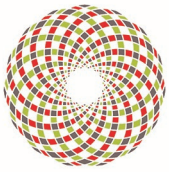

Te Pūnaha Matatini
Data ▪ Knowledge ▪ Insight

Note: This paper has not yet undergone external peer review

Contagion Network Modelling of Effectiveness for a Range of Non-Pharmaceutical Interventions for COVID-19 Elimination in Aotearoa New Zealand

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Summary

We address the question: **if a COVID-19 case is detected in the community (and not immediately connected to the border), what set of non-pharmaceutical interventions is sufficient to lead to elimination?** We consider a range of scenarios to address this question, all beginning from an initial, infected case in the community when only minimal (Alert Level 1) controls are in place. **We simulate with a network-based contagion model until the first infected case is detected, after which we trigger one of a range of possible interventions and continue the simulation**. Each of these interventions is a combination of multiple control measures. We represent these control measures as **context-specific transmission reductions, varying across home, workplace/school, and community contexts**. We allow transmission routes via both 'close' and 'casual' contacts within each infection context, each with specific intervention-dependent reductions in transmission rate. The precise effects of these interventions on the individual-level, context-dependent transmission rates are challenging to determine *a priori*. Thus, though given in terms of percentage reductions relative to baseline, these are primarily set qualitatively and intended as representative only. This analysis also serves as a **sensitivity study** for the dependence of our model on these transmission parameters.

A given intervention is held in place from the trigger point of case detection until the end of simulation; the whole simulation spans a fixed time range of 90 days, from seed case until simulation end. After this time, we assess the final state of the simulation in terms of:

1. Whether we can consider community transmission to be contained, i.e. all community cases have been isolated.
2. Which interventions (and what proportion of simulations) lead to uncontrolled outbreaks, suppression-like behaviour, or elimination-like behaviour.
3. The total number of infected cases for a specific intervention (and ratio of confirmed vs undetected infections).
4. The change in R_{eff} due to interventions.

We find that **increased testing rates (and hence contact tracing) by itself leads to a large reduction in R_{eff}, but is not typically enough to lead to either suppression or elimination**. **Elimination-like behaviour** may be produced by interventions **in addition to testing and tracing**. This typically requires either:

- **Both workplace and community controls** to be at an **Increased Control** level.
- One of these contexts (**workplace or community**) to have **Strict Control**.

Suppression-like behaviour can be produced by interventions that require one of:

- Both **workplace and community** controls to be at a **Partial Control** level and have **schools closed**.
- **Workplace controls at Increased Control** level.
- **Community** controls at an **Increased Control** level and **workplace** controls at a **Partial Control** level.

Thus **workplace transmission reduction appears to be the most effective control measure, followed closely by community transmission reduction controls**. In addition, it appears that even our elimination-like scenarios would typically require additional time to ensure elimination is achieved. We emphasise, however, that this scenario is based on seeding a community case, not immediately connected to the border, for which baseline testing rates are lower than those assumed for workers at high risk of exposure and who are expected to have scheduled weekly or fortnightly tests.

Simulation settings and intervention design

We run simulations of interventions on a baseline scenario that is intended to represent the situation in Aotearoa between outbreaks, during a period when the country is at Alert Level 1. **This scenario begins with a single infected individual in the Auckland Territorial Authority** resulting in (initially undetected) disease spread. During this initial phase of undetected disease spread there are limited control measures are in place, though it is assumed that disease control measures are ready to be activated upon detection and that testing and contact tracing resources are available. We neglect existing immunity in the population, due to the low number of cases observed in New Zealand to date.

Upon the detection of the first identified case of community spread, non-pharmaceutical control measures are introduced. These control measures result in reductions of transmission in different contexts - the home, the workplace, the school, or in the community. The control measures can be viewed as an implementation of policies that could range from shutting down particular interaction contexts, to increased physical distancing, to masking or other hygiene campaigns.

Regardless of which interventions are in effect, **we also consider a baseline test and trace mechanism** in the model. This involves two components as a symptomatic individual will have both a probability of getting a test, and a time to returning a result post-test. Upon receiving a positive test result, a symptomatic individual is categorised as *known* and is isolated in their home until recovery. Tracing also begins at this time, during which contacts with close interactions with the known individual are contacted after some time. We have neglected stay-at-home and additional testing behaviours of casual-plus contacts that were made part of official policy after these simulations were run.

We calibrate a Weibull distribution against the contact tracing times reported as metric S003 in the Update on Contact Tracing Assurance Committee Report Release[1] released in late August, 2020. Calibration was done by manually adjusting an automated weighted least-squares method on the cumulative distribution function to better capture the first 72 hours of tracing. This distribution is presented below and provides a reasonable, though not perfect, fit to the data (Figure 1).

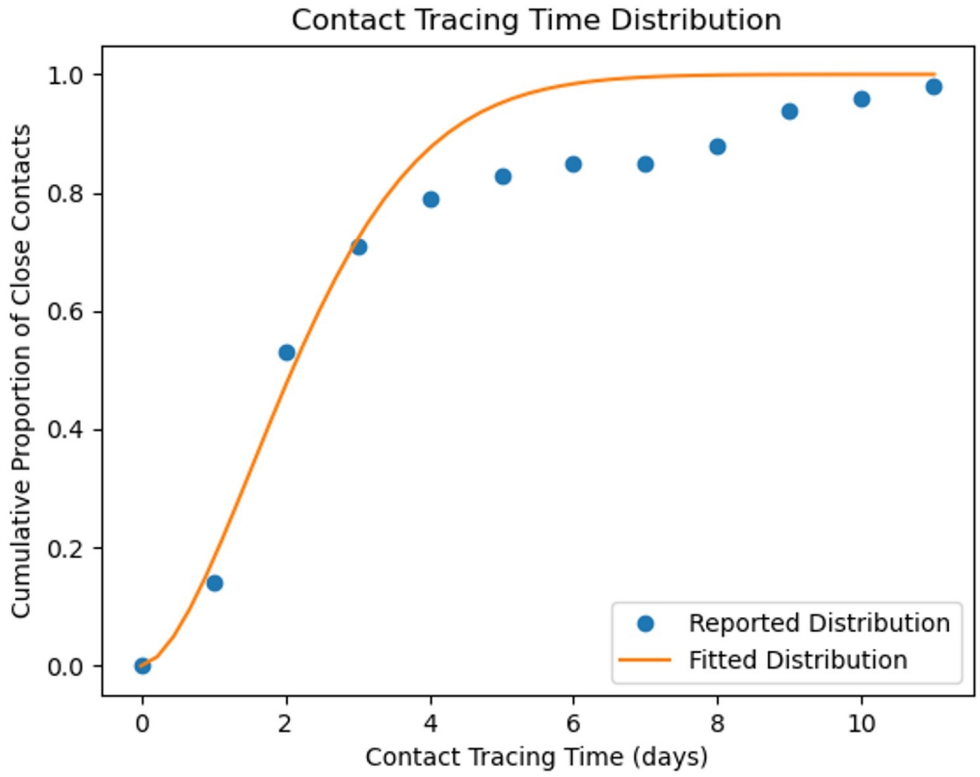

Figure 1. Cumulative distribution of contact tracing times fitted to reported distribution in S003 of HR20201521. The fitted distribution is a Weibull distribution with scale parameter of 2.6 and shape parameter of 1.7.

