

Adoption and impact of non-pharmaceutical interventions for COVID-19

MRC Centre for Global Infectious Disease Analysis, Imperial College, Centre for the Mathematical Modelling of Infectious Diseases, LSHTM

Summary

- School closures, remote working and quarantine have been the most common social distancing interventions applied to date.
- Symptomatic COVID-19 cases thus far have been disproportionately reported amongst the elderly population compared to children - it is unclear whether school closures will have the same benefits as have been shown for pandemic influenza.
- Travel restrictions have been widely implemented and found to be effective at slowing geographic spread by a few days and reducing initial case numbers.
- Timely implementation of control measures will have a greater impact on the COVID-19 epidemic, but the early lifting of control measures could lead to an increase in case numbers, as shown for influenza control. At this stage, data on this for COVID-19 are still sparse.
- A number of non-pharmaceutical interventions have been implemented at this point of time, most stringently in China. The assessment of these measures has been limited, especially concerning more recent interventions such as school closures. In many countries, it is too early to evaluate the effect of interventions.
- Findings from Hong Kong suggest that the combination of interventions implemented there, aided by significant behavioural changes by the general public, have significantly reduced influenza-like illness rates in early February. The estimated reproduction number for COVID-19 remains ~ 1 , which may be due to these interventions but there are insufficient cases to formally test this.
- Empirical and modelling studies of pandemic influenza suggest that measures implemented at an earlier stage of the epidemic (compared to later stages), either locally or nationally, are likely to have greater impact on reducing the potential epidemic size.

Measures in use

Social distancing (SD) measures can be effective control measures in outbreak settings. These can be broadly defined as: i) isolation, the separation of ill individuals from non-infected individuals; ii) quarantine, the separation of individuals who have been assumed to be exposed and; iii) community containment, an intervention applied to an entire community aimed at reducing contacts and movements [1]. However, the timing and duration of SD interventions will impact its effectiveness. Studies from pandemic influenza have emphasised the restricted benefits of time-limited interventions, with the potential reduction in mortality by up to 30% being eroded if the control was applied too late or lifted too early [2].

SD interventions have been implemented to different degrees by countries affected by the COVID-19 epidemic. Interventions have been most stringent in Hubei province, where the

effective lockdown of cities have affected 40-60 million residents in Hubei province and Wuhan City in particular [3, 4]. Across other provinces in China, huge public health efforts including quarantine, cancellation of large gatherings, and travel restrictions have been implemented. Outside of mainland China, countries and regions worst affected by COVID-19 have or have started to introduce SD interventions in efforts to contain and limit the spread of COVID-19. For example, Singapore has implemented extensive contact tracing and quarantine measures for confirmed cases.

The most common SD measures in Hubei province (China) and the eight countries and regions reporting the highest COVID-19 case numbers outside of mainland China to date, were school closures followed by remote working and quarantine (see appendix for most common non-SD measures). Table 1 summarises the SD intervention and the potential effects on mixing patterns.

Figure 1 shows the timing of interventions in different countries and regions relative to the reported cases over time. There has been substantial variation in interventions adopted. Some countries and regions such as the USA have implemented reactive and selective local school closures only, whereas Hong Kong, for similar case counts, has introduced a large number of voluntary (e.g. advice on avoiding crowded places) and mandatory (e.g. quarantine, contact tracing, wide-scale proactive school closures) SD measures. It is important to note that while the figure shows interventions by specific date of introduction, most countries and regions shown have implemented contact tracing and quarantine of cases in response to the first imported cases from Hubei, China (Japan, Thailand, South Korea, USA, Singapore since mid- to late-January). Other countries have implemented interventions in response to a large number of newly reported cases (Italy and Iran) more recently (supplementary table 3).

