
<th>Transmission probability (relative to households)</th>
<th>Quarantine effect</th>
<th>Population proportion</th>
<th>Lower age</th>
<th>Upper age</th>
<th>Clustered</th>
<th>^Contact tracing probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>110</td>
<td>Y</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Aged care</td>
<td>12</td>
<td>0.600</td>
<td>0.2</td>
<td>0.07</td>
<td>65</td>
<td>110</td>
<td>Y</td>
<td>0.95</td>
</tr>
<tr>
<td>Schools</td>
<td>21</td>
<td>0.124*</td>
<td>0.01</td>
<td>1</td>
<td>5</td>
<td>18</td>
<td>Y</td>
<td>0.95</td>
</tr>
<tr>
<td>Low risk work</td>
<td>5</td>
<td>0.282</td>
<td>0.1</td>
<td>1</td>
<td>18</td>
<td>65</td>
<td>Y</td>
<td>0.95</td>
</tr>
<tr>
<td>High risk work</td>
<td>5</td>
<td>0.847</td>
<td>0.1</td>
<td>1</td>
<td>18</td>
<td>65</td>
<td>Y</td>
<td>0.95</td>
</tr>
<tr>
<td>Church</td>
<td>20</td>
<td>0.043</td>
<td>0.01</td>
<td>0.11</td>
<td>0</td>
<td>110</td>
<td>Y</td>
<td>0.95</td>
</tr>
<tr>
<td>Community sport</td>
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<td>0.071</td>
<td>0</td>
<td>0.34</td>
<td>4</td>
<td>30</td>
<td>Y</td>
<td>0.95</td>
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<tr>
<td>Childcare</td>
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<td>0.274</td>
<td>0.01</td>
<td>0.545</td>
<td>1</td>
<td>6</td>
<td>Y</td>
<td>0.95</td>
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<tr>
<td>Community</td>
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<td>0.100</td>
<td>0.2</td>
<td>1</td>
<td>0</td>
<td>110</td>
<td>N</td>
<td>0.40</td>
</tr>
<tr>
<td>Social</td>
<td>6</td>
<td>0.124</td>
<td>0.5</td>
<td>1</td>
<td>15</td>
<td>110</td>
<td>N</td>
<td>0.95</td>
</tr>
<tr>
<td>Entertainment</td>
<td>25</td>
<td>0.008</td>
<td>0</td>
<td>0.3</td>
<td>15</td>
<td>110</td>
<td>N</td>
<td>0.95</td>
</tr>
<tr>
<td>Cafes/Restaurants</td>
<td>8</td>
<td>0.043</td>
<td>0</td>
<td>0.6</td>
<td>18</td>
<td>110</td>
<td>N</td>
<td>0.80</td>
</tr>
<tr>
<td>Pub/bar</td>
<td>8</td>
<td>0.057</td>
<td>0</td>
<td>0.4</td>
<td>18</td>
<td>110</td>
<td>N</td>
<td>0.80</td>
</tr>
<tr>
<td>Transport</td>
<td>25</td>
<td>0.164</td>
<td>0.01</td>
<td>0.114</td>
<td>15</td>
<td>110</td>
<td>N</td>
<td>0.40</td>
</tr>
<tr>
<td>Public parks</td>
<td>10</td>
<td>0.028</td>
<td>0</td>
<td>0.6</td>
<td>0</td>
<td>110</td>
<td>N</td>
<td>0.40</td>
</tr>
</tbody>
</table>

^ Values are estimated or assumed by the authors. They do not represent data from, or the views of, the Victorian Department of Health and Human Services.

*Includes a 50% reduction from pre-COVID levels based on additional public health interventions
Symptomatic testing

The general community will continue to test based on symptoms, even before any cases are detected. During the Victorian second wave, there were 4.72 tests per 1,000 people per day [21] (in the model calibration this corresponded to a symptomatic test probability of 20% per day of symptoms for COVID-19-positive individuals). In Queensland, a similar Australian setting that has experienced an extended period of zero community transmission, the symptomatic test rate is 0.71 per 1000 people per day\(^1\).

Lacking evidence to suggest otherwise, we assumed that for the \(~47\)% of people with COVID-19 who have anosmia [22] the symptomatic test rate will remain unchanged, given it is a specific COVID-19 symptom. However, for people with COVID-19 who have other symptoms, we assume that after a period of no community transmission in Victoria, the symptomatic testing rate will reduce by a factor of 0.15 (= QLD testing rate / Victoria testing rate). Therefore in the base scenario, an overall symptomatic testing probability of 11% per day of symptoms was used.

Community uptake of symptomatic testing has been observed to radically increase after incursions were detected recently in South Australia, NSW, Victoria and QLD. In the model, following detection of the first case symptomatic testing numbers were increased by a factor

\[
\frac{\text{average daily tests in the week following the detection of the first case}}{\text{average daily tests in the week prior to the detection of the first case}}
\]

which amounted to a 45% relative increase in the daily symptomatic test probability in Victoria.

Model calibration

The model was calibrated to the outbreak in Victoria over the June-September period, and the associated policy changes and interventions that were implemented over that period (Table S2).

