**Interventions to reduce spread of COVID-19 in closed environments: an outbreak investigation and modeling study in dormitories - Supplementary Info**

**Supplementary Table 1:** Suspect case definitions used in Singapore.

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| **Date** | **Suspect case definition** |
| 2 January 2020 (Initial) | 1. A person with clinical signs and symptoms suggestive of pneumonia or severe respiratory infection with breathlessness **AND** travel to or residence in **Wuhan city** within the last 14 days; or
2. A person with an acute respiratory illness of any degree of severity who, within 14 days before onset of illness, had **close contact1** with a pneumonia case of unknown cause linked to the Wuhan cluster.
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| 21 January 2020 | 1. A person with clinical signs and symptoms suggestive of pneumonia or severe respiratory infection with breathlessness AND travel to **mainland China** within 14 days before onset of illness; or
2. A person with an acute respiratory illness of any degree of severity who, within 14 days before onset of illness, had **been to a hospital in mainland China** or had close contact1 with a case of 2019 novel coronavirus infection.
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| 25 January 2020 | 1. A person with clinical signs and symptoms suggestive of pneumonia or severe respiratory infection with breathlessness AND travel to mainland China within 14 days before onset of illness; or
2. A person with an acute respiratory illness of any degree of severity who, within 14 days before onset of illness had:
3. Been to **Wuhan city or Hubei Province, China**; OR
4. Been to a hospital in mainland China; OR
5. Had close contact1 with a case of 2019 novel coronavirus infection.
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| 4 February 2020  | 1. A person with clinical signs and symptoms suggestive of pneumonia or severe respiratory infection with breathlessness AND travel to mainland China within 14 days before onset of illness; or
2. A person with an acute respiratory illness of any degree of severity who, within 14 days before onset of illness had:
3. Been to **Hubei Province (including Wuhan city) or Zhejiang Province (including Hangzhou city)**, China; OR
4. Been to a hospital in mainland China; OR
5. Had close contact1 with a case of 2019 novel coronavirus infection; OR
6. Had **frequent or close contact during work2** **with recent travellers from mainland China** (travel history in the last 14 days).
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| 9 March 2020 | 1. A person with clinical signs and symptoms suggestive of pneumonia or severe respiratory infection with breathlessness AND who within 14 days before onset of illness had travelled abroad (i.e. to any country outside of Singapore).
2. A person with an acute respiratory illness of any degree of severity who, within 14 days before onset of illness had:
3. Been to any of the **areas requiring heightened vigilance**3 as listed on the Healthcare Professionals Portal: https://www.moh.gov.sg/hpp/all-healthcare-professionals; OR
4. Been to **any hospital abroad**; **OR**
5. Close contact4 with a case of COVID-19 infection.
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| 16 April 2020 | 1. A person with clinical signs and symptoms suggestive of Community-Acquired Pneumonia5 or ­community-acquired severe respiratory infection with breathlessness.
2. A person with an acute respiratory illness of any degree of severity (e.g. symptoms of cough, sore throat, runny nose, anosmia), with or without fever, who, within 14 days before onset of illness had:
3. Travelled abroad (outside Singapore); OR
4. Close contact4 with a case of COVID-19 infection OR
5. Stayed in a foreign worker dormitory6
 |
| 8 May 2020 | 1. A person with clinical signs and symptoms suggestive of Community-Acquired Pneumonia5
2. A person with an acute respiratory illness of any degree of severity (e.g. symptoms of cough, sore throat, runny nose, anosmia), with or without fever, who, within 14 days before onset of illness had:
3. Travelled abroad (outside Singapore); OR
4. Close contact4 with a case of COVID-19 infection OR
5. Stayed in a foreign worker dormitory6
6. Worked in occupations or environments with higher risk of exposure to COVID-19 cases7
7. Any person with prolonged febrile8 acute respiratory infection (ARI) symptoms of 4 days or more, and not recovering
 |
| 1. June 2020
 | 1. A person with clinical signs and symptoms suggestive of Community-Acquired Pneumonia5
2. A person with an acute respiratory illness of any degree of severity (e.g. symptoms of cough, sore throat, runny nose, anosmia), with or without fever, who, within 14 days before onset of illness had:
3. Travelled abroad (outside Singapore); OR
4. Close contact4 with a case of COVID-19 infection OR
5. Stayed in a foreign worker dormitory6
6. Worked in occupations or environments with higher risk of exposure to COVID-19 cases7
7. Any person with prolonged febrile8 acute respiratory infection (PARI) symptoms of 4 days or more, and not recovering AND who had not undergone prior swabbing for ARI symptoms in the same episode of illness.
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1 Close contact is defined as: Anyone who provided care for the patient, including a health care worker or family member, or who had other similarly close physical contact; Anyone who stayed (e.g. lived with, visited) at the same place as a case.