Impact of interventions

A range of non-pharmaceutical interventions (extension of school holidays, flexible working hours and remote working, quarantine of travellers from mainland China, and flight restrictions) have been implemented in Hong Kong resulting in behaviour change of the general public (measured through telephone surveys). Using influenza incidence rates as a proxy, Cowling et al showed that influenza transmission declined substantially (uncertainty range 24 - 53% reduction in transmissibility) after introduction of control measures and changes in population behaviours (avoidance of crowded places and consistent use of face masks) in early February. However, it is unclear how long Hong Kong will be able to sustain these measures. It is difficult to disentangle the most effective interventions; however, the combination of isolation, contact tracing, and quarantine appear to be "working" and Hong Kong has not observed infections in healthcare workers to date (Cowling, personal communication).

Assessing travel restrictions, Tian et al. examined the impact of quarantine and movement restrictions in Wuhan. They found that travel restrictions slowed the rate of spread between cities, delaying the arrival by approximately 2.9 days (95%CI: 2.5-3.3 days) [5]. They also found that measures implemented pre-emptively could reduce cases in the first week of introduction by 37%. Further travel restrictions were examined by Anzai et al. who suggest that, due to the lockdown of Wuhan city, 226 cases were prevented from global exportation (95% CI 86, 449) corresponding to a reduction in exported cases of 70% [6]. Lai et al. found further support for

travel restrictions and non-pharmaceutical interventions (NPIs) in general, estimating that without them there would have been a 67-fold increase in cases in Baidu. They also highlighted that had interventions been applied earlier, for example by 3 weeks, the effects would have been even greater, leading to a 95% reduction in cases [8].

Table 1: Summary of social distancing interventions implemented in Wuhan City, China and the 8 countries or regions¹ reporting the highest number of COVID-19 cases.

Intervention [Num. countries/regions¹ which have implemented]	Description	Postulated mechanism of impact
School closure across region/country [4]	Closure of junior and/or senior schools across a region/country	Reduction in mixing amongst children
Individual School closure [1]	Reactive closure of specific schools in response to suspected cases	
School closure [2] (not related to outbreak)	Scheduled school holiday	
School restrictions [2]	Cancellation of exams or assembly, staggered break times	
Extension of school closure [1]	Extension of school holidays	
Remote working [4]	Businesses allow or enforce workers to work from home	Reduction in mixing amongst adults
University closure [2]	Teaching cancellation	
Work closure (not related to outbreak) [2] and extension [1]	Closure of workplaces over the New Year	
Restrictions on number of visitors [1]	Nursing homes and hospitals restricting visitor numbers	
Quarantine [3] ²	Isolation of potentially infected individuals incl. enforced quarantine of travellers from affected areas for 14 days	Reduction in transmission
Isolation [2] ²	Isolation of ill case	
Contact tracing [1] ²	Active case finding and surveillance	
Lockdown [3]	Enforced restriction of all travel and non-essential movement of the population	Reduction in community contact and mixing
Mass gathering advisory [2]	Public health advise against attending large social gatherings	
Mass gathering cancellation [2] or ban [1]	Enforced cancellation of events incl. prayers, concerts	
Social event cancellation [2]	Cancellation of smaller gatherings	
Reduced shop hours [1]	Subset of services with reduced operating hours	
Communication and advice [all]	Advice on avoidance behaviours or travel advice	

¹Countries and regions considered here are: Hong Kong, Iran, Italy, Japan, Singapore, South Korea, Thailand, USA and Wuhan. ²Many countries have been implementing quarantine measures of travellers. [The number refers to countries or regions where we have identified exact dates of implementation].