<table>
<thead>
<tr>
<th></th>
<th>Pre-stage 3</th>
<th>Stage 3 Phased in from 2 July</th>
<th>Masks 23 July</th>
<th>Stage 4 5 August</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schools</td>
<td>Open</td>
<td>Restrictions</td>
<td>Closed</td>
<td></td>
</tr>
<tr>
<td>workplaces</td>
<td>COVIDSafe plans</td>
<td>Restrictions</td>
<td>Heavier restrictions</td>
<td></td>
</tr>
<tr>
<td>Socialising</td>
<td>Size limits</td>
<td>Size limits</td>
<td>Curfew (ending on 28(^{th}) Sep) and outdoor limits</td>
<td></td>
</tr>
<tr>
<td>Community sport</td>
<td>Going</td>
<td>Cancelled</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pubs and bars</td>
<td>4 sq m rule</td>
<td>Closed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cafes and restaurants</td>
<td>4 sq m rule</td>
<td>Take-away only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Places of worship</td>
<td>4 sq m rule</td>
<td>Closed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Childcare</td>
<td>Open</td>
<td>Closed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public parks</td>
<td>Open</td>
<td>Playgrounds closed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public transport</td>
<td>Demand reduced indirectly</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large events</td>
<td>Banned</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entertainment venues</td>
<td>Closed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Masks</td>
<td>No masks</td>
<td>Mandatory</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table S2: Policy changes included in the model calibration process.

Testing was modelled by assigning a per day test probability to symptomatic and asymptomatic people that was fitted as part of calibration. We assumed some improvements over time, such that there were different inputs for testing and contact tracing for June-July and August-December, with the exact day the improvements occurred calibrated to fit the epidemic trajectory. We assumed that test results took 48 hours (exactly) to be processed initially and then 24 hours (exactly) after improvement.

---

Overall, the transmission probability per contact governs the rate of epidemic growth, and the testing parameters affect the daily diagnoses as well as the proportion of cases that go undiagnosed. We assume that the proportion of undiagnosed cases is reflected in the number of diagnoses relative to the number of hospitalizations, as severe cases are assumed to present at hospital regardless of whether they have been tested or not. Thus, we used data on the number daily diagnoses and number of hospitalizations to enable simultaneous calibration of the testing and transmission parameters.

For the calibration shown in Figure S1, the model was initialised with a population of 100,000 agents, and the overall transmission risk per contact (which multiplies the transmission probabilities in Table S1 for each layer) was varied such that when combined with inputs for the number of tests conducted over time and changes in contacts resulting from policy changes (e.g. community sports being cancelled and restaurants, cafes being take-away only when Stage 3 restrictions were introduced), the distribution of model outcomes was centred near the actual epidemic trajectory.

When calibrating, we fit the model transmission parameters under the assumption that the observed epidemic wave in June/July was the most likely outcome, which occurred in all simulations. In reality, it is possible that the second wave was an unlikely/unlucky outcome, or alternatively, that it could have been worse and was in fact a relatively lucky outcome, depending on the networks of seed cases and their contacts, as well as the overall transmission parameter. Therefore, we sampled over a set of initializations and transmission parameters, and only retained those runs where the seed/transmission parameter combination produced a projection that sufficiently matched the data – we considered the model to be a suitable fit if it was within 10% of the cumulative diagnosed cases each day, after the first 30 days. Figure S1 shows examples of the simulation runs used to estimate parameters for this study. We note that the variability permitted in the cumulative case counts is dominated by how high the peak of the second wave is, and as the epidemic declines, the variability in new diagnoses per day by mid-September is somewhat smaller. Overall, approximately 700 of the 10000 proposed initializations were accepted. Many initializations were rejected because they diverged from the actual second wave early on, when case numbers are relatively low and the outcomes of each individual case therefore have a significant impact on the trajectory of the outbreak.

The distribution of transmission probability parameter values for the accepted initializations is shown in Figure S2.

**Figure S1**: Model calibration to second wave in Victoria from June-September 2020. Vertical lines indicate when Stage 3 lockdowns took effect (9th July), masks were made mandatory (23rd July) and Stage 4 lockdowns took effect (6th Aug). Severe infections in the model represent infections requiring hospitalisation, and the corresponding data are for reported hospitalisations. Red lines indicate simulation runs that were maintained and used for the resurgence projections in this study; blue lines show a representative sample of simulations that were rejected.
A policy, health and implementation response to COVID-19

Figure S2: Distribution of beta values

Disease prognosis

Table S3: Age-specific susceptibility, disease progression and mortality risks.