2 Persons who attended business meetings/discussions, frontline staff in hospitality and tourism (e.g. hotels, shops, tours) with regular dealings with travellers from mainland China.

3 Refers to affected areas with high disease load or high connectivity to Singapore. As of 9 March 2020, these are: Mainland China, Republic of Korea, Italy, Iran, France, Germany, Spain, Japan and the United Kingdom. Please check the Healthcare Professionals Portal regularly for updates.

4 Close contact is defined as: Anyone who provided care for the patient, including a health care worker or family member, or who had other similarly close physical contact; Anyone who stayed (e.g. household members) at the same place as a case; Anyone who had close (i.e. less than 2m) and prolonged contact (30 min or more) with a case (e.g. shared a meal).

5 Excludes cases of nosocomial pneumonia and aspiration pneumonia with no links to confirmed cases

6 Separate processes apply to foreign workers from a dormitory that has dedicated medical station /clinic or dedicated workflow for assessment and swabbing

7 These include but are not limited to any staff (healthcare worker and non-healthcare worker) working in:

* Public and private healthcare settings, spanning acute care, primary care, intermediate and long-term care and community care settings
* Dormitories or involved in dormitory outbreak control operations
* Isolation / quarantine facilities
* Community care facilities (CCFs)/ community recovery facilities (CRFs)
* Ambulance and dedicated patient transport (including private hire vehicles).

8 Fever, of any duration, with measured or reported temperature of > 37.5ºC.

**Supplementary Table 2: Layout of dormitory**

|  |  |
| --- | --- |
| **Variables** | **Dormitory characteristics** |
| No. of occupants | 12 000 – 13 000 |
| Layout |  |
| No. of zones with restricted access | 3 |
| No. of blocks per zone | 4–5 |
| No. of levels per block | 4 |
| No. of rooms per level | 25 |
| No. of individuals per rooms | 10–12 |
| Facilities  |  |
| Toilet/Shower | Shared facility on each level |
| Cooking/Dining area | Ground level of each block |
| Recreational spaces  | Accessible to all occupants |

# **Transmission model**

## Dormitory contact network parameters

We simulated a dormitory comprising 11 blocks, with 4 levels per block and 25 rooms per level. The number of individuals per room was modelled using a uniform distribution ranging from 10 to 12 persons. The resulting dormitory population size was 12 091 individuals, which reflects the capacity of the dormitory under study.

Given the close living conditions in a room, we assumed all persons in the room have contact with each other. Each individual had an average of 10 close contacts in a room (i.e. the mean number of individuals per room minus the individual in question).

Outside a room, the number of random contacts formed on the same level, same block, or other parts of the dormitory was assumed to follow a Poisson distribution and the mean number of random contacts for each location was modelled according to a range of values listed in Table 1 main text.

## Disease transmission parameters

We assumed that the incubation period follows a gamma distribution (shape = 5.807, scale = 0.948; i.e. = 5.505, = 2.2845)1 and symptomatic individuals are infectious 3 days before symptoms onset and up to 14 days after symptoms onset.

We assumed that exposure to susceptible individuals follows a gamma distribution (shape = 2.5, rate = 0.5; i.e. = 5, = 3.1623) since the start of the infectious period of a case to allow for pre-symptomatic infections to occur approximately 30% of the time (within the estimated range presented by Ferretti et al. (2020))2. Pre-symptomatic cases are equally infectious as symptomatic cases.

Asymptomatic cases are also able to transmit infections with a lowered level of infectiousness. We assign a pseudo time of symptom onset for these cases following the same gamma distributed incubation period for symptomatic cases in order to define their infectious period same as that of symptomatic cases.

The proportion of asymptomatic cases, the relative infectiousness of an asymptomatic case, the probability of infection inside a room and the probability of infection outside a room was modelled according to a range of values listed in Table 1 main text.

## Outbreak intervention parameters

(i) Case isolation

For symptomatic cases that sought medical attention, case isolation was assumed to occur at most 3 days (uniform distribution min = 0 days, max = 3 days) after the onset of symptoms and this is reduced to at most 1 day after the deployment of ground officers 14 days since the earliest observed onset date (i.e. day 15).

The probability of a symptomatic case seeking medical attention was modelled according to a range of values listed in Table 1 main text.

(ii) Quarantine of close contacts

Throughout the simulation, contacts in the same room as a confirmed case would be quarantined in situ with other roommates. Persons under quarantine would spend most of their time confined to their room but would continue to share shower and toilet facilities with others on the same level only. This translates to lowered number of contacts formed with others on the same level but cessation of contacts with others in other parts of the dorm.