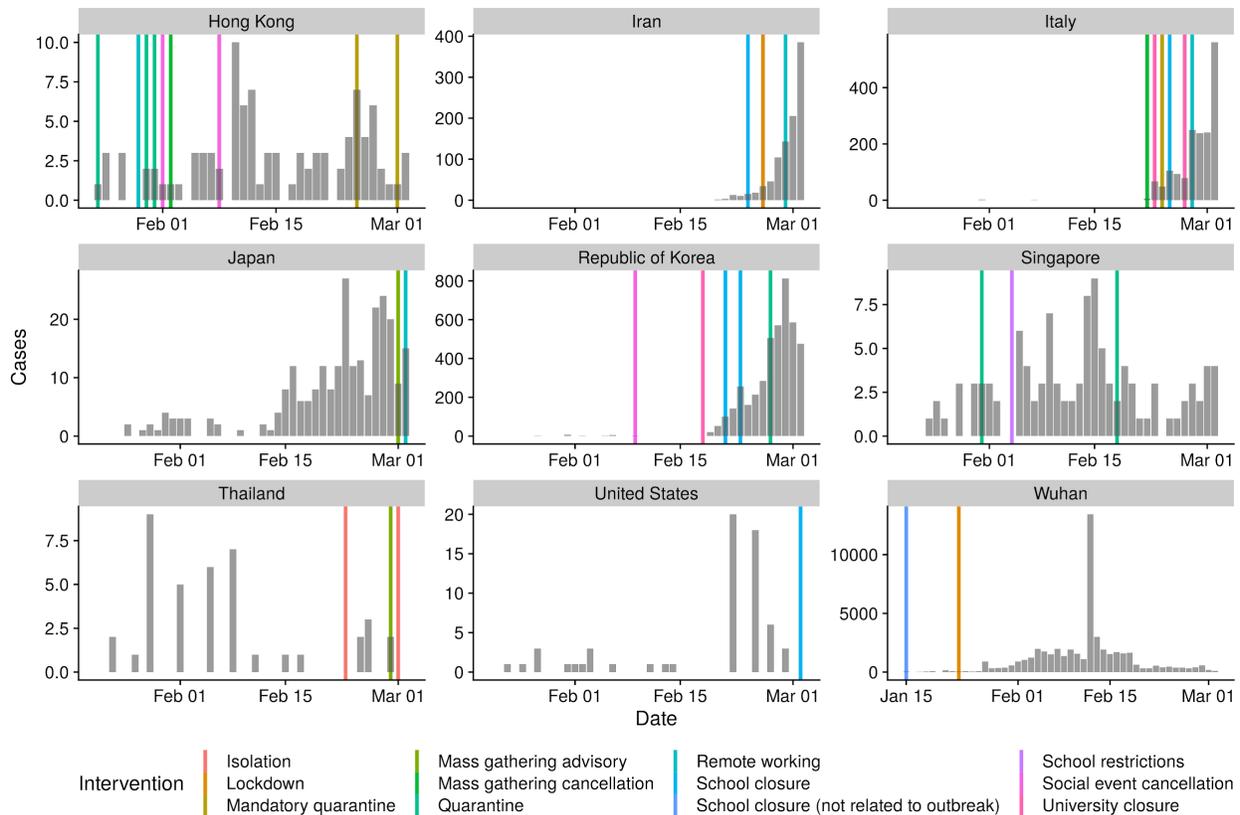


Figure 1: Number of cases by date of report for the 8 regions/countries with the highest number of cases outside of mainland China and Wuhan City as reported by WHO (taken from the WHO situational reports and Hubei Health Commission press releases). Note cases in Japan do not include the international conveyance. Each line represents the date of implementation of a social distancing measure. Note that some countries/regions had travel advice in place in response to the growing epidemic in China before the report of the first case in-country/ region. See supplementary information for NPIs other than SD.

