The impact of non-pharmaceutical interventions on COVID-19 cases in South Australia and Victoria

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Abstract

Objective: To assess the impact of different non-pharmaceutical interventions (NPIs) on COVID-19 cases across Victoria and South Australia.

Methods: Poisson regression models were fit to examine the effect of NPIs on weekly COVID-19 case numbers.

Results: Mask-wearing in Victoria had a pronounced lag effect of two weeks with an incidence rate ratio (IRR) of 0.27 (95%CI 0.26–0.29). Similarly, the effect of border closure (IRR 0.18; 95%CI 0.14–0.22) in South Australia and lockdown (IRR 0.88; 95%CI 0.86–0.91) in Victoria showed a decrease in incidence two weeks after the introduction of these interventions.

Conclusions: With the ongoing COVID-19 pandemic, varying levels of vaccination coverage rates and threats from variants of concern, NPIs are likely to remain in place. It is thus important to validate the effectiveness and timing of different interventions for disease control, as those that are more restrictive such as border control and lockdown can have an enormous impact on society.

Implications for public health: Low case numbers and deaths in Australia's first wave of COVID-19 are thought to be due to the timely use of interventions. The observed two-week lag effect associated with a decrease in incidence provides justification for early implementation of NPIs for COVID-19 management and future pandemics.

Key words: COVID-19, interventions, infectious diseases

In the first year of the COVID-19 outbreak, Australia's response to the pandemic was highly successful, resulting in low case incidence and case-fatality rates. At the end of 2020, Australia had recorded 1,110 cases per 1 million population and 36 deaths per 1 million population compared with the US, which recorded 10,643 cases and a death rate of 991 per 1 million population, and the UK with 33,232 cases and a death rate of 1,037 per 1 million population.[1] Moreover, Australia's daily hospitalisation and daily ICU occupancy rates for COVID-19 as of 31 December 2020 were 0.7 and 0 per 1 million population, respectively, compared to the UK (389.7 and 31.1 per 1 million respectively) and the US (370.5 and 83.3 per 1 million respectively).[2,3]

When facing a pandemic, governments respond by introducing a number of public health measures including policies, legislation and regulation, resource allocation, education, communication and advocacy.[4] With no effective treatments or vaccines at the beginning of the COVID-19 pandemic, governments worldwide focused on non-pharmaceutical interventions to slow the spread of the virus and avoid high rates of infections and deaths. In this containment phase, the interventions were aimed at reducing the rate of transmission and limiting the number of active cases to manageable levels for the health system.[5]

The interventions implemented in Australia in the pandemic's first year were aimed at slowing the spread of infection and resultant disease and included border controls (domestic and international), contact tracing, physical distancing, community containment, personal hygiene, personal protective equipment (PPE) and testing capabilities.[4,6] These non-pharmaceutical interventions were aimed at reducing virus transmission at the population level.[7] Border controls and travel restrictions limited the number of people arriving from countries and regions with high COVID-19 case incidence to prevent community transmission.[8] Case investigation and contact tracing were undertaken to isolate cases and quarantine contacts to prevent further spread and interrupt transmission. Ensuring access to prompt and reliable diagnostic testing was an integral component for the rapid identification and isolation of cases and contacts to detect and manage outbreaks. Community containment measures such as lockdown mandated the restriction of movement by allowing only essential services to operate, with the intention of limiting human-to-human transmission.[9,10] Broader public health measures of physical distancing, personal hygiene and mask-wearing were designed to prevent transmission at the population level by minimising the level of indirect and direct contact with COVID-19 virus-laden respiratory droplets or aerosols.[11,12]

There are gaps in the evidence base for the effectiveness of some measures for COVID-19.[13] However, even in the presence of

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vaccines, non-pharmaceutical interventions may have helped to reduce the incidence of other infectious diseases during the COVID-19 pandemic compared with previous years.