Traced contacts are expected to self-isolate in their homes and have elevated testing rates. After a set period of 14 days since being contacted, traced contacts are released from isolation if they have not been detected as infected. Based on a preliminary

discussion with the National Contact Tracing Service (NCTS), we have been made aware that reported tracing rates (now redacted) are likely too fast.*

We assume that the base testing rate of non-isolated (symptomatic) individuals increases after the first case has been detected, with this being a consistent increase across our intervention scenarios. This assumption emulates the behaviour change that was observed after the announcement of the Auckland August 2020 Outbreak, which was associated with a large increase in the rate of people seeking tests[2].

We categorise the levels of interventions in Table 1 and provide details in the Appendix with further details on parameter values.

Context	Level of Intervention	Description
Home	Baseline	**No reduction in transmission**
Schools	Baseline	**No reduction in transmission**
	Partial Control	Schools open but **transmission reduction of 20% for both close and casual contacts**, due to e.g. reduced interactions (assemblies, sports, etc.), and possibly mask wearing.
	Closure	**No transmission**
Workplaces	Baseline	**No reduction in transmission**
	Partial Control	Overall **transmission reduction of 30%** (this could be through behavioural changes such as social distancing and mask wearing, etc).
	Increased Control	Overall **transmission reduction of 70%** this could be similar to level 3 - a lot of people working from home, and some workplaces closed. [For this report we do not simulate closing specific individual (types of) workplaces]
	Strict Control	Overall **transmission reduction of 85% for close contacts** (this could be similar to level 3 with strict mask wearing or level 4) and **transmission reduction of 94% for casual contacts** (this would be staffing changes and cleaning or restricting use of shared spaces).
Community	Baseline	**No reduction in transmission**
	Partial Control	Overall **transmission reduction of 20% for close contacts** possibly through behavioural measures like social distancing, mask wearing, but could also be a slight reduction in number of social interactions and community events. Also **transmission reduction of 60% to casual contacts** through behavioural changes e.g. social distancing, mask wearing, etc.
	Increased Control	Overall **transmission reduction of 60% to close contacts** through reduction in number of social interactions and community events. And **transmission reduction of 80% to casual contacts** through reducing activity and behavioural changes e.g. social distancing, mask wearing, etc. while on the bus, or shopping, etc.
	Strict Control	Overall **transmission reduction of 90% to close contacts** through removing almost all social/community events. And **transmission reduction of 90% to casual contacts** through reducing activity and behavioural changes e.g. social distancing, mask wearing, etc. while on the bus, or shopping, etc.

Table 1. Levels of individual controls in different contexts. This table shows the levels of intervention across contexts, with a description of what each intervention entails.

For each intervention scenario, we independently select a level of intervention for each context. Some of these

*We will run additional simulations with updated rates once they are released and able to be shared with us.

combinations will relate to existing Alert Level combinations. For example, strict controls in workplaces and the community, as well as school closure, could represent a strict Alert Level 3 intervention. However, we also consider all other combinations of interventions, such as school closure and no reductions anywhere else, or strict Community control with no reduction in Workplaces or Schools. Some of these combinations are clearly unrealistic from a policy perspective, but provide additional insight into model sensitivities.

Through the combination of the various intervention levels across contexts, **we have 48 different intervention scenarios**. Due to the large number of scenarios considered, we only run **50 realisations of each scenario** in order to get rough estimates of the variance in the results. 50 realisations is (in some cases) the minimum needed for the behaviour of summary statistics, such as the mean of cumulative confirmed cases after a certain number of days, to be characterised by a normal distribution. In[3], we see that this allows us to assess the precision of such summary statistics as estimates of the corresponding simulation population characteristics. For example, we found that for 50 realisations the true simulation mean of cumulative cases for a representative set of parameters could be characterised to within about +/- 50 cases. This is a fairly optimistic scenario and more generally does not imply that 50 realisations leads to low variance estimates, rather that we expect that any less would be insufficient.

More generally, variance in results across simulations can be due to i) limited number of simulation runs; ii) inherent stochastic effects in the simulations; and iii) random choice of the initially seeded nodes. The latter of these determines which part of the network is initially exposed to disease spread and hence is affected by the different topology in different parts of the network.

At the 'Baseline' level, there is no transmission reduction in any contexts. As discussed above, in all scenarios we have a much-increased testing rate following the detection of the first case.

Below, we compute an approximate R_{eff} by fitting a linear model to the log of the number of active cases as a surrogate for the number of new cases, to determine a growth rate of cases in the system. This can then be transformed into R_{eff} by using the approximate relationship $R_{\text{eff}} = 1 + \text{growth rate} \times \text{generation time}$[4,5]. For pre-intervention, the growth rate is fitted from time of seeding up to the time of intervention; for post-intervention values, the growth rate is fitted from the time of intervention to the end of the simulation. Mean R_{eff} values are taken as an arithmetic mean of individual R_{eff} values over the realisations of each scenario.

Pre-intervention: Key results

Simulations are run at the Baseline level until the first case is detected (pre-intervention), and thus we expect the results for all simulations to be comparable prior to detection. The time to detection by total infections across simulations can be seen in Figure 2.

We see that across all simulations:

- Just over 18% of all realisations do not result in detection (and also do not result in an outbreak)
- Given detection, the mean time to the first detected case is 21 days, and the median [lower quartile, upper quartile] time to the first detected case is 20 [14, 27] days.
- We expect a median of 22 [9, 45] total cases when the first case is detected.
- The mean R_{eff} for realisations pre-detection is 1.84 with an interquartile range of [1.63 - 2.02].

We also compute the number of generations of infection before a first case is detected in our simulations (see Figure 3). We find that the median generation number of the first detected case is 3, and the mean generation number is 2.8.

Post-intervention: Key results

After the first detected case, an intervention is activated one day later. We observe from the number of active cases over time (see Figure 4) that interventions result in three main categories of simulation outcome:

- **Uncontained outbreak**, where the number of active cases is still increasing at the end of the 90-day simulation (Figure 4, A).
- **Suppression-like** behaviour, where the number of active cases is relatively constant at the end of the 90-day simulation (Figure 4, B).
- **Elimination-like** behaviour, where the number of active cases is decreasing, or zero at the end of the 90-day simulation (Figure 4, C).

