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

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# Summary

* School closures, remote working and quarantine have been the most common social distancing interventions applied for COVID-19 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.
* 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.

# Introduction

As of the 11/Mar/2020, over XXXX cases of coronavirus disease (COVID-19) have been confirmed globally across XX countries. Sustained human-to-human spread has now been observed in multiple countries or regions outside of mainland China such as Italy, Japan, and South Korea with XXX, XXX, and XXX cases reported respectively. Conversely some countries such as Bangladesh are only now reporting their first cases of COVID-19 resulting from importations of infected travellers from affected areas. In response, countries and regions have implemented a wide range of non-pharmaceutical interventions (NPIs). These NPIs have generally been scaled up over time in response to the magnitude of the outbreak in each country. Non-pharmaceutical interventions can be broadly categorised into: i) personal protective measures such as hand hygiene; ii) environmental measures such as disinfection and ventilation; iii) social distancing measures such as school and workplace closures; and iv) travel related measures such as travel restrictions [[1](#ref-pand_flu)]. As the first cases were exported from Wuhan City to countries and regions outside mainland China, early efforts focused on containment where infected individuals were rapidly identified and isolated. Contact tracing and active case finding efforts then identified any contacts potentially at risk of infection who were themselves isolated or monitored. Containment efforts thus focused on stopping transmission completely to prevent any community transmission [[2](#ref-anderson2020will)]. As case numbers increased and evidence of community transmission became apparent, countries and regions started to introduce a wider range of control measures including travel restrictions, improving public awareness through mass communication, widening surveillance efforts, distributing face masks, and social distancing measures.

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 including school and workplace closures and restrictions or cancellation of mass gatherings [[3](#ref-wilder)]. Social distancing measures are intended to reduce mixing and rates of contact between individuals in the community, therefore reducing rates of potential transmission through a susceptible population.

It is important to note that control measures implemented during an epidemic are usually layered with other interventions and are often targeted. As countries and regions start to move towards mitigating the impact of the epidemic, measures are likely to be implemented to varying degrees. In this study, we focus focused on the use and potential effectiveness of social distancing measures for COVID-19 only.

# Methods

## Interventions implemented

We extracted the date and type of social distancing interventions implemented by/in Wuhan City (China), South Korea, Japan, Hong Kong Special Administrative Region, Singapore, and Italy. These countries/regions were chosen as they were amongst the first affected countries or regions outside of mainland China and at the time of analysis were amongst the top 10 countries with the highest number of COVID-19 cases. Where possible, information on intervention and the date they were implemented were extracted from official government sources such as Ministry of Education websites (see supplementary table X). We categorised the social distancing measures into 7 broad categories as summarised in Table 1. Information and dates of non-pharmaceutical interventions implemented early on in the epidemic such as travel advisories were also extracted (supplementary table X).

**Table 1: Summary of social distancing measures considered and/or implemented in response to the COVID-19 epidemic**

| Measure | Description |
| --- | --- |
| Contact Tracing | Identifying individuals who might have been in contact with a confirmed case. |
| Isolation | Separation of ill persons with contagious diseases from non-infected persons. |
| Quarantine | Restriction of persons who are presumed to have been exposed to a contagious disease but are not ill, either because they did not become infected or because they are still in the incubation period. |
| School Closures | Closure of schools across a region ornation nation-wide. This is distinct from reactive closure of schools in response to an identified cases. |
| Workplace Closure and Measures | Closure of workplaces and advisories to work remotely. |
| Crowding | Advisories to avoid crowded places such as concerts. This includes mandatory cancellations of mass gatherings such as conferences, weddings, funerals etc. |
| University closure | Regional or nationwide closure of universities. |

## Potential effectiveness of social distancing measures

We searched PubMed and medRxiv for peer-reviewed literature and pre-prints on the potential impact of social distancing interventions implemented thus far in the COVID-19 epidemic. We did not restrict these studies by country.

# Results

SD interventions have been implemented to different degrees by countries and regions affected by the COVID-19 epidemic. Implementation of stringent social distancing measures including the effective lockdown of the city were introduced in Wuhan City on XXXX. The lunar new year holiday means that school and workplace have been closed since XXXX. In response to the COVID-19 epidemic, school holidays have been extended and are still closed as of 11 March 2020. Outside of mainland China, Japan and South Korea reported the first cases of COVID-19 on the 20th January 2020. This was followed quickly by cases reported in Hong Kong (23rd January), Singapore (24th January), and Italy (31 January). In response to these first exported cases, case isolation and contact tracing were implemented by each region or country. Figure 1 shows the timing of interventions in different countries and regions relative to the reported cases over time. The date of the first reported case is also shown to represent the start of contact tracing and case isolation of exported cases.