The transmission of other respiratory viruses including influenza and respiratory syncytial virus decreased substantially during 2020 in several countries including China,[14] Austria[15] and Taiwan.[16] Conversely, influenza, pertussis and rotavirus notifications in Queensland, Australia, also decreased.[17] Substantial reduction of influenza cases in Australia to near zero further supports the impact of non-pharmaceutical interventions on respiratory illness.[18] Decreases in notifications of other infectious diseases were reported for invasive pneumococcal disease in England[19] and invasive meningococcal disease in France.[20] It is likely that non-pharmaceutical interventions were the main drivers in the reduction of vaccine-preventable diseases reported during the pandemic.

This supports the evidence, albeit limited, of the potential effectiveness of these interventions implemented during the pandemic. For example, mandatory face masks in public, isolation or quarantine, physical distancing and travel restrictions[21] have been shown to contain COVID-19, and combinations of interventions were demonstrated to have a greater effect on reducing the spread of infection.[22-25] Modelling has shown that the international travel bans and use of masks delayed or reduced the spread of COVID-19 in Australia,[26,27] while the relaxation of policies such as limits on social gatherings posed greater risks than relaxing other physical distancing measures.[28] Nevertheless, there remains a need for research to distinguish between and validate the effectiveness of different interventions.[13]

At time of writing (November 2021), Australia was faced with newer emerging variants, vaccine hesitancy and extended lockdowns within several Australian jurisdictions coupled with closed borders in others. Against this background, and with the reopening of Australia's international borders and easing of restrictions based on high vaccination uptake, identifying effective strategies in reducing case numbers can inform public health responses in situations of resurgences of COVID-19 and other epidemics and pandemics. Thus, it is timely to reflect on the various public health measures implemented in 2020.

The aim of this study was to assess the impact of different public health measures on COVID-19 case numbers during the first wave across two Australian states. Victoria was selected because it had experienced a second wave of COVID-19, and South Australia was chosen as it had successfully managed local outbreaks. We examined the type of interventions implemented and their effect on the incidence of COVID-19.

Methods

Data collection

COVID-19 cases reported by date of notification across the 2020 calendar year from the South Australian and Victorian health departments were extracted from their respective COVID-19 dashboards.[29,30] The dashboards provide daily updates and summary of information from official state government sources and agencies. These state dashboards were preferred as they reported on daily case numbers by date of notification, whereas other sources only provided fortnightly or monthly data. We aggregated the daily number of cases to generate weekly counts for each state, with the weeks spanning 5 January 2020 to 2 January 2021.

We compiled a chronology of interventions implemented across both states for the study period described above using information from the Australian Government Department of Health's (DoH) weekly COVID-19 epidemiology reports, and respective state health departments' websites and Facebook pages. We also sourced information from online media reports including 7 News, 9 News and ABC news archives. Start and end dates were recorded for the duration of interventions and were cross-checked across the sources described above. The exact duration of some interventions was challenging to determine where information was no longer available or where there was inconsistent reporting across sources; in these circumstances, we used the date most commonly reported across sources. These data were used to count the number of times an intervention was implemented and the total days for which it was implemented. If an intervention was escalated (such as each successive decrease in gathering size), then this was also counted as an implementation of the intervention. De-escalation of an intervention was not counted as an implementation.

Non-pharmaceutical interventions

Interventions were grouped into three broad domains of personal strategies, community-wide interventions and travel restrictions. Personal strategies are actions that individuals must follow and can also enact alone. These included mask-wearing, hand hygiene, using the COVIDSafe app and staying 1.5 metres apart from others. The community intervention category refers to actions that affect groups of people and the community and captured two distinct interventions: i) activity and density restrictions; and ii) lockdown, including restrictions that required people to stay at home. Travel advice and restrictions considered movement intrastate, interstate and internationally, with interventions aimed at state and national border closures and regional travel restrictions.