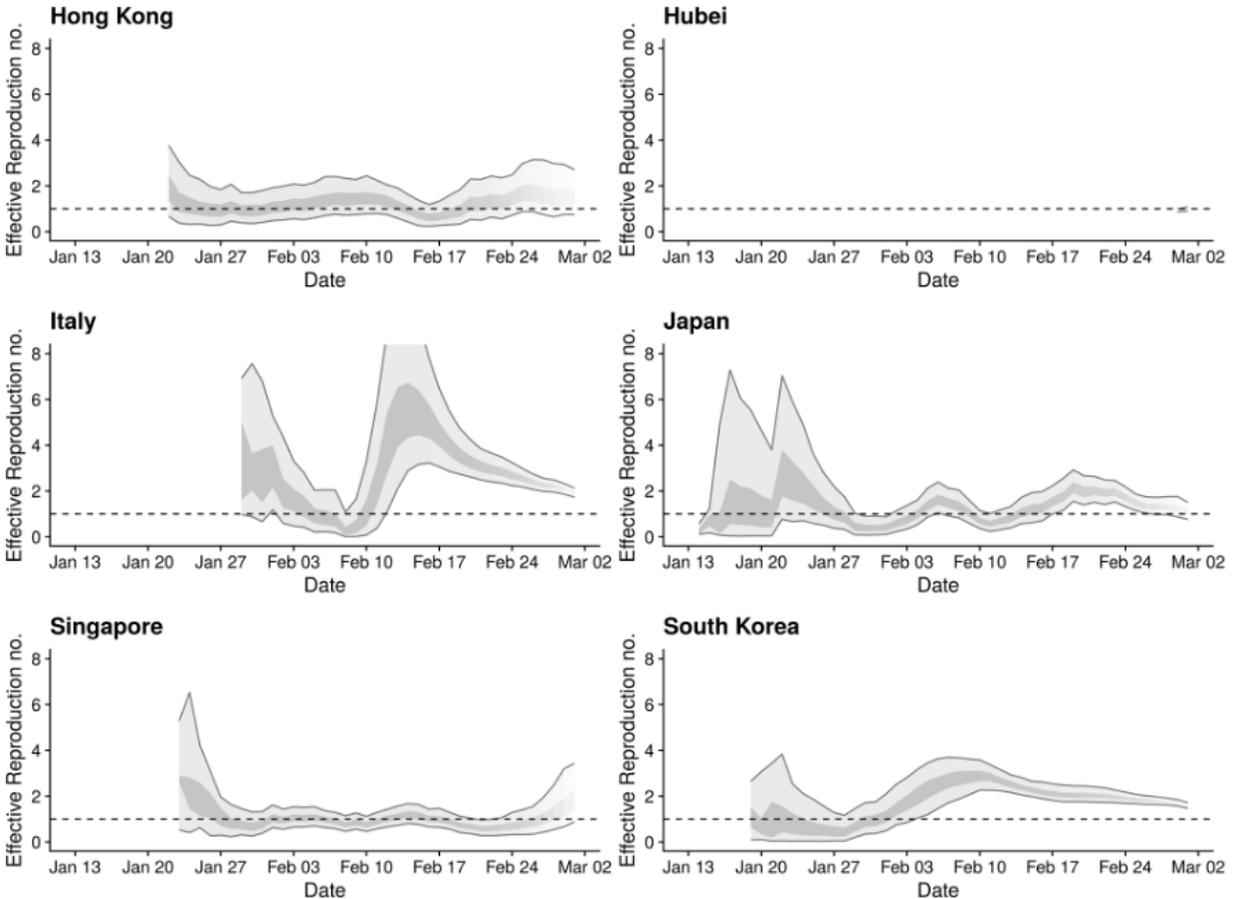
References

1. Wilder-Smith, A., & Freedman, D. O. (2020). Isolation, quarantine, social distancing and community containment: pivotal role for old-style public health measures in the novel coronavirus (2019-nCoV) outbreak. *Journal of travel medicine*.
2. Bootsma, M. C., & Ferguson, N. M. (2007). The effect of public health measures on the 1918 influenza pandemic in US cities. *Proceedings of the National Academy of Sciences*, 104(18), 7588-7593.
3. Wu, Z., & McGoogan, J. M. (2020). Characteristics of and Important Lessons From the Coronavirus Disease 2019 (COVID-19) Outbreak in China: Summary of a Report of 72 314 Cases From the Chinese Center for Disease Control and Prevention. *JAMA*.
4. WHO. (2020). Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19).
5. Tian, H., Liu, Y., Li, Y., Kraemer, M. U., Chen, B., Wu, C. H., ... & Wang, B. (2020). Early evaluation of transmission control measures in response to the 2019 novel coronavirus outbreak in China. *medRxiv*.