Under a modified dormitory setting, en suite facilties help to ensure that persons under quarantine do not leave their rooms (i.e. number of contacts formed with outside the room for persons under quarantine is reduced to zero)

(iii) Social distancing

Ground officers were deployed to implement social distancing measures in the dormitory 14 days since the earliest observed onset date (i.e. day 15). The reduction in the mean number of random contacts for each location was modelled according to a range of values listed in listed in Table 1 main text.

Under a modified dormitory setting scenario, en suite facilities help to ensure that no mixing of residents who are not under quarantine across different levels and different parts of the dormitory when the dormitory is placed under lockdown (i.e. For persons not under quarantine, the number of contacts formed with others on different levels and in different blocks is reduced to zero and there is a reduction in mean number of contacts formed on the same level).

(iv) Reduction in probability of infection outside the household

In the actual outbreak situation, majority of the residents have restricted movement in the dormitory, heighten awareness of the situation and practice mask wearing since the deployment of ground officers. Hence, the probability of infection upon contact with a case outside the room is assumed to decrease.

The reduction in the probability of infection outside the household and the time which this reduction occurred was modelled according to a range of values listed in Table 1 main text.

We hypothesized that a diverse range of parameters could drive similar outbreak trajectory in dormitory under study. We generated 50,000 random parameter combinations with parameters in Table 1 main text.

# **Model Fitting**

We denote as the number of observed cases with symptom onset on day (with day 1 as the day of the earliest symptom onset in the observed case(s)) and as the cumulative number of rooms, levels and blocks in a dormitory with observed cases by day . is the combination of parameters in Table 1 main text for the current iteration.

We assume that is drawn from a Poisson distribution with mean , the number of modelled cases with symptom onset on day where

and the modelled cases with the earliest onset on is dependent on the initial number of cases, the probability of a case being symptomatic, probability of a symptomatic case seeking medical attention (i.e. parameters in ), and the model specification to give the following:

We also assume that are each drawn from a Poisson distribution with mean in the respective order, the cumulative number of rooms, levels and blocks in a dormitory with modelled cases by day . The formulation of follows the formulation of .

We denote the number of serology positive residents by day 79 of the outbreak among eligible dormitory residents who participated in the seroprevalence survey. We assumed the observed seroprevalence follows a Binomial distribution parameterized by , the modelled seroprevalence by day 79.

For an iteration, , and a given parameter combination, , we define the likelihood of observing the cases, affected rooms, levels, units up to day 12 and the seroprevalence on day 79 as:

The first line gives the probability of the number of cases, affected rooms, levels and blocks up to day 12 of the outbreak (change in data collection methods after day 12, hence subsequent data not used for model validation). The second line gives the probability of the seroprevalence on day 79 of the outbreak.

# **Modelling outbreak intervention scenarios**

Each iteration for a parameter combination is assigned a weight as follows:

and we resampled the parameter combinations proportional to . Resampling of the parameter combination with replacement is performed for 10,000 times before simulating all 4 outbreak interventions scenario with the resampled parameter combinations.

# **Supplementary Table 3: Unique sampled parameter combinations**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parameter category | Parameter set | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Disease transmission | Initial number of cases | 13 | 17 | 14 | 15 | 10 | 17 | 14 | 8 | 13 | 16 |
| Proportion of asymptomatic cases (%) | 88.2 | 40.1 | 75.3 | 87.9 | 88.5 | 65.6 | 84.6 | 80.4 | 81.4 | 66.3 |
| Relative infectiousness of an asymptomatic case (%) | 11.0 | 35.4 | 12.9 | 10.8 | 38.2 | 46.5 | 7.9 | 3.6 | 24.2 | 13.3 |
| Probability of infection inside a room  | 0.50 | 0.55 | 0.75 | 0.91 | 0.79 | 0.73 | 0.76 | 0.83 | 0.54 | 0.82 |
| Probability of infection outside a room | 0.90 | 0.16 | 0.84 | 0.76 | 0.34 | 0.17 | 0.84 | 0.92 | 0.71 | 0.45 |
| Contact network | Mean number of random contacts form on the same level | 16.2 | 12.0 | 8.6 | 13.8 | 12.9 | 15.2 | 14.3 | 6.3 | 3.3 | 7.4 |
| Mean number of random contacts form on different levels but same block | 3.6 | 5.3 | 2.1 | 4.7 | 10.0 | 7.6 | 8.8 | 6.1 | 4.8 | 3.6 |
| Mean number of random contacts form in different blocks | 3.7 | 0.3 | 3.2 | 3.5 | 0.2 | 0.6 | 3.0 | 4.5 | 2.6 | 2.2 |
| Health seeking behaviour | Proportion of symptomatic cases seeking medical attention (%) | 87.6 | 10.0 | 61.2 | 86.4 | 54.2 | 18.4 | 36.7 | 36.5 | 62.8 | 37.8 |
| Effectiveness of public health measures | Probability that contacts with persons on the same level remains after social distancing | 0.55 | 0.02 | 0.03 | 0.49 | 0.48 | 0.43 | 0.32 | 0.14 | 0.50 | 0.23 |
| Probability that contacts with persons on different levels of the same block remains after social distancing | 0.57 | 0.46 | 0.10 | 0.03 | 0.46 | 0.63 | 0.06 | 0.38 | 0.02 | 0.26 |
| Probability that contacts with persons in different block remains after social distancing | 0.72 | 0.93 | 0.90 | 0.45 | 0.87 | 0.03 | 0.09 | 0.25 | 0.36 | 0.56 |
| Reduction in probability of infection outside a household | 0.32 | 0.22 | 0.32 | 0.30 | 0.05 | 0.01 | 0.22 | 0.33 | 0.37 | 0.24 |
| Days since deployment of ground officers when reduction in probability of infection outside a household occurred  | 2.2 | 6.3 | 2.1 | 4.0 | 5.1 | 3.7 | 3.8 | 6.4 | 1.9 | 2.3 |