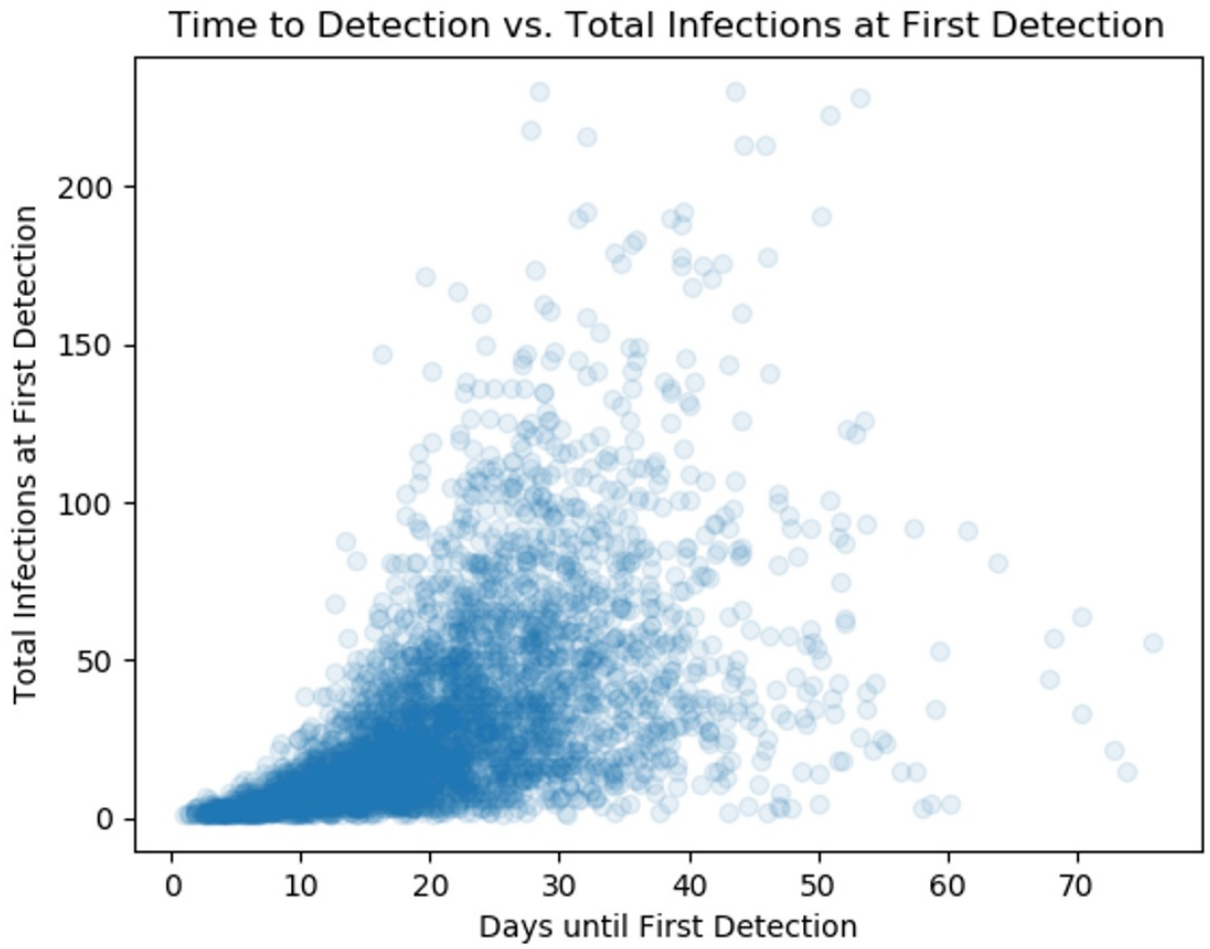

Figure 2. Number of days before the first case is detected compared to the total infections at the time of the first detected case. For the 3920 out of 4900 simulations in which a case was detected.

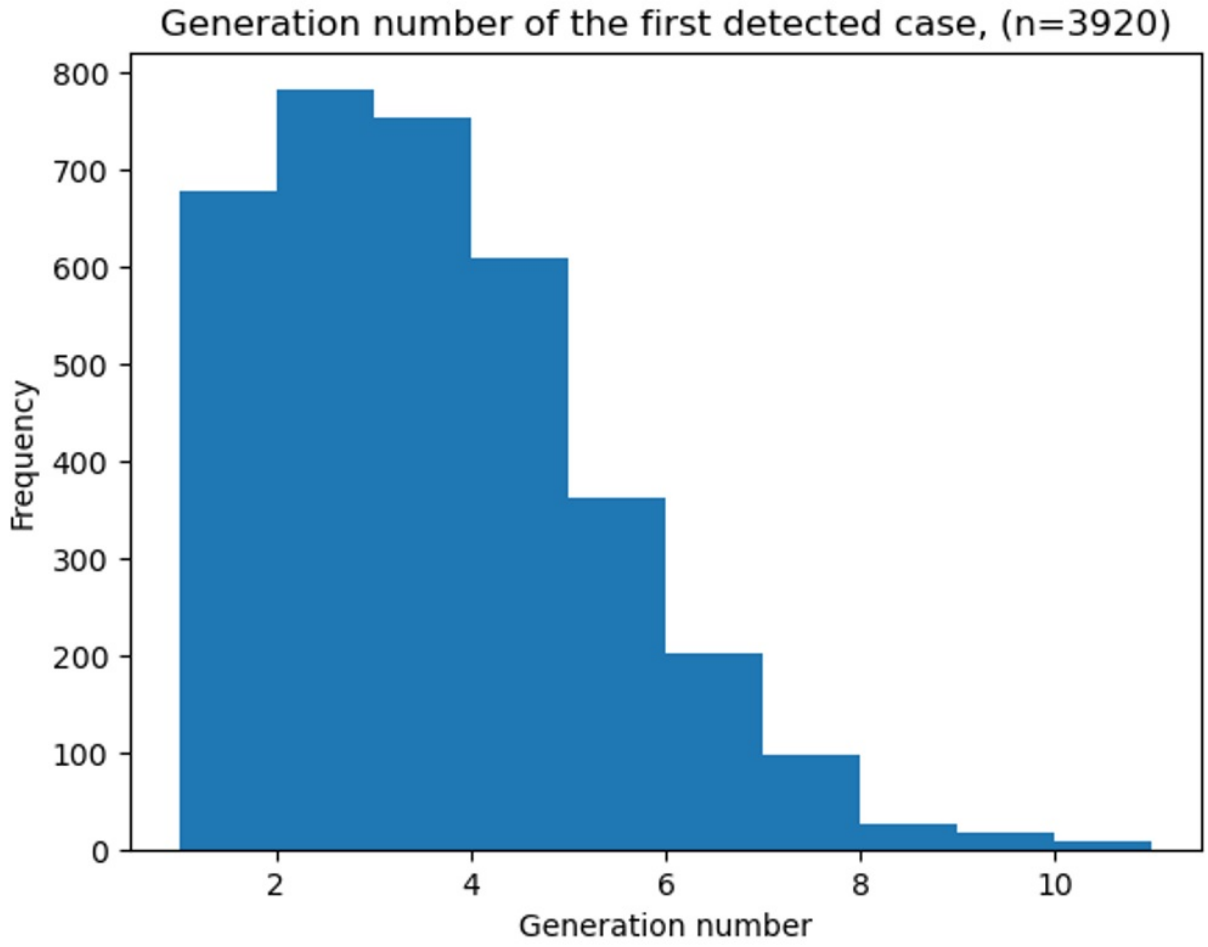

Figure 3. Number of generations of infection before a first case is detected. For the 3920 out of 4900 simulations in which a case was detected.