<table>
<thead>
<tr>
<th>Age bracket</th>
<th>Relative susceptibility*</th>
<th>Prob[symptomatic]^</th>
<th>Prob[severe]#</th>
<th>Prob[critical] ##</th>
<th>Prob[death] ###</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>0.34</td>
<td>0.55</td>
<td>0.00004</td>
<td>0.0004</td>
<td>0.0002</td>
</tr>
<tr>
<td>6-12</td>
<td>0.34</td>
<td>0.55</td>
<td>0.00004</td>
<td>0.0004</td>
<td>0.0002</td>
</tr>
<tr>
<td>13-15</td>
<td>0.34</td>
<td>0.65</td>
<td>0.00004</td>
<td>0.00011</td>
<td>0.00006</td>
</tr>
<tr>
<td>16-19</td>
<td>1</td>
<td>0.7</td>
<td>0.0004</td>
<td>0.00011</td>
<td>0.00006</td>
</tr>
<tr>
<td>20-29</td>
<td>1</td>
<td>0.77</td>
<td>0.011</td>
<td>0.0005</td>
<td>0.0003</td>
</tr>
<tr>
<td>30-39</td>
<td>1</td>
<td>0.79</td>
<td>0.034</td>
<td>0.00123</td>
<td>0.0008</td>
</tr>
<tr>
<td>40-49</td>
<td>1</td>
<td>0.79</td>
<td>0.043</td>
<td>0.00214</td>
<td>0.0015</td>
</tr>
<tr>
<td>50-59</td>
<td>1</td>
<td>0.8</td>
<td>0.082</td>
<td>0.008</td>
<td>0.006</td>
</tr>
<tr>
<td>60-69</td>
<td>1</td>
<td>0.8</td>
<td>0.118</td>
<td>0.0275</td>
<td>0.022</td>
</tr>
<tr>
<td>70-79</td>
<td>1.24</td>
<td>0.8</td>
<td>0.166</td>
<td>0.06</td>
<td>0.051</td>
</tr>
<tr>
<td>80+</td>
<td>1.47</td>
<td>0.8</td>
<td>0.184</td>
<td>0.10333</td>
<td>0.093</td>
</tr>
</tbody>
</table>

*Zhang et al. [18] found children <14 had 34% less susceptibility to adults, and people >65 years had 47% increased susceptibility

^Victorian data: percentage of (infected) close contacts who had symptoms when they were tested

# [23, 24]; ## [24]; ### [23-25]
Policies
The effect of each policy is detailed below summarized from [9], showing the impact on the transmission probability per contact, and/or the number of contacts in the network. Policies that reduce the number of contacts in the network better preserve the clustering associated—for example, the ‘Work from home’ policy reduces the number of workplace contacts to model the same people working from home every day.

Large events cancelled
- Large event transmission reduced by 100%

Entertainment venues closed
- Entertainment transmission reduced by 100%

Cafes/restaurants open with 4sqm physical distancing
- Cafes/restaurants transmission reduced by 50%

Pubs/bars open with 4sqm physical distancing
- Pubs/bars transmission reduced by 50%

Churches/places of worship open with 4sqm physical distancing
- Church/places of worship transmission reduced by 60%

Work from home where possible/COVID-safe
- Household transmission increased by 10%
- Work transmission (all risk groups) reduced by 36%
- Additional community transmission reduced by 33%
- Public transport transmission reduced by 33%

Outdoor gatherings limited to <10 people
- Additional community transmission reduced by 20%
- Entertainment transmission reduced by 50%
- Public transport transmission reduced by 50%
- Public parks transmission reduced by 40%

Stage 3, Melbourne and Mitchell Shire, additional impacts
- Household transmission increased by 10%
- School transmission decreases by 85%
- Community sport transmission reduced by 85%
- Cafes/restaurants transmission reduced by 85%

Community sports cancelled
- Community sport transmission reduced by 100%

Cafes/restaurants takeaway only
- Cafes/restaurants transmission reduced by 100%

Pubs/bars takeaway closed
- Pubs/bars transmission reduced by 100%

Churches and places of worship closed
- Church/places of worship transmission reduced by 100%

Aged care improvements
- Aged care transmission reduced by 50%

Mandatory masks
- Work transmission reduced by 30%
- Additional community transmission reduced by 25%
- Church/places of worship transmission reduced by 25%
- Entertainment transmission reduced by 30%
- Cafes/restaurants transmission reduced by 25%
- Pubs/bars transmission reduced by 10%
- Public transport transmission reduced by 10%
- Public parks transmission reduced by 25%
- Large event transmission reduced by 30%
- Social gatherings transmission reduced by 25%
- Aged care transmission reduced by 30%
- Schools: 0% (assumed not mandatory in these projections)

Small social gatherings banned
- Stage 3: social contact transmission reduced by 67%
- Stage 4: social contact transmission reduced by 90%

Childcare closed
- Childcare transmission reduced by 100%

Schools closed
- School transmission reduced by 100%

Mobility restrictions
- Public transport transmission reduced by 80%
- General community transmission reduced by 70%

Stage 4 work restrictions
- Low risk work transmission reduced by 90%
- High risk work transmission reduced by 40%

50% reduction in transmissibility in Schools
- School transmission reduced by 50%

Outdoor gatherings limited to 50 people
- Public transport transmission reduced by 20%

---

2 A comprehensive meta-analysis [26] (conducted after two others [27,28]), covering 41 studies of mask effectiveness concluded that masks are associated with a reduction in infection for mask-wearers by a third compared to control groups. For this analysis, we have used a 30%, 25% or 10% transmission reduction in specific community settings, based on a 33% individual-level efficacy and approximately 90%, 75% and 25% usage, respectively.