At the time of analysis, the most commonly implemented SD measures in Hubei province (China) and the five countries and regions reporting the highest COVID-19 case numbers outside of mainland China, were school closures followed by remote working and quarantine. Table 2 summarises the SD intervention and the potential effects on mixing patterns. We found a substantial variation in the timing and type of SD interventions adopted by different countries and regions outside of mainland China. Notably Singapore had implemented some partial social distancing measures even before the first case of COVID-19 being reported in-country. We observed that countries affected most recently have implemented SD measures most rapidly and in quick succession. There were also differences in the degree to which SD measures such as school closures have been implemented. For example, school closures in Japan were initially implemented very locally in response to a positive case within the school, then preemptively at the prefecture level, followed by national school closures. We also observed that amongst the non-SD measures that travel restrictions and advice were the first NPIs implemented by each country or region (see Table S1 for the most common non-SD measures).

**Table 2: Summary of social distancing interventions implemented in Wuhan City, China and the 8 countries or regions1 reporting the highest number of COVID-19 cases. Countries and regions considered here are: Hong Kong, Italy, Japan, Singapore, South Korea and Wuhan. Many countries have been implementing quarantine measures of travellers. [The number refers to countries or regions where we have identified exact dates of implementation].**

| **Intervention** | **Number of regions where intervention is 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 (not related to outbreak) | 2 | 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 | Closure of workplaces over the New Year |
| Work closure extension | 1 | Closure of workplaces over the New Year |
| Restrictions on number of visitors | 1 | Nursing homes and hospitals restricting visitor numbers |
| Quarantine | 3 | Isolation of potentially infected individuals incl. enforced quarantine of travellers from affected areas for 14 days | Reduction in transmission |
| Isolation | 2 | Isolation of ill case |
| Contact tracing | 1 | 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 | Enforced cancellation of events incl. prayers, concerts |
| Mass gathering 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 |

