



RESEARCH ARTICLE

Adoption and impact of non-pharmaceutical interventions for COVID-19 [version 1; peer review: 1 approved, 3 approved with reservations]

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Abstract

Background: Several non-pharmaceutical interventions (NPIs) have been implemented across the world to control the coronavirus disease (COVID-19) pandemic. Social distancing (SD) interventions applied so far have included school closures, remote working and quarantine. These measures have been shown to have large impacts on pandemic influenza transmission. However, there has been comparatively little examination of such measures for COVID-19.

Methods: We examined the existing literature, and collated data, on implementation of NPIs to examine their effects on the COVID-19 pandemic so far. Data on NPIs were collected from official government websites as well as from media sources.

Results: Measures such as travel restrictions have been implemented in multiple countries and appears to have slowed the geographic spread of COVID-19 and reduced initial case numbers. We find that, due to the relatively sparse information on the differences with and without interventions, it is difficult to quantitatively assess the efficacy of many interventions. Similarly, whilst the comparison to other pandemic diseases such as influenza can be helpful, there are key differences that could affect the efficacy of similar NPIs.

Conclusions: The timely implementation of control measures is key to their success and must strike a balance between early enough application to reduce the peak of the epidemic and ensuring that they can be feasibly maintained for an appropriate duration. Such measures can have large societal impacts and they need to be appropriately justified to the population. As the pandemic of COVID-19 progresses, quantifying the impact of interventions will be a vital consideration for the appropriate use of mitigation strategies.

Keywords

non-pharmaceutical interventions, COVID-19

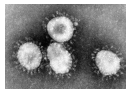
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Reviewer Status

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This article is included in the [Coronavirus \(COVID-19\)](#) collection.

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Introduction

As of the 21 March 2020, over 271,364 cases of coronavirus disease (COVID-19) have been confirmed globally across 174 countries and regions¹. Sustained human-to-human transmission has now been observed in multiple countries outside of mainland China including Italy, Japan, and South Korea with 47,021, 1,007, and 8,799 cases reported respectively¹. Conversely, some countries such as Bangladesh have more recently reported 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 country². NPIs 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 restrictions³. As the first cases were exported from Wuhan City, China to countries and regions outside mainland China, early efforts focused on containment where infected individuals were rapidly identified and isolated⁴. 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 transmission⁵. 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 (SD) measures⁶.

SD measures can be effective control measures in outbreak settings⁷. These can be broadly defined as: i) isolation, the separation of ill individuals from susceptible 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 gatherings⁴. Social distancing measures are intended to reduce mixing and rates of contact between individuals in the community, therefore reducing rates of potential transmission to the susceptible population⁸.

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 on the use and implementation of social distancing measures in the current COVID-19 pandemic.

Methods

Interventions implemented

We extracted the date and type of SD interventions implemented in Wuhan (Hubei, China), South Korea, Japan, Hong Kong (Special Administrative Region of China), Singapore, and Italy. Apart from Wuhan, the other countries and regions were chosen as they were among the first or most affected places outside of mainland China (at the time of analysis) in the COVID-19 pandemic⁹.

Relevant government websites such as ministry of health, ministry of education, and ministry of trade were identified through web searches. Information on interventions and the date they were implemented were extracted. We then supplemented these data using web searches with information from media reports on NPIs implemented in each country (see supplemental Table 1, extended data¹⁰). We categorised the SD measures into 7 broad categories as summarised in Table 1. Information and

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 susceptible 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 or because they did not become infected
School closures	Closure of schools nationally or across a region. This is distinct from reactive closures of schools in response to 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, and funerals.
University closure	Regional or nationwide closure of universities.

dates of other NPIs, aside from SD measures, implemented early on in the epidemic such as travel advisories were also extracted (Supplemental Table 1, extended data¹⁰).

Analysis

Data on NPIs and SD measures were categorized manually and analysed using R version 3.6.2¹¹. Replication code is available as extended data¹². Output data is available as underlying data¹².