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parameter category | Parameter set | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Disease transmission | Initial number of cases | 9 | 19 | 12 | 15 | 16 | 6 | 14 | 19 | 18 | 12 |
| Proportion of asymptomatic cases (%) | 58.4 | 77.4 | 69.6 | 67.9 | 51.7 | 73.1 | 66.0 | 86.2 | 50.0 | 55.9 |
| Relative infectiousness of an asymptomatic case (%) | 25.4 | 13.0 | 16.4 | 10.6 | 0.9 | 44.5 | 3.5 | 23.4 | 8.7 | 0.2 |
| Probability of infection inside a room  | 0.82 | 0.84 | 0.50 | 0.54 | 0.64 | 0.55 | 0.81 | 0.51 | 0.91 | 0.72 |
| Probability of infection outside a room | 0.20 | 0.69 | 0.46 | 0.72 | 0.20 | 0.99 | 0.24 | 0.73 | 0.14 | 0.50 |
| Contact network | Mean number of random contacts form on the same level | 6.7 | 8.2 | 12.6 | 0.3 | 12.5 | 2.2 | 16.1 | 11.5 | 10.3 | 8.1 |
| Mean number of random contacts form on different levels but same block | 3.6 | 4.3 | 3.0 | 7.1 | 5.2 | 0.7 | 8.8 | 1.7 | 4.8 | 3.9 |
| Mean number of random contacts form in different blocks | 4.0 | 3.8 | 2.8 | 3.0 | 4.7 | 0.8 | 4.8 | 0.1 | 2.4 | 2.0 |
| Health seeking behaviour | Proportion of symptomatic cases seeking medical attention (%) | 13.5 | 46.8 | 77.7 | 37.1 | 21.7 | 68.0 | 25.0 | 53.1 | 15.6 | 18.7 |
| Effectiveness of public health measures | Probability that contacts with persons on the same level remains after social distancing | 0.23 | 0.19 | 0.43 | 0.29 | 0.50 | 0.87 | 0.66 | 0.15 | 0.49 | 0.70 |
| Probability that contacts with persons on different levels of the same block remains after social distancing | 0.18 | 0.54 | 0.50 | 0.60 | 0.05 | 0.44 | 0.95 | 0.48 | 0.95 | 0.80 |
| Probability that contacts with persons in different block remains after social distancing | 0.35 | 0.76 | 0.49 | 0.99 | 0.18 | 0.48 | 0.70 | 0.43 | 0.25 | 0.32 |
| Reduction in probability of infection outside a household | 0.13 | 0.04 | 0.44 | 0.14 | 0.3 | 0.03 | 0.09 | 0.44 | 0.27 | 0.02 |
| Days since deployment of ground officers when reduction in probability of infection outside a household occurred  | 1.3 | 3.0 | 6.5 | 3.4 | 6.4 | 4.0 | 3.0 | 6.3 | 1.6 | 4.0 |

**References**

1 Lauer SA, Grantz KH, Bi Q, *et al.* The Incubation Period of Coronavirus Disease 2019 (COVID-19) From Publicly Reported Confirmed Cases: Estimation and Application. *Ann Intern Med* 2020; **172**: 577–82.

2 Ferretti L, Wymant C, Kendall M, *et al.* Quantifying SARS-CoV-2 transmission suggests epidemic control with digital contact tracing. *Science* 2020; **368**: eabb6936.