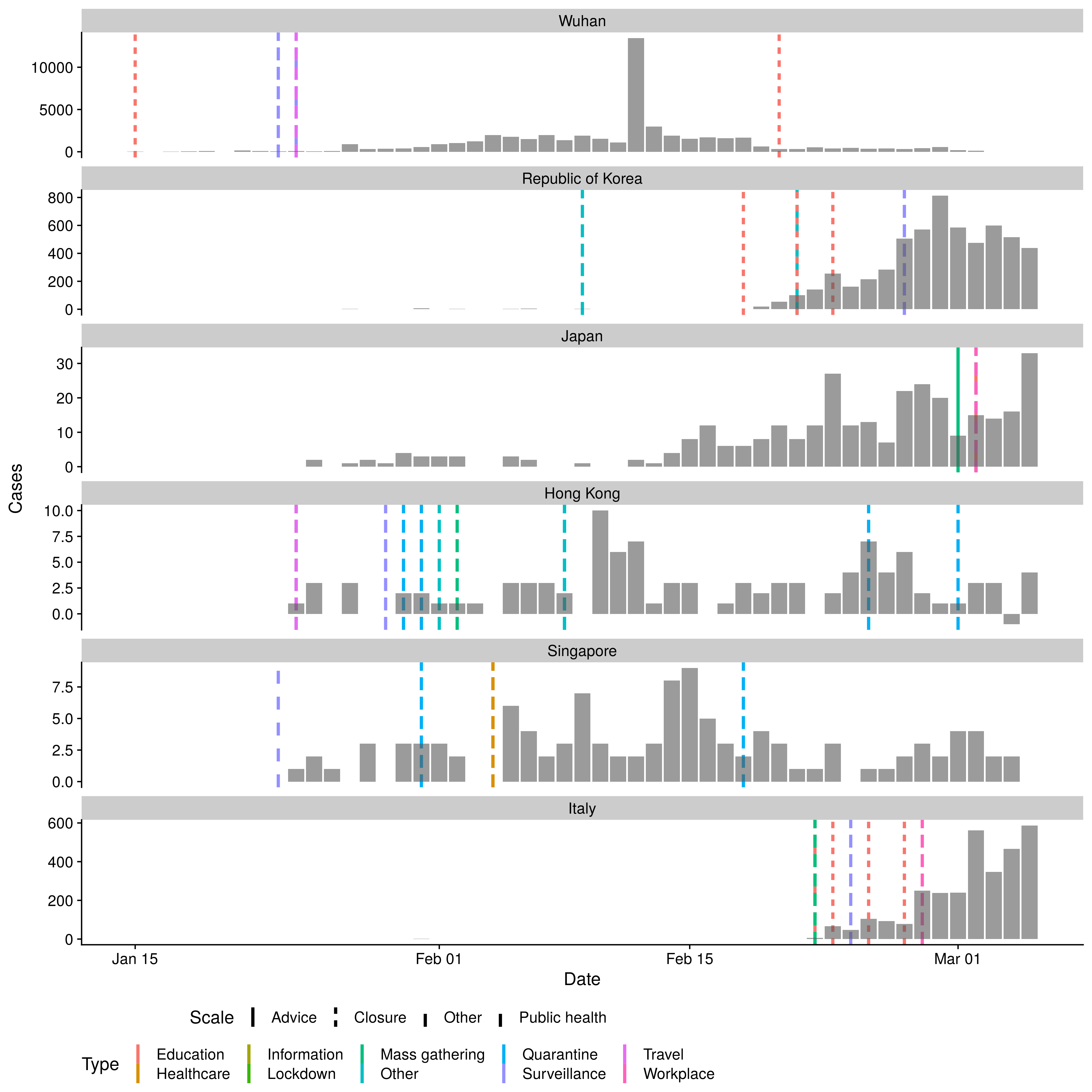


Figure 1: Number of cases by date of report for the 6 regions/countries with the highest number of cases outside of mainland China and Wuhan City as reported by WHO (taken from the WHO situational reports and Hubei Health Commission press releases). Note cases in Japan do not include the international 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.

# Discussion

SD interventions have been implemented to different degrees by countries and regions 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 [[4](#ref-wu2020characteristics)]. Across other provinces in China, huge public health efforts including quarantine, cancellation of large gatherings, and travel restrictions have been implemented [REF]. 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 and Italy has implemented nationwide school closures [REF].

The timing of and the degree to which social distancing measures have been implemented varies between the subset of countries and regions considered here but also globally. For example, 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 most countries and regions have implemented isolation of cases, contact tracing and quarantine 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).

Many SD interventions have focused on public messaging to encourage behaviour change. For example, encouraging individuals to work remotely, avoid crowded areas, and to restrict movement to essential trips only. As such interventions are not enforced, its effectiveness will be dependent on uptake and compliance by the general public. A recent YouGov survey found that risk perception differed by country [[6](#ref-yougov)]. A higher proportion of respondents in Asian countries reported being concerned about their risk of being infected compared to countries in Europe or North America. This is also reflected in self-reported behaviour changes. A majority of respondents in all Asian countries and regions surveyed are avoiding crowded places including 83% in Hong Kong. Encouragement of remote working have also had the greatest reported behaviour change in China and Hong Kong with 67% and 45% reportedly avoiding going to the office respectively. These high figures compared to other countries in Asia, may be due to implementation of remote working for government offices.

Outside of Hubei province, China where the 30 days of substantial social distancing layered with the strict movement restrictions in Wuhan City and Hubei have reduced the estimated reproduction number from 2.2 (95% CI: 1.4 - 3.9) to 1.58 (95% CI: 1.34 - 2.07), it is likely too early to be able to evaluate or quantify the true effectiveness of specific social distancing interventions on the epidemic in affected countries or regions [[7](#ref-zhang2020impact)]. Indeed as most countries have implemented a range of non-pharmaceutical measures such as travel restrictions, health screenings, and advice such as hand and cough hygiene intended to prompt behaviour change, it is likely impossible to quantify the effectiveness of social distancing in the absence of other control measures. However early studies have found that the relative effectiveness of case isolation and contact tracing was greater than travel restrictions or contact reduction [[8](#ref-lai2020effect)]. They additionally found that the rapid implementation of these combined NPIs, conducted one, two, or three weeks earlier could have reduced case numbers by 66%, 86%, and 95%, respectively.