Data analysis

We used Poisson regression models to examine the effect of the interventions on COVID-19 case numbers. The outcome was the total count of COVID-19 cases per week for each week in 2020. In our analyses, we considered three interventions as distinct exposure variables – state border closure, lockdown and mask-wearing. We investigated the effect of mask-wearing and lockdown for Victoria only as these measures were enforced in South Australia for a very short time. These interventions were selected based on the timing and duration of interventions across South Australia and Victoria and if they differed across states. Personal interventions (physical distancing, use of the COVIDSafe app, and handwashing) and community interventions (density restrictions) were not included in our analysis as they did not vary between the states or were introduced in both states at the same time. For each intervention considered, we generated a binary exposure variable that indicated if the corresponding intervention was enacted in a given week (coded as 1) or not (0). Population size for South Australia and Victoria was derived from the Australian Bureau of Statistics' Estimated Resident Population as of 30 June 2020[31] and was included as an offset term in the statistical models.

To estimate the delayed effect of state border closure, lockdown and mask-wearing on weekly counts of COVID-19 cases, we considered different lag effects of two, three or four weeks for each intervention.

These time lags were based on the accepted 14-day incubation period for COVID-19 as well as considering extended incubations based on review findings.[32] Separate models were fitted to examine the effects of each of the three interventions on weekly COVID-19 counts. For the model examining border closures, we included an interaction between the exposure variable and state, so as to assess any differential effect of border closures between the two states. In each model considered, we included linear, centred quadratic and centred cubic terms for the effect of week, in order to adjust for a potential non-linear time effect. Model assumptions were checked and the overdispersion of counts was modest, so that Poisson models were considered appropriate.

Incidence rate ratios (IRR) with 95% confidence intervals (CI) are reported. Ethics approval was not sought for this study as we accessed COVID-19 data that were publicly available.

Results

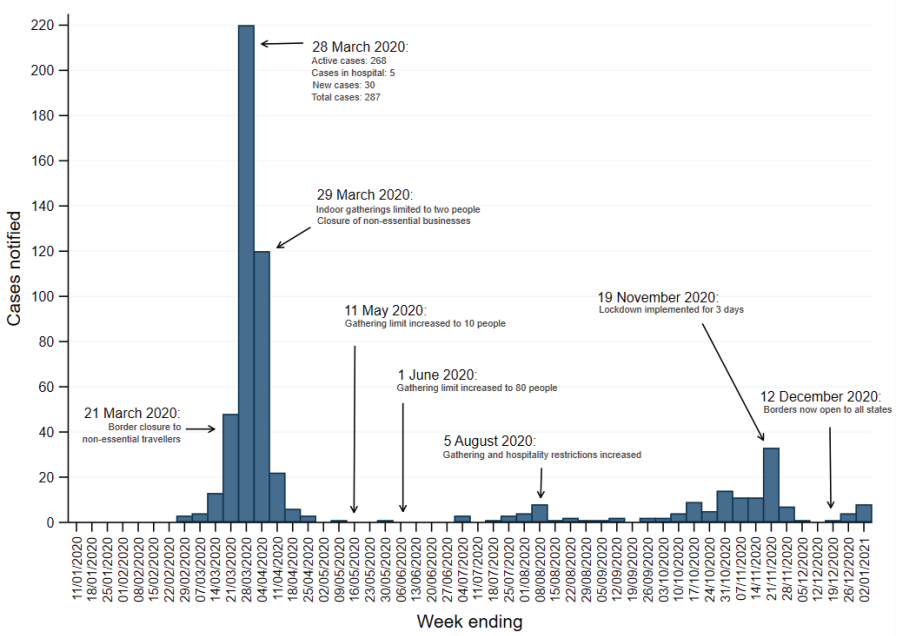
Table 1 presents the number of times each intervention was implemented, as well as the total number of days (during 2020) each was enacted. Across the categories of interventions, the implementation times and days for COVIDSafe app and QR check-in codes, hygiene advice, national border closures and quarantine for international arrivals were similar for both states. However, for mandatory face masks, state closure borders, and closure of non-essential activities and lockdown, there were differences between South Australia and Victoria in the number of times the intervention was implemented and the length of the implementation. Limits on gathering sizes were implemented more often in Victoria, but the length of implementation for both states was the same.