6. Anzai, A., Kobayashi, T., Linton, N. M., Kinoshita, R., Hayashi, K., Suzuki, A., ... & Nishiura, H. (2020). Assessing the impact of reduced travel on exportation dynamics of novel coronavirus infection (COVID-19). *Journal of Clinical Medicine*, 9(2), 601.
7. Bhatia, S. & Imai, N. & Cuomo-Dannenburg G. et al. (2020) Report 6: Relative sensitivity of international surveillance. Available online at <https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-fellowships/Imperial-College---COVID-19---Relative-Sensitivity-International-Cases.pdf>
8. Lai, S. & Ruktanonchai, N. & Zhou, L. et al. (2020) Effect of non-pharmaceutical interventions for containing the COVID-19 outbreak: an observational and modelling study (unpublished)
9. Hellewell, J., Abbott, S., Gimma, A., Bosse, N. I., Jarvis, C. I., Russell, T. W., ... & Flasche, S. (2020). Feasibility of controlling COVID-19 outbreaks by isolation of cases and contacts. *The Lancet Global Health*.
10. Halloran, M. E., Ferguson, N. M., Eubank, S., Longini, I. M., Cummings, D. A., Lewis, B., ... & Wagener, D. (2008). Modeling targeted layered containment of an influenza pandemic in the United States. *Proceedings of the National Academy of Sciences*, 105(12), 4639-4644.

Supplementary information

Transmissibility over time



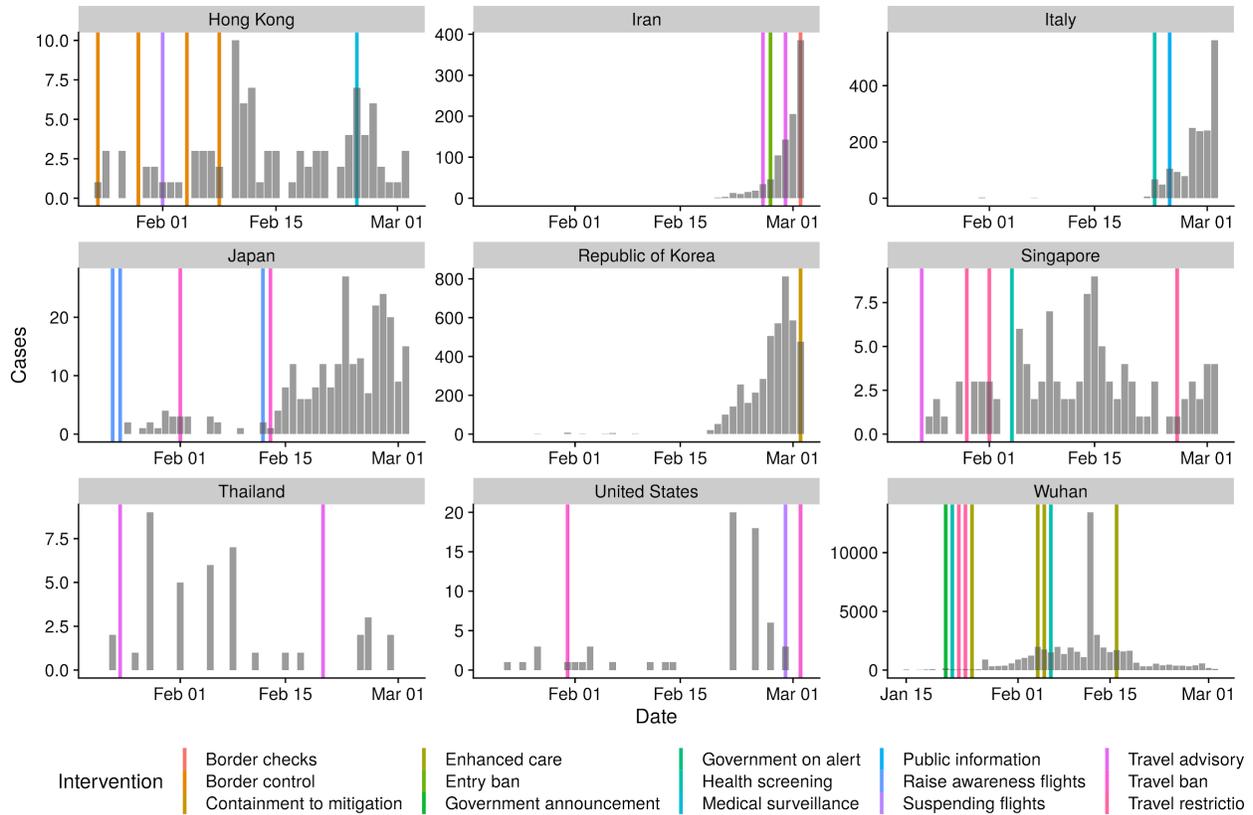
Supplemental Figure 1: Time-varying estimate of the effective reproduction number (R_t) (light grey ribbon = 95% credible interval; dark grey ribbon = the interquartile range) based on data from the 2020-03-01 in each region considered in the analysis. Confidence in the estimated values is indicated by shading with reduced shading corresponding to reduced confidence. The dotted line indicates the target value of 1 for the effective reproduction no. required for control. Note: for Hubei province, estimates were generated based on data from the 18th February onwards due to changes in reporting, so R_t estimates are only shown from early March. Source: <https://cmmid.github.io/topics/covid19/current-patterns-transmission/global-time-varying-transmission.html>

