The Medical Journal of Australia

Supporting Information

Supplementary methods and results

This appendix was part of the submitted manuscript and has been peer reviewed.
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Appendix to: Szanyi J, Howe S, Wilson T, Blakely T. Consistent mask use and SARS-CoV-2 epidemiology: a simulation modelling study. Med J Aust 2023; doi: 10.5694/mja2.52003.

Supplementary methods

Agent-based model

We used an agent-based model (ABM) with 5000 agents simulating the population of Victoria and a daily cycle length, described in detail elsewhere.[1] Input parameters have probability distributions from which values are drawn for each of the 500 iterations for each of the Monte Carlo analyses in the ABM – key input parameters are shown in Table 1.

The model GitHub repository is available at https://github.com/population-interventions/CovidABM.

Table 1. Key model input parameters

Parameter	Estimate
Agent infectiousness	Agent infectiousness on each day is parameterised by agent-level draws for peak infectiousness and the parameters listed below. Infectiousness prior to the peak is linearly interpolated to 0% of peak infectiousness on day 0, and infectiousness after the peak is linearly interpolated to zero at the end of the infectious period.
Incubation period (time from infection to development of symptoms) (days)	Gamma distribution with mean 3.485, SD 1.1953 (95% UI 1.55 to 6.19).[2] A theoretical time to symptom development was specified for all agents, but only manifest (e.g. for self-isolation) for the proportion of agents defined as symptomatic.
Time from symptom development to peak infectiousness (days)	Gamma distribution with mean 3.7486, SD 2.0499.[3]
Time from initially becoming infectious to peak infectiousness (days)*	Gamma distribution with mean 1.8691, SD 1.202.[3]
Time from peak infectiousness to end of infectiousness (days)*	Gamma distribution with mean 2.9989, SD 1.8278.[3]
Mean adherence with isolation of infected cases	Global beta distribution (beta(450.3, 23.7); mean = 95%, SD = 1%)
Infectiousness of asymptomatic v. symptomatic cases per contact	RR 0.58 (95% CI 0.34 to 0.99)[4] (parameterised as a log normal distribution with median = -0.545 and SD = 0.270)
Household size	Beta distribution with median = 3. Beta(2.2, 2.2) scaled to [1, 5], draws rounded to nearest integer
Chance of an infected household contact of a known case becoming known, per day.	100%
Proportion of undetected symptomatic cases who spontaneously reported themselves	Beta(6,6)
Time for undetected symptomatic cases spontaneous self-reporting	At symptom development (see above)
Transmission multiplier of person who is complying with their isolation	0.33
Relative susceptibility to infection, by age (OR for infection given exposure)	0 – 9 years: 0.34 10-19: 0.67 20 – 59 years: 1 60-69: 1.23 ≥70 years: 1.47 [5] Uncertainty on all values +/- 15% SD
Relative 'carefulness' multiplier to susceptibility, by age	0 – 9 years: 1.882 10 – 19 years: 1.179 20 – 59 years: 1 60 – 69 years: 0.975 70 – 79 years: 0.667 80 – 89 years: 0.646 ≥90 years: 0.646 Uncertainty on all values +/- 15% SD

OR = odds ratio; RR = relative risk; SD = standard deviation; UI = uncertainty interval.

The model was calibrated to achieve 1.2 million infections in the 60 days following 1 April 2022 with the same age distribution of infections as occurred in Victoria in this period.[1]

Public health and social measures

Public health and social measures were implemented (Table 2); these were set at stage 2 for the first 60 days and then halfway between stages 1 and 2 for the remainder of the model run.

Table 2. Public health and social measures by stage

	Stage 1	Stage 2
Proportion of people who try to avoid contact with others (excluding their household)[†*]	20%	36%
Proportion of time spent trying to avoid contacts, for those that attempt to do so[†*]	30%	46%
Proportion of workers attending work in person[†]	80%	66%
Schools open (disable contact-avoiding behaviour among students)	Yes	Yes
Proportion of people that engage in super spreading behaviour each day (move to a random gathering location)[†]	6%	4.7%
Underlying frequency of visiting a random nearby gather location each day (e.g., a supermarket)[†]	14.28%	14.28%
Radius for determining whether a gather location counts as nearby	8.8	8.63
Maximum distance moved by an agent each day	14	11.56

[†]Odds ratios of 2, 4 and 6 are applied to isolation compliance, proportion of people that avoid others, and proportion of time spent avoiding others for those aged 50-59, 60-69 and ≥70 years respectively to capture increasing infection avoidance behaviour in older age groups. Reciprocals of these odds ratios are applied to the daily chance of visiting a gather location, and daily chance of superspreading. Note agents ≥60 years old are excluded from the category of workers.
[*]The proportion of people who try to avoid contact with others and the proportion of time spent trying to avoid contacts for those attempting to do so are dynamic, based on the average number of infections over the last 7 days.