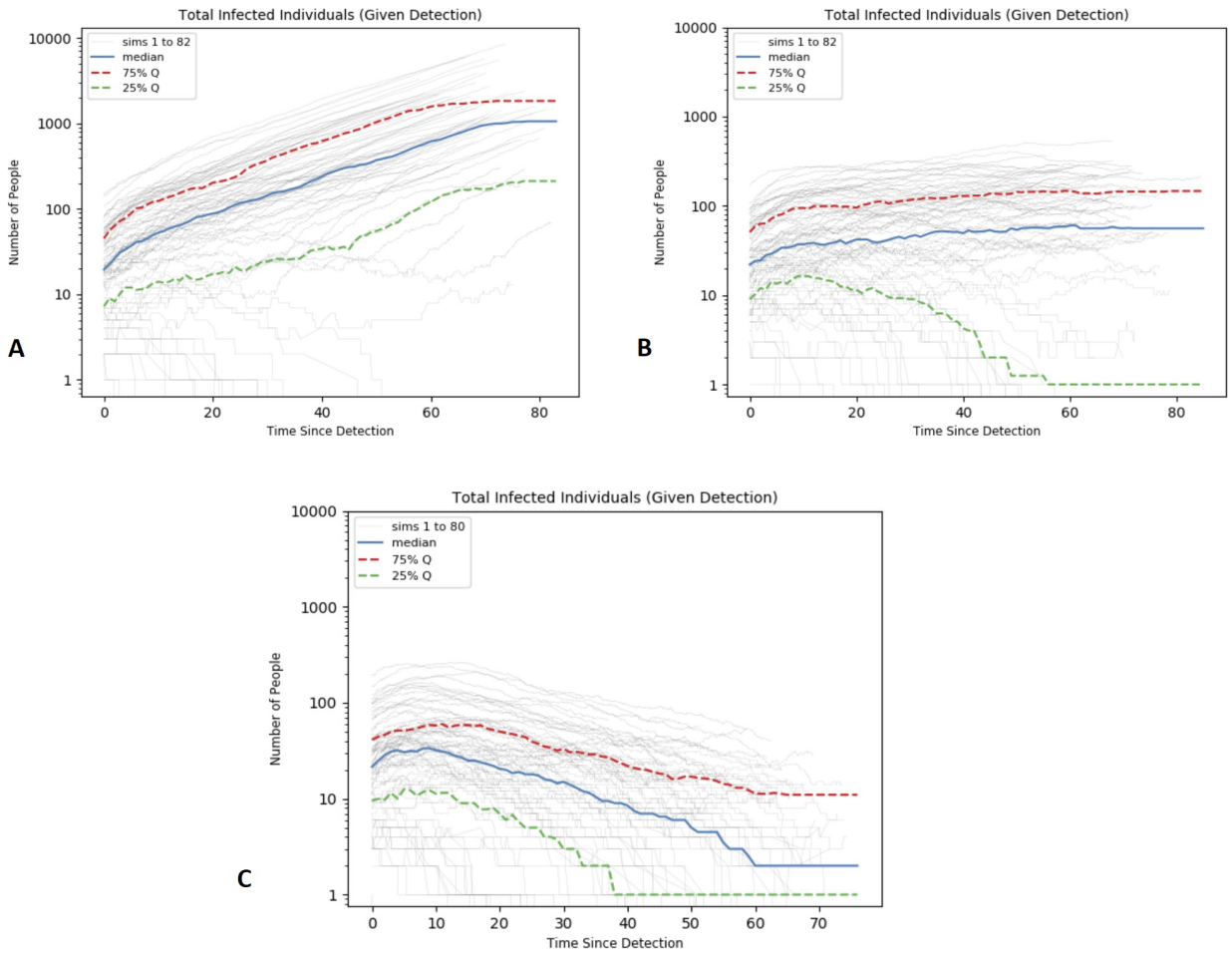

Figure 4. Total infected individuals at *time since first detection*, for simulation realisations with at least one detected case. These plots represent examples of interventions resulting in: **A.** Uncontained outbreak (Intervention 4), where the number of active cases is still increasing by the end of the 90-day simulation; **B.** Suppression (Intervention 22), where the number of active cases remains relatively consistent over the 90-day simulation; and **C.** Elimination (Intervention 27), where the number of active cases is decreasing or at zero by the end of the 90-day simulation. **NB: because of the different times of first detection in each simulation, the simulations all finish at different times. The flat line in the median and IQ ranges at the end of these graphs should be ignored. It is a consequence of the post-processing assuming that simulations remain at a constant number of cases once the simulation ends. This needs to be addressed in future reporting.**

Of the 48 interventions (including baseline - which only involves an increase in testing):

- 18 interventions result in uncontained spread
- 17 interventions result in suppression-like behaviour
- 13 interventions result in elimination-like behaviour

For interventions that typically result in an **uncontained outbreak**, we see that they:

- Have a typical mean post-intervention R_{eff} of 1.17
- Typically end the simulation at 90 days with a median of 780 active cases, and trending upward
- Typically have a median of 1609 total (cumulative) cases by 90 days
- Typically have a median peak number of 589 new isolated individuals per day via contact tracing

- Typically have 36% all active cases known at day 90, with a further 9% of active cases in isolation (via contact tracing), but unknown

For interventions that typically result in **suppression-like** behaviour, we see that they require one of:

- Both workplace and community controls to be at a Partial Control level and have schools closed.
- Workplace controls at Increased Control level
- Community controls at an Increased Control level and workplace controls at a Partial Control level
- Have a typical mean post-intervention R_{eff} of 0.99
- Typically end the simulation at 90 days with a median of 31 active cases, and trending constant
- Typically have a median of 201 total (cumulative) cases by 90 days
- Typically have a mean peak number of 143 new isolated individuals per day via contact tracing
- Typically have 65% of all active cases known at day 90, with a further 5% of active cases in isolation (via contact tracing), but unknown

For interventions that typically result in **elimination-like** behaviour, we see that they:

- Require either both workplace and community controls to be at an Increased Control level, or one of these contexts to have Strict Controls
- Have a typical mean post-intervention R_{eff} of 0.82
- Typically end the simulation at 90 days with a median of 1 active case, and trending downward.
- Typically have a median of 76 total (cumulative) cases by 90 days
- Typically have a median peak number of 73 new isolated individuals per day via contact tracing
- Typically have a median of 99% of all active cases known at day 90, with a further 1% of active cases in isolation (via contact tracing), but unknown

Figure 5 shows that, in general, stronger controls lead to greater reductions in R_{eff}, but that there is a large amount of variability. Some key points to note are that school closures do not have much effect in the present model, and that combinations of lower levels of interventions have more effect than just one stricter intervention.