Results

SD measures have been implemented to different degrees by countries and regions affected by the COVID-19 pandemic. The beginning of this pandemic coincided with the Lunar New Year holiday and winter break in China, for which schools and workplaces were scheduled to close on 17 January and 24 January 2020, respectively. Due to the outbreak in Wuhan, stringent SD measures including intensive travel restrictions were introduced in the city on 23 January 2020. In response to the COVID-19 pandemic, school closures across China have been extended and remain in place as of 21 March 2020¹³. Outside of mainland China, Japan and South Korea reported the first cases of COVID-19 on 20 January 2020^{9,14}. This was followed quickly by cases reported in Hong Kong (23 January), Singapore (24 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 Wuhan (Hubei, 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 measures. We found a substantial variation in the timing and type of SD measures adopted by different countries and regions outside of mainland China. Notably, Singapore had implemented some partial SD measures even before the first in-country COVID-19 case was reported. 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, within weeks, school closures in Japan which were initially implemented locally in a few affected schools were preemptively extended to the entire nation¹⁵. We also observed that among non-SD measures, travel advisories and restrictions were the first NPIs implemented by each country or region (see Supplemental Table 1 for the most common non-SD measures and Supplemental Figure 1 for the timing of these interventions in different countries and regions relative to the reported cases over time; extended data¹⁰).

Discussion

SD measures have been implemented to different degrees by countries and regions affected by the COVID-19 pandemic.

Interventions have been most stringent in Hubei province (China), where intensive travel restrictions have affected 40–60 million residents^{16,17}. Across other parts of China, extensive public health efforts including quarantine, cancellation of large gatherings, and travel restrictions have been implemented¹⁸. Outside of mainland China, countries and regions most 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 conducted extensive contact tracing and quarantine measures for confirmed cases and Italy has enforced nationwide school closures¹⁹.

The timing and the degree to which SD measures have been implemented varied between the countries and regions we considered, 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 cumulative 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 measures²⁰. 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)^{9,21}. Other countries have introduced interventions in response to a large number of newly reported cases (Italy and Iran) more recently^{22,23}.

Many SD interventions have focused on public messaging to encourage positive behaviour change. For example, encouraging individuals to work remotely, avoid crowded areas, and restrict non-essential travel. As such interventions are not enforced, its effectiveness will be dependent on public compliance. A recent YouGov survey found that risk perception differed by country²⁴. A higher proportion of respondents in Asian countries reported being concerned about their risk of being infected compared to European or North American countries. This is also reflected in self-reported positive behaviour changes. A majority of respondents in Asia surveyed reported avoiding crowded places (e.g. 83% in Hong Kong). Advocating for remote working have led to the greatest positive behavior in mainland 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 long-term implementation of substantial SD layered with the strict movement restrictions in Wuhan City and Hubei have reduced the reproduction number R_0 , estimated to be greater than 2 during the early stages of the outbreak, it is likely too early to be able to evaluate or quantify the true effectiveness of specific SD interventions on the epidemic in affected countries or regions^{25–27}. 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 difficult to quantify the effectiveness of SD in the absence of other control