Interventions not related to social distancing

Supplemental table 1: Table of common non-social distancing interventions in the eight countries/regions with the highest number of cases outside of mainland China and Wuhan City, China.

Intervention [Num. countries/regions¹ which have implemented]	Description
Travel advisory [4] ²	Advice to travellers to avoid non-essential travel to affected areas
Travel restriction [3] ²	Enforced travel restrictions on inbound travellers from affected areas
Travel or entry ban [3]	Enforced travel or entry ban on inbound travellers from affected areas
Suspension of flights [2]	Suspension of flights from some affected areas
Border checks [2] ²	Temperature screening implemented to inbound travellers from affected areas
Border control [1] ²	Strengthening border health measures, travellers to complete travel declaration form
Medical surveillance of inbound travellers [2]	Inbound travellers from affected areas will be required to undergo medical surveillance for 14 days
Government alert [5]	Government raised alert level on the coronavirus situation
Enhancements to care [2]	Strengthening of primary and tertiary care response
Health screening [4] ²	Health screening at various locations within the country or region
Surveillance [1] ²	Stepping up surveillance and risk communication
Raise awareness flights [1] ²	Public health messaging on flights to help raise awareness amongst inbound travellers on flights from affected areas
Raise awareness of public and health care workers [2] ²	Surveillance and risk communication

¹Countries and regions considered here are: Hong Kong, Iran, Italy, Japan, Singapore, South Korea, Thailand, USA and Wuhan. ²Many countries and regions have been implementing quarantine measures of travellers. The number shown here refers to countries or regions where we have identified exact dates of implementation.



Supplemental Figure 2: Cases numbers by date of report for the ten countries with the highest number of cases outside of mainland China as reported by WHO (taken from the WHO situational reports and from Hubei Health Commission press releases). Note cases in Japan do not include the international conveyance. Bar fill is related to the introduction of non-pharmaceutical interventions other than social distancing.

Supplementary table 3: Date of first report of COVID-19 cases in the most affected countries or regions outside of mainland China.

Country/ Region	Date of first case report
Republic of Korea	2020-01-20
Japan	2020-01-20
Thailand	2020-01-20
Hubei	2020-01-20
United States	2020-01-23
Hong Kong	2020-01-23
Singapore	2020-01-24
Italy	2020-01-31
Iran	2020-02-20