The timing of key interventions and the corresponding case numbers can be seen in Figures 1 and 2. South Australia (Figure 1) experienced lower case numbers in 2020 when compared to Victoria (Figure 2), with a total of 579 cases (33 per 100,000) compared to Victoria's total of over 20,000 cases (305 per 100,000). The first spike in cases occurred at approximately the same time in both states and was met with similar interventions. When cases numbers began to increase, both South Australia and Victoria began to close non-essential businesses.

Table 1: Summary of the implementation of non-pharmaceutical interventions for COVID-19 in Victoria and South Australia, 2020.

Category	Intervention	Victoria		South Australia	
		Number of times implemented	Total days implemented	Number of times implemented	Total days implemented
Personal strategies	Face masks mandatory	1	39	1	3
	COVIDSafe app	1	248	1	250
	QR codes for check in	1	31	1	31
	Hygiene advice	1	350	1	350
Travel interventions	National border closure	1	286	1	286
	State border closure	1	140	2	96
	Regional travel ban	1	22	2	49
Community interventions	Decreased limit on gathering size	6	290	4	290
	Closure of non-essential activities	3	173	2	48
	Quarantine for all international arrivals	1	286	1	286
	Lockdown	2	140	1	3

Figure 1: COVID-19 cases in South Australia by week of notification to 2 January 2021 with timing of non-pharmaceutical interventions.



Victoria also implemented lockdown during the first peak. South Australia closed their border to most other states whereas Victoria remained open until later in the year. Restrictions were not eased until case numbers returned to consistently low levels in both states. In Victoria, the easing of restrictions was followed by the second wave of cases beginning in July 2020, which was considerably worse than the first. Significant restrictions, border closure and lockdown were then implemented in Victoria for a prolonged period. By the end of the year, cases in both states returned to low levels and most major restrictions were eased. Hygiene and social distancing advice were still in place, as well as the use of QR code check-in for all venues to assist contact tracing.

The statistical models demonstrate a clear relationship between the introduction of each intervention and a reduction in the IRR two weeks later (Table 2). The model for the effect of border closure showed important differences between states in the effects of the intervention, with IRR for Victoria consistently larger than for South Australia, reflecting the much greater relative burden of disease in that state. The effect of mask-wearing in Victoria appeared to remain constant between two and four weeks, while the IRR for lockdown in Victoria was 0.88 (95%CI 0.86–0.91) at two weeks increasing

markedly in effect at three (IRR 0.53, 95%CI 0.51–0.54) and four weeks (IRR 0.34, 95%CI 0.33–0.35).

Discussion

We report on the effect of non-pharmaceutical interventions on COVID-19 cases in Victoria and South Australia in 2020. Mask-wearing and lockdown were effective measures implemented in Victoria. In contrast, border control instituted in South Australia when the case burden was small (eight cases in the week ending 8 August 2020) was effective in decreasing COVID-19 incidence, while in Victoria border control was introduced when the case burden was higher (1,226 cases in the week ending 11 July 2020). We believe that it took much longer for the combination of mask-wearing, lockdown and border closure to affect new case numbers in Victoria. Border closure in Victoria was less likely to have an impact two weeks after introduction because case numbers were already high.

The timing of when to introduce interventions based on the type of intervention and on the number of daily cases is critical for the effective control of COVID-19 outbreaks. A modelling study examining the timing of public health interventions in Australia[33] found that a combination of physical distancing and wearing face masks is effective in controlling COVID-19 outbreaks if they are introduced prior to the number of cases exceeding six per day. This is supported by an earlier study which demonstrated that during the first wave of the COVID-19 outbreak in Thailand, the peak of the outbreak occurred one week following the introduction of the intervention, reinforcing the need for timely interventions.[34] Furthermore, daily cases will continue to rise until the effective reproduction number (R_e), – the number of susceptible people in a population who can be infected by an individual is reduced to below one.[33]