Studies from pandemic influenza have also shown that the timing and duration of SD interventions will impact its effectiveness. For example, for influenza there are restricted benefits to 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 [[9](#ref-bootsma)]. When considering targeted layered containment strategies, Ferguson et al found that the effectiveness of social distancing, rapid case ascertainment, and targeted prophylaxis were similar, with school closures playing an important role in each scenario, especially if values of R0 were ≤2 [REF]. A systematic review of the effectiveness of social distancing measures for pandemic influenza identified varying levels of evidence for avoiding crowding, workplace measures, and case isolation in the community [[8](#ref-lai2020effect)]. These particular SD measures are more resource intensive and are socially and economically disruptive. For COVID-19 most isolation has thus far been in a hospital setting. As more cases are reported in the community, protocols around case isolation may change towards voluntary home isolation or household quarantine. Household quarantine for influenza was found to have an overall effect, but within an affected household could increase risk of infection amongst quarantined individuals. Other resource intensive measures such as contact tracing were found to be effective in reducing influenza transmission when used in combination with other interventions such as quarantine and isolation. However this is not feasible in all settings or sustainable beyond the early phase of an epidemic when there are fewer cases. For influenza where children are known to be important for transmission as they are more susceptible to infection, are more infectious, and contribute to higher person-to-person contact rates, there was evidence that school closures could have a substantial effect on reducing transmission. However, the role of children in transmission of COVID-19 is still unknown. If children have the same or similar role in transmission as for influenza, then we could expect the same level of impact as has been estimated for influenza.

However, across all social distancing measures the most important consideration is perhaps the feasibility of its long-term implementation. The most effective measures in terms of stopping transmission, for example the lockdown of entire cities as implemented in Hubei province, are also the most socially and economically disruptive [REF]. As many measures start to be lifted across cities in China, as transmission has effectively been paused, we may observe a bounce-back effect. Countries and regions are therefore faced with the difficult task of balancing economically and socially sustainable and acceptable control measures which are likely to have the largest overall impact with the need to control growing case numbers.

Should we keep the following? *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].*

# References

[1] WORLD HEALTH ORGANISATION. Non-pharmaceutical public health measures for mitigating the risk and impact of epidemic and pandemic influenza. 2019.

[2] ANDERSON, Roy M, Hans HEESTERBEEK, Don KLINKENBERG a T Déirdre HOLLINGSWORTH. How will country-based mitigation measures influence the course of the COVID-19 epidemic? *The Lancet*. 2020.

[3] WILDER-SMITH, A a DO FREEDMAN. 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*. 2020.

[4] WU, Zunyou a Jennifer M MCGOOGAN. 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*. 2020.

[5] WORLD HEALTH ORGANISATION. Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19). 2020.

[6] YOUGOV. Coronavirus: how do attitudes differ across the world? *Yougov.co.uk*. 2020.

[7] ZHANG, Yuzhen, Bin JIANG, Jiamin YUAN a Yanyun TAO. The impact of social distancing and epicenter lockdown on the COVID-19 epidemic in mainland China: A data-driven SEIQR model study. *medRxiv*. 2020.

[8] LAI, Shengjie, Nick W RUKTANONCHAI, Liangcai ZHOU, Olivia PROSPER, Wei LUO, Jessica R FLOYD, Amy WESOLOWSKI, Chi ZHANG, Xiangjun DU, Hongjie YU a OTHERS. Effect of non-pharmaceutical interventions for containing the COVID-19 outbreak: an observational and modelling study. *medRxiv*. 2020.

[9] BOOTSMA, Martin CJ a Neil M FERGUSON. The effect of public health measures on the 1918 influenza pandemic in US cities. *Proceedings of the National Academy of Sciences*. 2007, **104**(18), 7588–7593.