Mask and respirator effectiveness

There is a paucity of high-quality evidence providing estimates of the degree of protection afforded by mask-wearing at the individual level in community settings for the transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). We based our estimates of mask effectiveness on a test-negative case-control study which provides estimated effect sizes for protection stratified by type of mask.[6] In this study, the adjusted odds of infection of 0.44 (95% Confidence Interval (CI) 0.24 to 0.82) associated with always using any type of mask or respirator was reported compared to nil mask. A further set of odds ratios (ORs) were presented disaggregated by type of mask, but these were for a smaller sub-sample of the cohort.

If one carefully looks at these sub-study results (OR of 0.44 for cloth, 0.34 for surgical and 0.17 for N95 - all compared to nil mask) and weights them by the proportion of the control cohort using the masks (39%, 53% and 8%) one arrives at an OR for any mask use compared to nil of 0.37. This is considerably different from the primary any mask to nil OR reported in the paper of 0.44. We assume the 0.44 for any mask use is more valid than the 0.37 (due to the latter being based on small numbers), so we scaled all the mask-specific ORs up by 0.44/0.37. As well as, we argue, being more valid, we note this is also more conservative as the protection for the types of mask compared with nil mask use moves moderately to the null. For parsimony, we combined the cloth and surgical masks (weighting again by the proportion of the cohort in each group). Thus, our further adjusted odds for infection associated with masks were as follows*:*

- Cloth/surgical masks: odds ratio (OR) for infection 0.468 (or -0.76 on ln scale, with SD 0.31)
- N95 respirators: OR 0.204 (or -1.59 on ln scale, with SD 0.65)

We specified 100% correlation on draws of mask effectiveness and assumed the same risk reduction in onward transmission if wearing a mask. Mask use was also 100% correlated among the 5,000 model agents, such that the same agents were consistently parameterised (or not) as mask wearers.

SARS-CoV-2 variants

The dominant variant at model outset was parameterised after the Omicron BA.1/2 sub-variants with an R_0 of 8 to 10 and virulence based on age-stratified infection fatality, infection hospitalisation, infection ICU admission and symptomatic infection risks that were either drawn directly from the published literature or scaled from published estimates of ancestral variant virulence to match Victorian data from April and May 2022 (a period of Omicron BA.2 dominance). Full details are published elsewhere.[1] The Omicron BA.4/5 sub-variants emerged gradually in the model from May 2022 and had additional immune escape capacity (but the same innate transmissibility, i.e., the same R_0), compared to Omicron BA.1/2.

Vaccination coverage

Agents were assigned vaccination doses to match age-stratified Victorian coronavirus disease 2019 (COVID-19) vaccination coverage to June 30, 2022 (Table 3).[7] No further vaccine administration was modelled for this analysis.

Table 3. Vaccination coverage as of June 30,2022, by age and dose

Age (in 10-year strata)	Second dose coverage	Third dose coverage
0-9	29.31%	0.06%
10-19	96.95%	14.87%
20-29	87.34%	48.45%
30-39	94.18%	60.12%
40-49	96.59%	70.65%
50-59	96.63%	76.85%
60-69	97.22%	84.11%
70+	99.02%	91.14%

Vaccine- and infection-derived immunity

Immunity to SARS-CoV-2 infection and severe or critical COVID-19 following vaccination or infection (or both) was based on a previously published logistic regression model of immune protection and waning[8], extended in the aforementioned integrated epidemiologic and economic analysis of optimal COVID-19 policy in Victoria.[1]