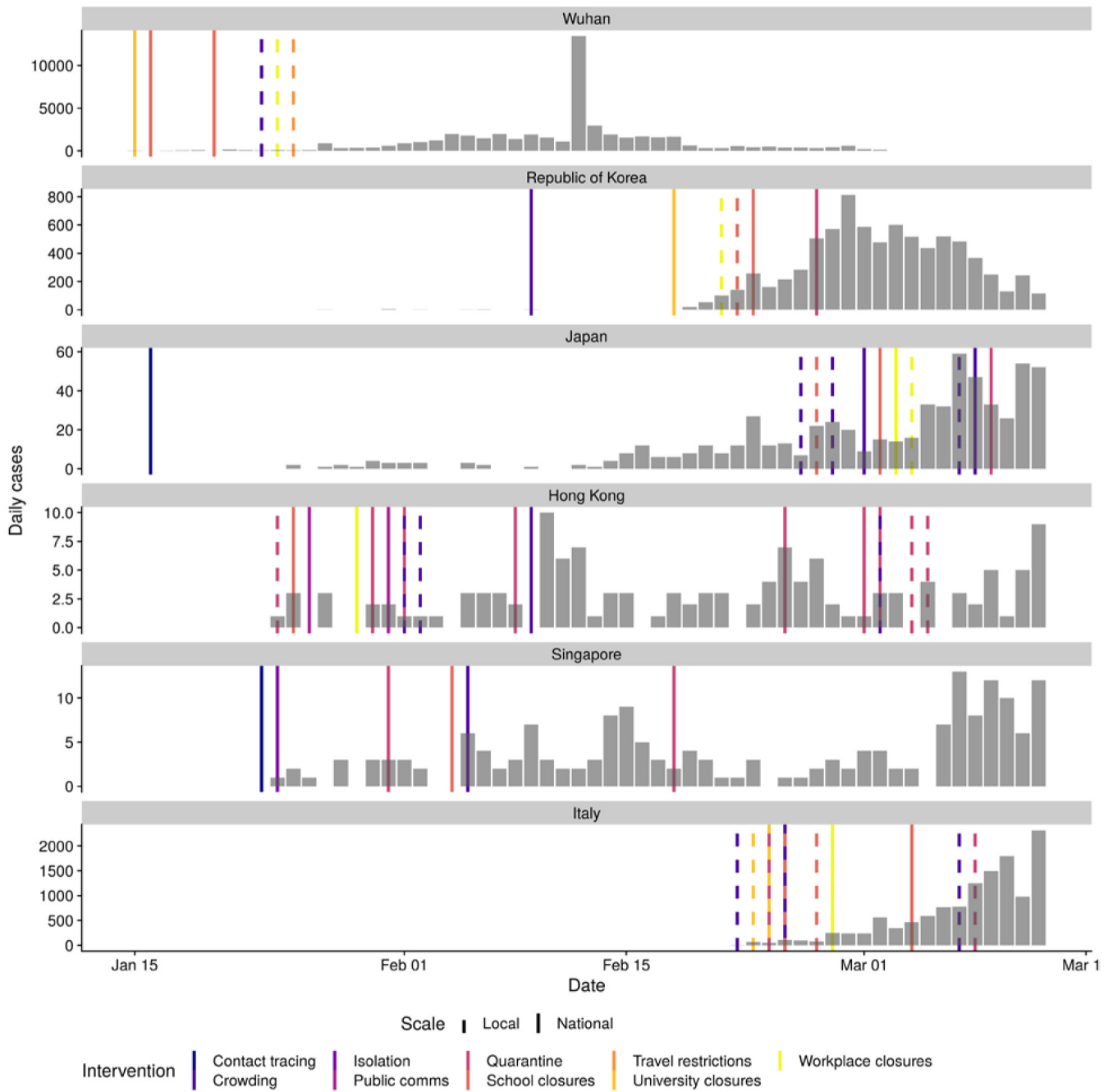


Figure 1. Number of cases by date of report for the five regions or countries with the highest number of cases outside of mainland China and Wuhan City as reported by WHO (taken from the WHO situational reports and Hubei Health Commission press releases). Note cases in Japan do not include the international conveyance. Each line represents the date of implementation of a social distancing measure. Note that some countries or 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 non-pharmaceutical interventions (NPIs) other than social distancing (SD).

Table 2. Summary of social distancing interventions implemented in Wuhan City, China and the 5 countries or regions 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.

Intervention type	Number of regions that have implemented	National (%)	Enforced (%)	Regions
Crowding	6	33.3%	100%	Hong Kong, Italy, Japan, Republic of Korea, Singapore, Wuhan
School closures	6	50%	66.7%	Hong Kong, Italy, Japan, Republic of Korea, Singapore, Wuhan
Quarantine	5	60%	80%	Hong Kong, Italy, Japan, Republic of Korea, Singapore
Workplace closures	5	60%	80%	Hong Kong, Italy, Japan, Republic of Korea, Wuhan
University closures	3	100%	100%	Italy, Republic of Korea, Wuhan
Contact tracing	2	100%	100%	Japan, Singapore
Isolation	2	100%	100%	Hong Kong, Singapore
Public communications	1	100%	0%	Hong Kong
Travel restrictions	1	0%	100%	Wuhan

measures. However early studies have found that the relative effectiveness of case isolation and contact tracing was greater than travel restrictions or contact reduction¹⁸. 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 up to three months from their introduction. However, the impact that these NPIs beyond May 2020 remains unknown.

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 early²⁹. 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 R_0 were ≤ 2 ⁸. A systematic review of the effectiveness of SD measures for pandemic influenza identified varying levels of evidence for avoiding crowding, workplace measures, and case isolation in the community¹⁸. 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 SD measures the most important consideration is 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 disruptive⁵. 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.

Data availability

Underlying data

Zenodo: seabbs/CovidInterventionReview: Initial release. <http://doi.org/10.5281/zenodo.3730771>¹²

This project contains the following underlying data:

- output-data
 - counts.csv (Daily case counts for the countries/regions considered)
 - first-cases.csv (Date of first notified case by countries/regions considered)
 - interventions.csv (A compiled list of categorised interventions in the countries/regions considered)
 - summarised-non-social-distancing-ints.csv (Summary of non-social distancing measures)
 - summarised-social-distancing-ints.csv (Summary of social distancing measures)

Data are available under the terms of the [Creative Commons Zero “No rights reserved” data waiver](#) (CC0 1.0 Public domain dedication).