# Supplementary information

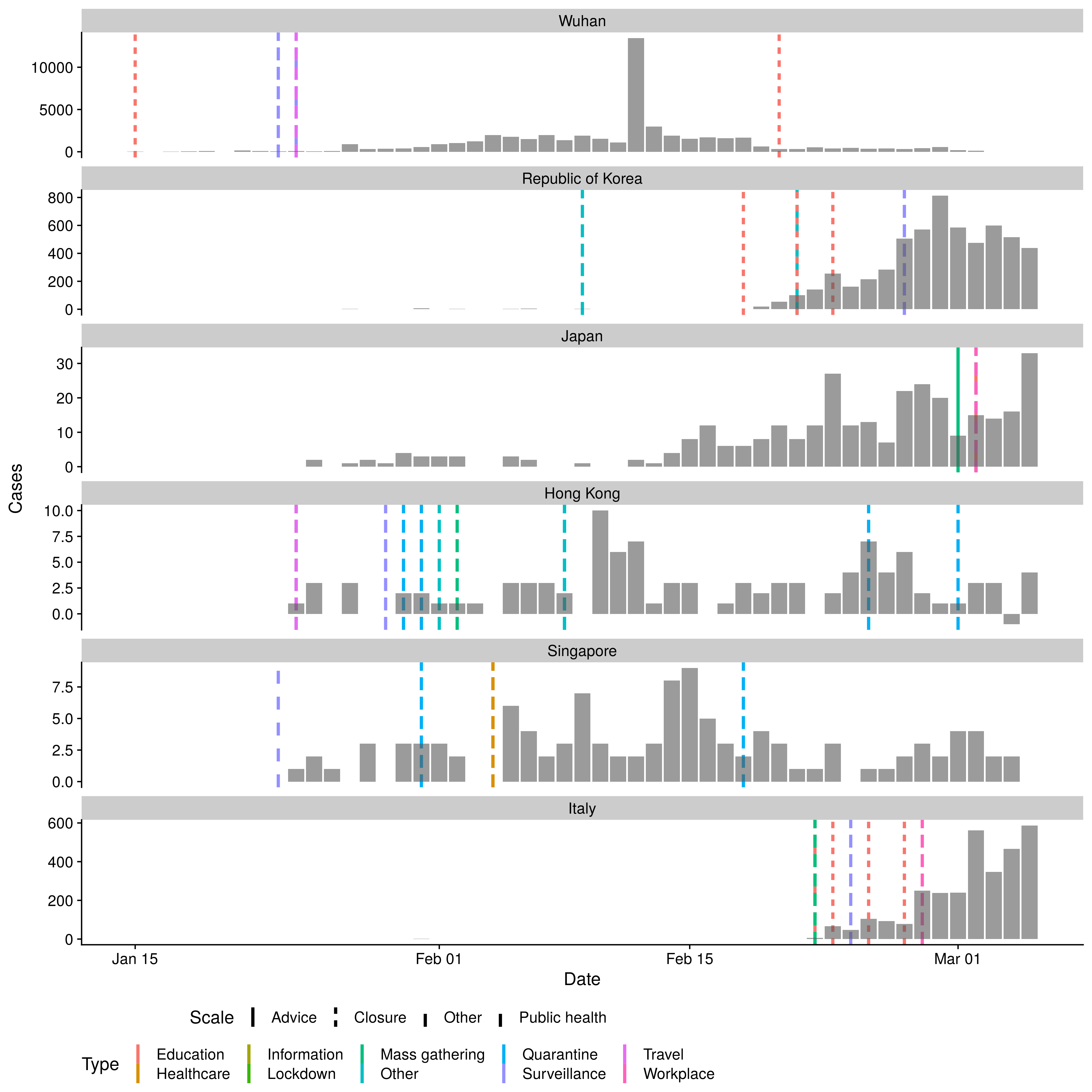
## Transmissability over time

ADD FIGURE

## Interventions not realted 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** | **Description** |
| --- | --- |
| Travel advisory [4] | Advice to travellers to avoid non-essential travel to affected areas |
| Travel restriction [3] | 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] | Temperature screening implemented to inbound travellers from affected areas |
| Border control [1] | 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] | Health screening at various locations within the country or region |
| Surveillance [1] | Stepping up surveillance and risk communication |
| Raise awareness flights [1] | 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] | Surveillance and risk communication |



Supplemental figure 1: 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.

## Data Dictionary

1. Contact Tracing: Identifying individuals who might have been in contact with a confirmed case
2. Isolation: Separation of ill persons with contagious diseases from non-infected persons
3. Quarantine: Restriction of persons who are presumed to have been exposed to a contagious disease but are not ill, either because they did not become infected or because they are still in the incubation period
4. School Closures. Closure of schools across a region or nation-wide. This is distinct from reactive closure of schools in response to an identified case.
5. Workplace Closure and Measures. Closure of workplaces and advisories to work remotely.
6. Crowding: Advisories to avoid crowded places such as concerts. This includes mandatory cancellations of mass gatherings such as conferences, weddings, funerals etc.
7. University closure. Regional or nationwide closure of universities