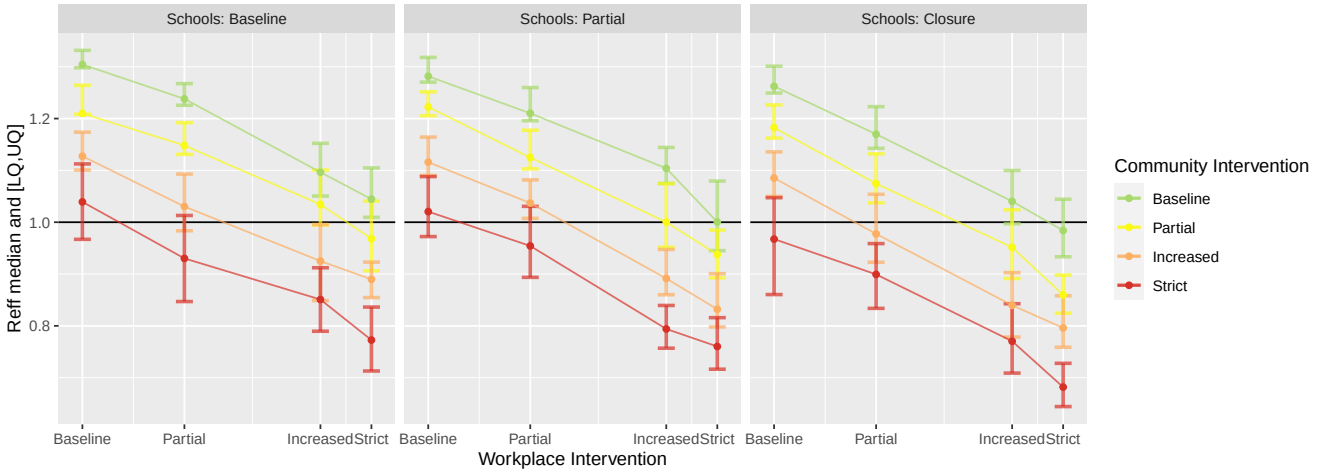

Figure 5. R_{eff} changes with different interventions Each intervention is placed on the x axis according to the approximate % reduction from baseline, on a 0 (baseline) to 1 (strict) scale).

In addition to R_{eff}, we can look at the total (cumulative) number of cases over the first 90 days (Figure 6).

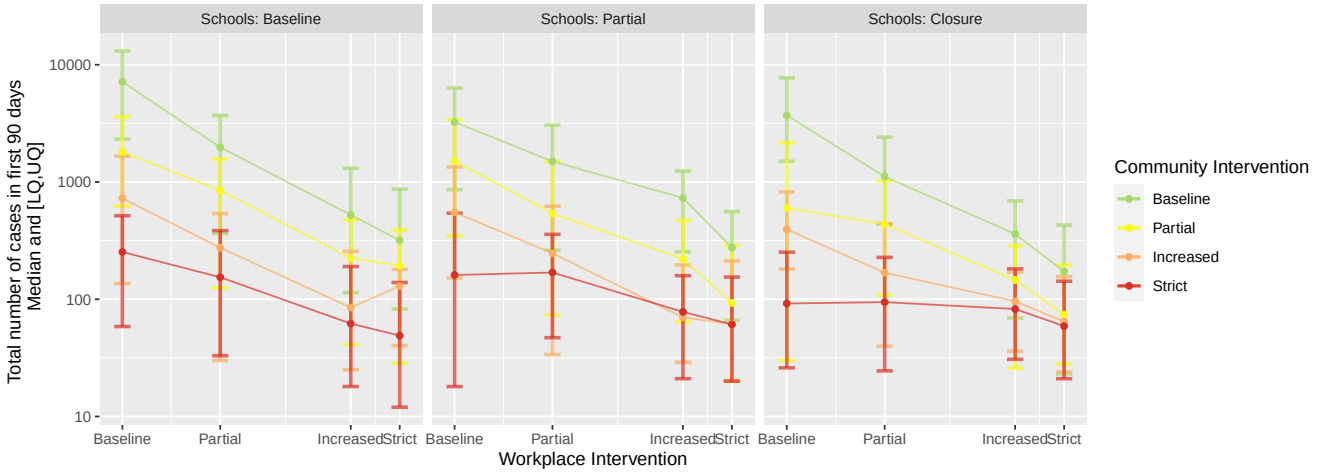

Figure 6. Total number of cases (detected and undetected) over the first 90 days. Note that the y-axis is on a log scale. Each intervention is placed on the x axis according to the approximate % reduction from baseline, on a 0 (baseline) to 1 (strict) scale).

From the total number of cases over the first 90 days, we can see that scenarios where we observe uncontrolled outbreak behaviour, there are a high number of total cases. For scenarios with interventions that lead to elimination, we still see around 100 cumulative cases over the simulation period (for outbreaks that reached the detection threshold).

To see when scenarios are tending to elimination, we can look at the number of active cases at 90 days (Figure 7.

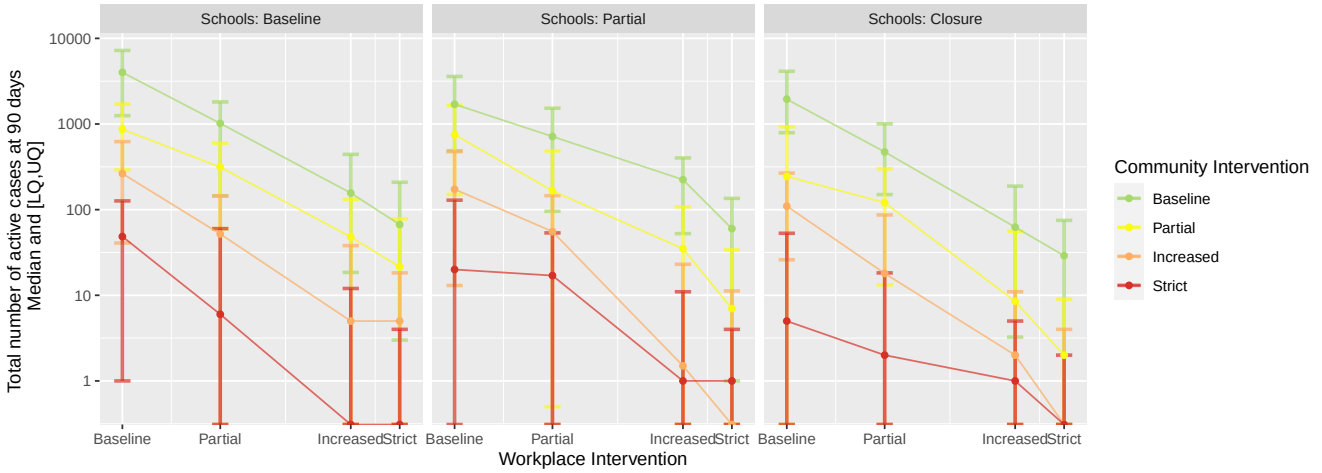

Figure 7. Number of active cases at 90 days (end of the simulation). Note: y-axis is on a log scale, so zeros are transformed and shown at the bottom of the y-axis. Each intervention is placed on the x axis according to the approximate % reduction from baseline, on a 0 (baseline) to 1 (strict) scale).