Extended data

Figshare: Adoption and impact of non-pharmaceutical interventions for COVID-19. <https://doi.org/10.6084/m9.figshare.12037512.v1>¹⁰

This project contains the following extended data:

- Adoption and impact of non-pharmaceutical interventions for COVID-19 Supplementary information.docx (Document containing supplementary figure and table)

Data are available under the terms of the [Creative Commons Attribution 4.0 International license](#) (CC-BY 4.0).

Replication code is available from GitHub

Replication code: <https://github.com/seabbs/CovidInterventionReview>

Archived replication code: <http://doi.org/10.5281/zenodo.3730771>¹²

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Author contributions

*These authors contributed equally.

Acknowledgements

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Version 1

Reviewer Report 01 June 2020

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Alyssa Bilinski

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This study provides a useful summary of non-pharmaceutical interventions implemented early in the COVID-19 pandemic. The authors collated data about different non-pharmaceutical interventions implemented in Wuhan, South Korea, Japan, Hong Kong, Singapore, and Italy and plotted these compared to case growth. During the rapidly changing pandemic, the authors' curation of data and framing remain useful for thinking about the basket of available interventions and different times at which they may be applied.

Major comments

1. While the paper is entitled "Adoption and impact of non-pharmaceutical interventions for COVID-19", there does not appear to be much analysis of the impact of interventions. As authors note, it is difficult to develop a causal identification strategy when multiple interventions were being implemented simultaneously, but without further analysis, I would move away from the framing as an impact assessment.
2. I was slightly confused by the paper's framing of the analysis as all non-pharmaceutical interventions vs. specifically social distancing measures. The authors separate travel measures from social distancing measures in the introduction's 4 categories, but describe "stringent SD measures including intensive travel restrictions" in the results section. (I assume that the latter may refer to local 'lockdown' while the former is out-of-area travel, but this would be useful to clarify). Most of the methods and results sections seem to focus only on social distancing; other NPIs do not appear in figures or tables, and are only mentioned in one sentence of the results section. While these are clearly harder to quantify, it may be clearer to frame the paper as social distancing-focused?
3. I had some trouble following Figure 1, as there are many subtly different colors. It may be more informative to select a smaller number of interventions and/or annotate these with letter abbreviations. I also found the local/national distinction confusing to interpret on this plot, particularly when multiple lines overlapped.

Minor comments

1. While the authors note that selected countries were “among the first or most affected places outside of mainland China”, it might be useful to specify a more formal selection criteria, if this was applied. Likewise, were NPI types pre-specified before searching?
2. Unless I am misreading the colors, surprisingly few countries seem to incorporate case isolation. That seems odd and contrary to my understanding of epidemic control in e.g. Wuhan, unless I am misunderstanding the criteria for that intervention.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Health economics, infectious disease modeling.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 26 May 2020

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Sheree M S Smith 

School of Nursing and Midwifery, Western Sydney University, Penrith, NSW, Australia

Thank you for the invitation to review this manuscript associated with non-pharmaceutical interventions (NPIs) utilised to limit the spread of SARS-CoV2 during this current pandemic. The obvious differences

between this viral pandemic and recent influenza pandemics are that vaccines are not available and to date, pharmaceutical interventions such as anti-viral therapies have not been proven in the treatment of COVID-19. Irrespective of when a pharmaceutical therapy or vaccine becomes available, NPIs will continue to have a role in interrupting the spread of viral illnesses, locally, nationally and internationally.

The importance of *Imai et al's* paper centres on role of NPIs and specifically social distancing measures that have been implemented and the subsequent number of COVID-19 cases reported. Previous published research associated with influenza NPIs tends to separate social distancing measures from home quarantine and isolation of infected individuals. The separation of these two NPI health behaviours (social distancing and isolation) may centre on the issue that the former tends to reflect policy or action by government on activities where large numbers of people may gather such as schools, shopping malls and places of worship and the latter as a public health person-specific action (CDC,2020; Aiello,2009²; Jefferson, 2011¹).