Although the use of these interventions differed between the two states due to the larger population and disease burden in Victoria, our findings highlight that they were crucial to controlling case numbers while a vaccine was not available. They also reinforce the important role of non-pharmaceutical interventions to curb the spread of COVID-19 as well as other infectious diseases, as evidenced by the drop in rates of influenza, pertussis and rotavirus[14-17] during the pandemic when these interventions were enforced. With a low vaccination uptake in some states and territories and the emergence of more transmissible variants such as the Delta and Omicron variants, the need for non-pharmaceutical interventions demonstrating effectiveness in reducing incidence is likely to be ongoing to constrain epidemic growth, even with vaccination.

Mask-wearing produced the largest reduction in case incidence of all the interventions tested in our model for Victoria. This adds to the existing evidence, albeit limited, on the effectiveness of mask-wearing. Case incidence rates were lower in Hong Kong compared to non-mask-wearing countries,[35] while a 29% reduction in R_e of COVID-19 was found following the introduction of wearing face masks in 50 American states.[36] Narrative syntheses[37,38] also describe the potential benefits of mask-wearing. However, our study is one of a few to model the effectiveness of mask-wearing using COVID-19 case data and estimating the delayed effects of interventions.

Lockdown in Victoria was also successful in reducing case incidence, with the greatest benefit observed at four weeks after its introduction. In other studies, evidence on the effectiveness of lockdown is less clear; stay at home interventions in American states contributed to a 51% reduction in R_e,[36] while lockdown was associated with non-significant 2.4% reductions in weekly COVID-19 related deaths.[39] Chowdhury et al. described local and rolling lockdown strategies to control epidemics and alleviate social and economic costs, although these were specific to low- and middle-income countries.[40] Differences in findings support the importance of validating the effectiveness of this intervention in particular because it is considered the most controversial measure in Australia with ensuing social and economic disruption.

Border closure was also found to be an effective measure to reduce disease incidence in both South Australia and Victoria. In

Figure 2: COVID-19 cases in Victoria by week of notification to 2 January 2021 with timing of non-pharmaceutical interventions.

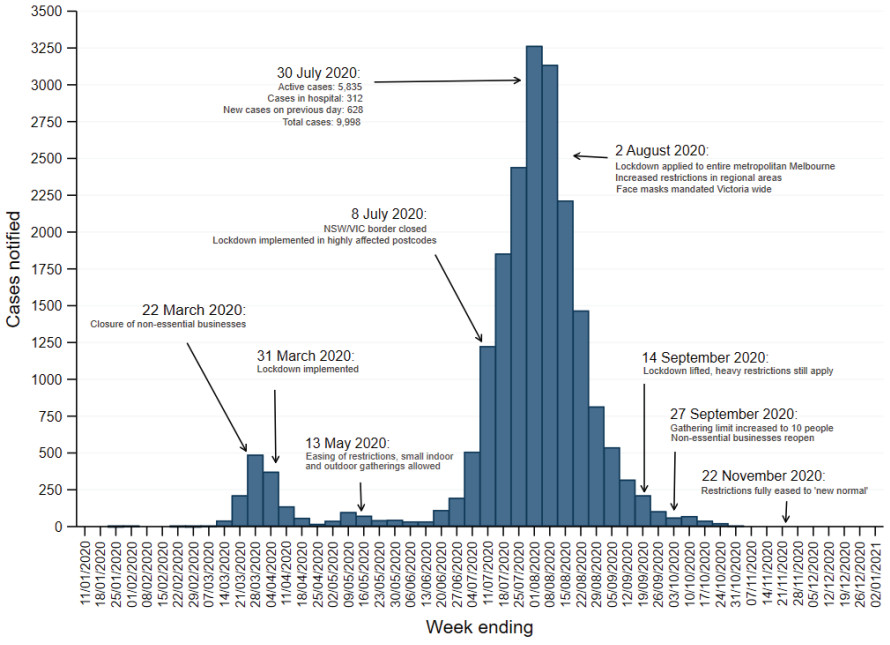


Table 2: Summary of effects of interventions on weekly COVID-19 counts.