References

1. Szanyi J, Wilson T, Howe S, et al. Epidemiologic and economic modelling of optimal COVID-19 policy: public health and social measures, masks and vaccines in Victoria, Australia. *Lancet Reg Health West Pac* 2023; **32**: 100675.
2. Manica M, De Bellis A, Guzzetta G, et al; Reggio Emilia COVID-19 Working Group. Intrinsic generation time of the SARS-CoV-2 Omicron variant: An observational study of household transmission. *Lancet Reg Health Eur* 2022; **19**: 100446.
3. Hakki S, Zhou J, Jonnerby J, et al; ATACCC study investigators. Onset and window of SARS-CoV-2 infectiousness and temporal correlation with symptom onset: a prospective, longitudinal, community cohort study. *Lancet Respir Med* 2022; **10**: 1061-1073.
4. Byambasuren O, Cardona M, Bell K, et al. Estimating the extent of asymptomatic COVID-19 and its potential for community transmission: systematic review and meta-analysis. *J Assoc Med Microbiol Infect Dis Can* 2020; **5**: 223-234.
5. Zhang J, Litvinova M, Liang Y, et al. Changes in contact patterns shape the dynamics of the COVID-19 outbreak in China. *Science* 2020; **368**: 1481-1486.
6. Andrejko KL, Pry JM, Myers JF, et al. Effectiveness of face mask or respirator use in indoor public settings for prevention of SARS-CoV-2 Infection: California, February–December 2021. *MMWR Morb Mortal Wkly Rep* 2022; **71**: 212-216.
7. Victorian Government. Weekly COVID-19 vaccine data. https://www.coronavirus.vic.gov.au/weekly-covid-19-vaccine-data (viewed Jan 2023).
8. Szanyi J, Wilson T, Scott N, Blakely T. A log-odds system for waning and boosting of COVID-19 vaccine effectiveness. *Vaccine* 2022; **40**: 3821-3824.

Supplementary results

Table 4. Median cumulative infections and deaths over twelve months in Victoria, April 2022 –March 2023 (based on 500 model runs with separate draws of input parameters), by mask wearing levels for people under 60 years or aged 60 years or more

	Mask wearing: people under 60 years of age*			
Outcome/mask wearing: people aged 60 years or more†	**0**	**20%**	**35%**	**50%**
Cumulative infections, median (UI)				
0%	5 458 276 (3 057 096–8 907 912)	—	—	—
20%	5 383 305 (3 182 906–8 825 941)	4 455 439 (2 540 124–7 452 940)	—	—
35%	5 224 787 (3 069 930–8 727 881)	4 413 930 (2 478 200–7 387 294)	3 990 881 (1 118 477–6 652 354)	—
50%	5 233 940 (3 067 807–8 651 006)	4 422 155 (2 456 578–7 225 412)	3 975 181 (1 082 820–6 711 900)	3 563 312 (119 725–6 018 061)
75%	5 125 956 (2 961 732–8 504 066)	4 335 317 (2 463 741–7 230 145)	3 931 840 (668 280–6 616 167)	3 506 638 (112 474–5 934 968)
Cumulative deaths, median (UI)				
0%	4554 (1656–9785)	—	—	—
20%	4448 (1614–9666)	4184 (1422–9307)	—	—
35%	4244 (1620–9426)	4076 (1368–8553)	3759 (1065–8206)	—
50%	4276 (1514–9159)	3953 (1360–8187)	3757 (1184–8277)	3436 (83–8217)
75%	4157 (1525–8915)	3832 (1317–8115)	3548 (998–7676)	3300 (75–7683)

UI = uncertainty interval (5th – 95th percentiles).

* Mask use proportions apply to people aged 20–59 years; level for children and adolescents aged 10–19 years set to two-thirds of this value, values, and for 0–9-year-old children to two-thirds of the proportion for 10-19-year-old children and adolescents.

† We only modelled mask wearing rates for people aged 60 years or more that matched or exceeded the rate for people under 60.

Table 5. Median cumulative hospitalisations over twelve months in Victoria, April 2022 –March 2023 (based on 500 model runs with separate draws of input parameters), by mask wearing levels for people under 60 years or aged 60 years or more

	Mask wearing: people under 60 years of age*			
Outcome/mask wearing: people aged 60 years or more†	**0%**	**20%**	**35%**	**50%**
Cumulative hospitalisations, median (UI)				
0%	32,865 (17,475–59,982)	—	—	—
20%	32,084 (17,206–57,919)	29,234 (14,577–52,362)	—	—
35%	31,318 (16,440–56,049)	28,547 (15,082–50,683)	27,166 (9,046–46,752)	—
50%	31,034 (16,286–53,541)	27,655 (13,775–48,835)	26,960 (9,046–44,260)	25,593 (837–43,590)
75%	29,448 (15,948–53,377)	27,337 (13,819–48,438)	25,539 (6,595–43,062)	23,935 (729–40,473)

UI = uncertainty interval (5th – 95th percentiles).

* Mask use proportions apply to people aged 20–59 years; level for children and adolescents aged 10–19 years set to two-thirds of this value, values, and for 0–9-year-old children to two-thirds of the proportion for 10–19-year-old children and adolescents.

† We only modelled mask wearing rates for people aged 60 years or more that matched or exceeded the rate for people under 60.