Scenarios that have fewer than 10 active cases at 90 days will be on a trajectory towards elimination, while those with around 100 active cases will on the trajectory towards suppression. Uncontrolled outbreak trajectories have close to 1000 active cases.

A "Do Nothing" Case

One additional scenario we have run is a baseline case but without any increase in testing after the first case is detected. In this case, testing and contact tracing still occur, but there is no significant transmission reduction, or increase in testing and tracing rates. This could be interpreted as a non-response strategy by health officials. This is perhaps a *slightly-better-than-worst-case* scenario, in the sense that we still make the assumption that some passive control processes are happening, and without physical resource constraints. We note that in this scenario, cases are still exponentially increasing after 90 days and that this scenario would overwhelm the contact tracing service with the amount of tracing required.

We list metrics for the "Do Nothing" scenario in the format summarised in Table 2.

R_{eff}	1.58 (1.59) [1.57, 1.60]
Total cases at day 90	129,935 (120,065) [43,887, 196,858]
Percentage of realisations with elimination	34%
Active cases at day 90	87,883 (86,916) [32,778, 137,034]
Peak new isolated contacts per day	20,276 (19,054) [6,634, 32,856]

Table 2. Metrics for the "Do Nothing" scenario. Mean (Median) [Lower Quartile, Upper Quartile]

References

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Appendix: Table of simulation settings and results

Unless otherwise specified, metrics are reported in the format: Mean (Median) [Lower Quartile, Upper Quartile]

Control	**Context-specific transmission rate as a proportion of baseline (1-percentage reduction)**
Schools: *Partial control*	0.80
Schools: *Closure*	0
Workplaces: *Partial control*	0.70
Workplaces:*Increased control*	0.30
Workplaces: *Strict control*	0.06 (casual interaction) 0.15 (close interaction)
Community: *Partial control*	0.40 (casual interactions) 0.80 (close interactions)
Community: *Increased control*	0.20 (casual interactions) 0.40 (close interactions)
Community: *Strict control*	0.10 (casual interactions) 0.10 (close interactions)

Table 3. Context-specific transmission rate for each control, as a proportion of baseline (no controls). Note that for the community controls, we term close interactions as interactions that are frequently high-risk for transmission. This includes, for example, interactions with extended family members that do not co-habitate, social gatherings with friends, church, or community events. Close interactions in a workplace are representative of frequent risky interactions in a defined space. For small workplaces (fewer than 10 people) we assume this is every employee at that workplace. For large workplaces, we create smaller 'teams' (mean of 10, heavy-tailed distribution) in which these close interactions occur. Interactions with colleagues in the wider workforce would be classified as casual.

	Pre-intervention		Post-intervention		Isolation (via tracing)	
Case severity	Probability of getting a test and testing positive*	Mean number of days from onset to test return	Probability of getting a test and testing positive*	Mean number of days from onset to test return	Probability of getting a test and testing positive*	Mean number of days from onset to test return
Asymptomatic	0%	-	0%	-	90%	2
Mild	6.4%	4	50%	3	90%	2
Severe	50%	4	70%	3	90%	2

Table 4. Testing Parameters. *test positivity rates vary with viral load throughout the time course of infection. The test positivity is around 70%, so to get 90% for close contacts we are assuming two tests (approximately day 3 and day 12 testing). For post-intervention testing we are assuming all people with 'severe' cases (those with pneumonia or similar and high hospitalisation rate) get tested, and most (70%) of those with a 'mild' case (from runny nose through to anything short of 'severe', but including those with serious illness).

	Control Level		
Intervention	School	Workplace	Community
Baseline	Baseline	Baseline	Baseline
1	Baseline	Baseline	Partial Control
2	Baseline	Baseline	Increased Control
3	Baseline	Baseline	Strict Control
4	Baseline	Partial Control	Baseline
5	Baseline	Partial Control	Partial Control
6	Baseline	Partial Control	Increased Control
7	Baseline	Partial Control	Strict Control
8	Baseline	Increased Control	Baseline
9	Baseline	Increased Control	Partial Control
10	Baseline	Increased Control	Increased Control
11	Baseline	Increased Control	Strict Control
12	Baseline	Strict Control	Baseline
13	Baseline	Strict Control	Partial Control
14	Baseline	Strict Control	Increased Control
15	Baseline	Strict Control	Strict Control
16	Partial Control	Baseline	Baseline
17	Partial Control	Baseline	Partial Control
18	Partial Control	Baseline	Increased Control
19	Partial Control	Baseline	Strict Control
20	Partial Control	Partial Control	Baseline
21	Partial Control	Partial Control	Partial Control
22	Partial Control	Partial Control	Increased Control
23	Partial Control	Partial Control	Strict Control
24	Partial Control	Increased Control	Baseline
25	Partial Control	Increased Control	Partial Control
26	Partial Control	Increased Control	Increased Control
27	Partial Control	Increased Control	Strict Control
28	Partial Control	Strict Control	Baseline
29	Partial Control	Strict Control	Partial Control
30	Partial Control	Strict Control	Increased Control
31	Partial Control	Strict Control	Strict Control
32	Closure	Baseline	Baseline
33	Closure	Baseline	Partial Control
34	Closure	Baseline	Increased Control
35	Closure	Baseline	Strict Control
36	Closure	Partial Control	Baseline
37	Closure	Partial Control	Partial Control
38	Closure	Partial Control	Increased Control
39	Closure	Partial Control	Strict Control
40	Closure	Increased Control	Baseline
41	Closure	Increased Control	Partial Control
42	Closure	Increased Control	Increased Control
43	Closure	Increased Control	Strict Control
44	Closure	Strict Control	Baseline
45	Closure	Strict Control	Partial Control
46	Closure	Strict Control	Increased Control
47	Closure	Strict Control	Strict Control

Table 5. Listing of component controls of each intervention.