Intervention	aIRR[a]	95% CI
Border closure		
SA 2 week lag	0.18	0.14–0.22
SA 3 week lag	0.014	0.009–0.020
SA 4 week lag	0.021	0.014–0.030
VIC 2 week lag	4.04	3.83–4.27
VIC 3 week lag	2.19	2.09–2.30
VIC 4 week lag	0.97	0.92–1.01
Lockdown		
VIC 2 week lag	0.88	0.86–0.91
VIC 3 week lag	0.53	0.51–0.54
VIC 4 week lag	0.34	0.33–0.35
Masks		
VIC 2 week lag	0.27	0.26–0.29
VIC 3 week lag	0.21	0.20–0.22
VIC 4 week lag	0.25	0.23–0.27

Note:

a: Models adjusted for week, week^2 and week^3; State population included as offset term in final model

Victoria, the benefits of border closure were evident between two and four weeks after the intervention was implemented. Border closure is likely an effective measure as it isolates the population, which reduces opportunities for disease transmission. Despite the limited available evidence, studies have demonstrated some effectiveness. Modelling the effects of travel bans found a 79% reduction in COVID-19 cases imported into Australia and a delay in the outbreak by one month,[26] while interstate travel restrictions contributed to an 11% reduction in R_e across 50 American states.[36]

The aim of this study was to assess the relative effectiveness of non-pharmaceutical COVID-19 interventions in South Australia and Victoria, but these measures were often implemented simultaneously. As interventions overlapped, it was difficult to disentangle each intervention's individual effect on case numbers. Despite this, our results show that benefits continued to accrue for masks and lockdowns, with a clear reduction in the IRR for lockdowns across time. Another limitation was the lack of detailed information on past interventions and inconsistency in the reporting of intervention key dates between sources. Health department websites contained only the current restrictions, so information on past interventions was sourced mostly from news archives. Lack of consistency between these sources may have led to minor differences between true counts of active intervention days and data values used in our study but this was unlikely to systematically overestimate or underestimate the number of intervention days. Some interventions were only applicable to part of the state, such as the metropolitan Melbourne lockdown, but case numbers reflected the entire state. Given that most cases occurred in metropolitan areas with higher population density, this is unlikely to have had a large impact on the results reported here. Balanced against these limitations, a strength of our study was the use of case notification data, rather than simulated modelling or narrative syntheses used in other studies, to examine the effect of interventions on case incidence.

Conclusion

With the ongoing nature of the COVID-19 pandemic, it is important to validate the effectiveness of different interventions implemented by the government. Non-pharmaceutical interventions have been critical for COVID-19 control. With low COVID-19 vaccination coverage rates and threats from variants of concern, non-pharmaceutical interventions are likely to be introduced as needed, for example, when there is high community prevalence or outbreaks. Some may become the new norm, and it is likely that wearing face masks with and without vaccination will be part of future pandemic control measures as they can be readily implemented at minimal cost with little impact on society. Our results show that the timely use of restrictive interventions applied in Australia such as border closure, lockdown and the mandatory wearing of face masks resulted in comparatively low COVID-19 case numbers and deaths.

Vaccination alone may not be sufficient to prevent the transmission of newly emerging infectious diseases or new variants of concern. This has come to light recently with the Omicron variant demonstrating the potential for immune evasion and the incidence of reinfection and breakthrough infection reported in people who have had three vaccinations (two doses and a booster).[41] While the booster dose has been reported to offer good protection against severe disease for Omicron, non-pharmaceutical interventions should be maintained to minimise the potential for infection while the booster dose program is being rolled out.[41] Hence, there will be a continued role for non-pharmaceutical interventions, and knowing which interventions will work will be important for policy makers.

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