Intervention [S,W,C]	Overall behaviour type	Total Cases in the first 90 days post seed case	Percentage reduction compared to baseline	Percentage of realisations with elimination (within 90 days)
Baseline	Uncontained	8682 (7155) [2321, 13106]	-	11%
1	Uncontained	2584 (1805) [622, 3604]	70.2% (74.8%)	10%
2	Uncontained	1067 (726) [136, 1659]	87.7% (89.9%)	17%
3	Suppression	364 (253) [59, 516]	95.8% (96.5%)	20%
4	Uncontained	2801 (1979) [364, 3687]	67.7% (72.3%)	18%
5	Uncontained	1088 (847) [125, 1569]	87.5% (88.2%)	18%
6	Suppression	396 (275) [30, 538]	95.4% (96.2%)	22%
7	Suppression	280 (154) [33, 385]	96.8% (97.8%)	21%
8	Uncontained	829 (523) [114, 1311]	90.4% (92.7%)	14%
9	Suppression	348 (225) [41, 476]	96% (96.9%)	22%
10	Suppression	168 (85) [25, 257]	98.1% (98.8%)	30%
11	Elimination	127 (62) [18, 190]	98.5% (99.1%)	41%
12	Suppression	530 (319) [83, 870]	93.9% (95.5%)	19%
13	Suppression	267 (193) [29, 393]	96.9% (97.3%)	22%
14	Elimination	141 (130) [40, 180]	98.4% (98.2%)	28%
15	Elimination	104 (49) [12, 139]	98.8% (99.3%)	50%
16	Uncontained	4755 (3247) [859, 6333]	45.2% (54.6%)	11%
17	Uncontained	2264 (1509) [346, 3410]	73.9% (78.9%)	15%
18	Uncontained	863 (551) [152, 1344]	90.1% (92.3%)	14%
19	Suppression	344 (161) [18, 542]	96% (97.7%)	33%
20	Uncontained	2131 (1499) [262, 3054]	75.5% (79.1%)	15%
21	Uncontained	819 (538) [73, 1497]	90.6% (92.5%)	23%
22	Suppression	394 (247) [34, 621]	95.5% (96.5%)	24%
23	Suppression	245 (169) [47, 358]	97.2% (97.6%)	22%
24	Uncontained	804 (731) [254, 1243]	90.7% (89.8%)	10%
25	Suppression	294 (221) [64, 470]	96.6% (96.9%)	20%
26	Elimination	172 (70) [29, 196]	98% (99%)	34%
27	Elimination	122 (78) [21, 159]	98.6% (98.9%)	34%
28	Uncontained	451 (276) [66, 559]	94.8% (96.1%)	18%
29	Suppression	194 (93) [20, 288]	97.8% (98.7%)	28%
30	Elimination	146 (62) [20, 212]	98.3% (99.1%)	42%
31	Elimination	97 (61) [20, 155]	98.9% (99.1%)	36%
32	Uncontained	5048 (3701) [1502, 7734]	41.9% (48.3%)	5%
33	Uncontained	1450 (599) [30, 2164]	83.3% (91.6%)	23%
34	Uncontained	655 (394) [181, 823]	92.5% (94.5%)	16%
35	Suppression	252 (92) [26, 252]	97.1% (98.7%)	24%
36	Uncontained	1730 (1112) [437, 2414]	80.1% (84.5%)	10%
37	Uncontained	620 (436) [108, 1030]	92.9% (93.9%)	17%
38	Suppression	307 (169) [40, 441]	96.5% (97.6%)	27%
39	Elimination	170 (95) [25, 228]	98% (98.7%)	33%
40	Suppression	451 (361) [69, 690]	94.8% (95%)	15%
41	Suppression	208 (146) [26, 286]	97.6% (98%)	30%
42	Elimination	119 (96) [36, 170]	98.6% (98.7%)	35%
43	Elimination	119 (83) [31, 182]	98.6% (98.8%)	35%
44	Suppression	343 (172) [23, 429]	96% (97.6%)	27%
45	Elimination	125 (74) [28, 196]	98.6% (99%)	34%
46	Elimination	95 (65) [24, 156]	98.9% (99.1%)	47%
47	Elimination	92 (59) [21, 143]	98.9% (99.2%)	50%

Table 6. **Total number of cases at 90 days after first case is exposed and elimination metrics, by intervention.**

Intervention [S,W,C]	Peak Active Cases	Time of Peak (Days post seed case)
Baseline	4785 (4006) [1255,7228]	78 (90) [90,90]
1	1227 (869) [291,1709]	79 (90) [90,90]
2	390 (270) [48,624]	72 (90) [75,90]
3	117 (78) [25,143]	57 (58) [32,88]
4	1356 (1020) [145,1813]	72 (90) [88,90]
5	416 (317) [61,599]	71 (90) [63,90]
6	112 (74) [13,159]	56 (67) [28,88]
7	82 (54) [15,97]	40 (40) [25,54]
8	287 (160) [37,443]	69 (89) [46,90]
9	104 (70) [16,142]	54 (57) [31,82]
10	56 (35) [14,82]	37 (36) [17,48]
11	49 (27) [11,77]	28 (28) [15,38]
12	156 (102) [30,234]	59 (70) [31,89]
13	77 (75) [19,120]	45 (39) [25,69]
14	50 (43) [21,61]	32 (30) [20,39]
15	48 (26) [9,56]	26 (27) [15,36]
16	2615 (1702) [490,3598]	78 (90) [90,90]
17	1050 (752) [153,1651]	75 (90) [90,90]
18	307 (174) [47,477]	70 (90) [50,90]
19	103 (48) [12,142]	51 (48) [21,87]
20	1003 (716) [98,1532]	75 (90) [90,90]
21	298 (166) [30,487]	66 (89) [24,90]
22	112 (77) [19,173]	55 (63) [23,87]
23	74 (59) [22,99]	43 (38) [27,58]
24	266 (229) [68,412]	74 (89) [78,90]
25	86 (70) [24,130]	51 (50) [26,76]
26	57 (29) [14,64]	31 (29) [17,42]
27	53 (37) [13,66]	30 (30) [22,38]
28	133 (80) [33,150]	53 (51) [35,86]
29	59 (37) [11,79]	33 (31) [22,47]
30	55 (34) [10,72]	28 (29) [18,36]
31	48 (30) [13,76]	23 (24) [17,33]
32	2659 (1951) [791,4129]	84 (90) [90,90]
33	618 (246) [19,932]	66 (90) [26,90]
34	215 (125) [52,268]	68 (85) [56,90]
35	77 (37) [14,89]	44 (42) [20,66]
36	745 (472) [152,1006]	77 (90) [89,90]
37	195 (141) [30,302]	65 (87) [35,90]
38	91 (53) [24,124]	47 (43) [28,68]
39	55 (33) [15,74]	34 (33) [22,43]
40	131 (99) [30,208]	60 (69) [36,88]
41	64 (55) [15,86]	40 (35) [20,59]
42	48 (38) [19,65]	29 (30) [23,35]
43	55 (41) [16,79]	27 (27) [19,36]
44	98 (55) [17,130]	44 (39) [29,62]
45	49 (34) [16,75]	29 (27) [17,38]
46	44 (30) [16,72]	27 (26) [17,34]
47	51 (34) [15,83]	26 (26) [18,32]

Table 7. Peak active cases by intervention (note a mean peak time at 90 days represents increasing or constant active cases at the end of simulation)

Intervention [S,W,C]	Post-intervention Reff	Intervention [S,W,C]	Post-intervention Reff
Baseline	1.30 (1.32) [1.30,1.33]	24	1.10 (1.12) [1.07,1.14]
1	1.21 (1.23) [1.21,1.26]	25	1.00 (1.01) [0.95,1.07]
2	1.13 (1.14) [1.1,1.17]	26	0.89 (0.90) [0.86,0.95]
3	1.04 (1.06) [0.97,1.11]	27	0.79 (0.81) [0.76,0.84]
4	1.24 (1.25) [1.23,1.27]	28	1.00 (1.04) [0.95,1.08]
5	1.15 (1.17) [1.13,1.19]	29	0.94 (0.95) [0.89,0.98]
6	1.03 (1.05) [0.98,1.09]	30	0.83 (0.84) [0.80,0.90]
7	0.93 (0.95) [0.85,1.01]	31	0.76 (0.75) [0.72,0.82]
8	1.10 (1.12) [1.05,1.15]	32	1.26 (1.28) [1.25,1.30]
9	1.03 (1.05) [0.99,1.10]	33	1.18 (1.19) [1.16,1.23]
10	0.93 (0.94) [0.85,1.00]	34	1.09 (1.09) [1.05,1.14]
11	0.85 (0.87) [0.79,0.91]	35	0.97 (0.99) [0.86,1.05]
12	1.04 (1.06) [1.01,1.10]	36	1.17 (1.19) [1.14,1.22]
13	0.97 (0.97) [0.91,1.04]	37	1.07 (1.09) [1.04,1.13]
14	0.89 (0.89) [0.85,0.92]	38	0.98 (1) [0.92,1.05]
15	0.77 (0.77) [0.71,0.84]	39	0.90 (0.91) [0.83,0.96]
16	1.28 (1.30) [1.27,1.32]	40	1.04 (1.06) [1.00,1.10]
17	1.22 (1.23) [1.21,1.25]	41	0.95 (0.95) [0.89,1.02]
18	1.12 (1.14) [1.09,1.16]	42	0.84 (0.85) [0.78,0.90]
19	1.02 (1.05) [0.97,1.09]	43	0.77 (0.77) [0.71,0.84]
20	1.21 (1.23) [1.20,1.26]	44	0.98 (0.99) [0.93,1.04]
21	1.12 (1.14) [1.10,1.18]	45	0.86 (0.86) [0.82,0.90]
22	1.04 (1.05) [1.01,1.08]	46	0.80 (0.78) [0.76,0.86]
23	0.95 (0.96) [0.89,1.03]	47	0.68 (0.67) [0.64,0.73]

Table 8. Reff post-intervention by intervention.

Intervention [S,W,C]	Percentage of Active Cases Known at Day 90 post seed case	Percentage of Active Cases Known or Isolated at Day 90 post seed case
Baseline	40.5% (30.3%)	48.1% (39.5%)
1	42.9% (34.0%)	51.1% (43.4%)
2	51.2% (39.2%)	57.9% (48.8%)
3	60.4% (47.1%)	66.4% (56.5%)
4	46.0% (32.5%)	52.7% (41.5%)
5	52.7% (39.1%)	59.3% (47.9%)
6	59.6% (45.2%)	64.9% (55.6%)
7	68.7% (62.5%)	74.7% (66.7%)
8	50.7% (37.8%)	57.2% (46.6%)
9	61.6% (50.0%)	67.0% (58.8%)
10	70.6% (76.1%)	73.9% (78.6%)
11	80.7% (100.0%)	84.0% (100.0%)
12	57.4% (44.1%)	63.2% (53.6%)
13	64.5% (59.7%)	69.9% (66.6%)
14	75.2% (87.9%)	78.7% (95.0%)
15	87.4% (100.0%)	89.9% (100.0%)
16	40.5% (30.3%)	48.0% (39.3%)
17	47.1% (34.7%)	54.2% (43.6%)
18	51.6% (40.0%)	58.7% (48.7%)
19	66.4% (56.3%)	71.4% (62.2%)
20	45.3% (33.0%)	52.4% (42.2%)
21	55.5% (40.8%)	61.9% (48.9%)
22	61.7% (49.8%)	67.2% (56.8%)
23	68.4% (59.6%)	73.4% (66.7%)
24	48.1% (40.0%)	55.2% (49.3%)
25	65.1% (57.4%)	71.3% (65.5%)
26	78.2% (100.0%)	80.5% (100.0%)
27	78.4% (100.0%)	80.8% (100.0%)
28	59.3% (50.0%)	64.3% (55.5%)
29	72.7% (76.9%)	77.3% (87.5%)
30	82.9% (100.0%)	85.4% (100.0%)
31	84.6% (100.0%)	85.7% (100.0%)
32	36.3% (31.2%)	44.8% (40.0%)
33	54% (37.1%)	60.3% (45.9%)
34	52.2% (40.8%)	58.4% (49.5%)
35	69.6% (71.4%)	73.3% (78.6%)
36	44.2% (35.3%)	51.2% (43.6%)
37	53.0% (42.4%)	59.0% (50.8%)
38	71.2% (62.1%)	74.9% (71.0%)
39	80.0% (100.0%)	83.2% (100.0%)
40	56.6% (43.7%)	62.8% (53.4%)
41	71.6% (68.6%)	75.2% (76.9%)
42	80.6% (100.0%)	83.9% (100.0%)
43	82.7% (100.0%)	83.9% (100.0%)
44	64.7% (51.9%)	69.6% (60.5%)
45	80.8% (100.0%)	82.7% (100.0%)
46	86.8% (100.0%)	88.2% (100.0%)
47	90.8% (100.0%)	92.2% (100.0%)

Table 9. Known and isolated cases, by intervention at 90 days after the initial case was exposed

Intervention [S,W,C]	Peak new isolated close contacts per day	Intervention [S,W,C]	Peak new isolated close contacts per day
Baseline	3096.6 (2728.5) [817.8,4585.3]	24	274.2 (257) [125.3,365.8]
1	910.5 (664) [293.5,1271.5]	25	145.5 (139) [64.5,217.5]
2	359.7 (298) [76.5,612.8]	26	105.1 (64.5) [29.3,147.5]
3	163 (129.5) [66.8,209]	27	95.1 (76) [23,136]
4	998.1 (771) [200.3,1404.8]	28	185.2 (133.5) [72,251.3]
5	387.7 (322) [102,613]	29	104.5 (80) [35,141]
6	162.1 (139) [57,228.5]	30	97 (77) [28,141.8]
7	137.7 (98) [44,177]	31	91.4 (77.5) [32,140.5]
8	294.3 (195.5) [82.3,465.8]	32	1678.5 (1254) [516,2460]
9	153.3 (118) [54,201]	33	459.6 (247) [59,667]
10	103.5 (89) [37.3,153]	34	227.2 (154) [101,340]
11	93.6 (64) [31,136]	35	118.2 (91) [27,161]
12	208.1 (169) [71,309.5]	36	570.2 (377) [154,770]
13	131.8 (142.5) [44.5,185.3]	37	195.1 (171) [50.8,298.5]
14	93.7 (89) [48.5,128.5]	38	134.4 (102) [51,203.8]
15	89.7 (59) [17,131]	39	98.8 (84.5) [34,145]
16	1730.7 (1103) [444.5,2583]	40	158.9 (140.5) [64.5,200.8]
17	779.6 (557) [149,1177.5]	41	99.9 (89.5) [38,153]
18	290.8 (191) [91.8,457.3]	42	89.2 (71) [37.5,132]
19	140.6 (113) [34,190]	43	94.8 (82) [30,143]
20	739.1 (528) [128.8,1164.8]	44	136 (105) [51,161]
21	282.2 (201) [74.5,435.5]	45	91.8 (71.5) [39.3,139]
22	158.7 (135) [55,237.3]	46	77.2 (52) [27.8,111.8]
23	127.4 (112) [48,182.5]	47	95.3 (82) [31,122]

Table 10. Peak daily contact tracing rate in the first 90 days after the initial case was exposed