The strength of this paper is that it provides a timeline of the implementation of social distancing measures across a number of countries (Figure 1). Whilst travel restrictions are briefly mentioned, a detailed description of what these restrictions entailed may be of interest as the Wuhan travel restrictions were primarily between cities and across borders. Understanding changes to local public transport and whether social distancing measures associated with public transport and/or increased cleaning procedures at stations and on buses and trains were implemented, may be important in understanding community transmission. Culture may also play a role in adherence to social restrictions if the public health message is not tailored for that community or the threat is not perceived at an individual or societal level. Furthermore, understanding the community's acceptance of previous public health messaging during other recent pandemics may also inform our understanding of social distancing, community behaviour and transmission during this current pandemic.

Recommendations:

- Definitions for social distancing differ between public health authorities in various countries and this manuscript may benefit from acknowledgement of these differences.
- In both table 1 and table 2 recommend removing contact tracing as a social distancing measure.
- There has been a number of published systematic reviews on NPIs that may inform the discussion. The incorporation of findings from well conducted reviews may enhance the interpretation of social distancing measures and their effectiveness during this current pandemic.

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Jefferson T, Del Mar CB, Dooley L, Ferroni E, AlAnsary LA, Bawazeer GA, van Driel ML, Nair NS, Jones MA, Thorning S, Conly JM. Physical interventions to interrupt or reduce the spread of respiratory viruses. Cochrane Database of Systematic Reviews 2011, Issue 7. Art. No.: CD006207. DOI: 10.1002/14651858.CD006207.pub4.¹

Aiello AE, Coulborn RM, Aragon TJ, et al. Research findings from nonpharmaceutical intervention studies for pandemic influenza and current gaps in the research. Am J Infect Control. 2010;38(4):251258. doi:10.1016/j.ajic.2009.12.007²

Centers for Disease Control and Prevention (2020) Coronavirus Disease 2019 – Social distancing updated 6 May 2020

<https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/social-distancing.html>

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1. Jefferson T, Del Mar CB, Dooley L, Ferroni E, et al.: Physical interventions to interrupt or reduce the spread of respiratory viruses. *Cochrane Database Syst Rev.* 2011. CD006207 [PubMed Abstract](#) | [Publisher Full Text](#)
2. Aiello AE, Coulborn RM, Aragon TJ, Baker MG, et al.: Research findings from nonpharmaceutical intervention studies for pandemic influenza and current gaps in the research. *Am J Infect Control.* 2010; **38** (4): 251-8 [PubMed Abstract](#) | [Publisher Full Text](#)

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: I have published a systematic review on influenza non-pharmaceutical interventions.

Reviewer Expertise: health services research, models of care for lung health, influenza NPIs

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 15 May 2020

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Núria Torner 

Department of Medicine, University of Barcelona, Barcelona, Spain

Thank you for inviting me to review this study of utmost importance right now. NPI have been implemented before in influenza pandemics, yet this new coronavirus virus offers some differences that could diminish NPI's effectiveness. And, until an effective vaccine and treatment are available to treat

those at risk of severe illness, these are the only tools at hand to slow down transmission and keep healthcare facilities within a reasonable and affordable work load.

Nevertheless the economic and social impact of NPI that take into account school closure, shutdown of economic activity related to travel and commodities such as restaurants, non-essential retailers and so on, also has to be carefully measured to ensure a balance that is feasible to cope with.

The critical importance of children and teenagers in transmission of influenza is well described, but is it so for SARS CoV-2? Instead nursing homes and elderly dwelling facilities have been shown to be the target for this virus, so in the face of a second wave or a new winter season comeback, it will be important to focus on these latter facilities to stop transmission and spare hospitalizations of severely ill patients that overload ICUs. So it might be more effective to implement strict NPIs instead of school closure that is highly disruptive for the community.

Implementation of social distancing strategies is challenging indeed and if compliance with the strategy is high, hopefully transmission in a community can be averted. However, if neighboring communities do not also use these interventions, infected neighbors will continue to introduce the virus. In all, this research is very important to deliver at this time so it can be used as guideline to take the confinement decisions.

As to specific considerations to this paper:

Only a few countries/territories have been taken into account outside of mainland China, perhaps France and Spain could have also been added because the onset of exponential transmission did not differ that much from Italy and the NPI measures taken have been slightly different. Anyhow, according to Fig 1 the result of delay in implementation of NPI on a nationwide scale is quite evident.

As to Fig 1, note that there is a different numerical expression in the vertical axis for Hong Kong, please delete the decimal point.

The Wuhan city graph has local and national NPIs, but Wuhan is a city in the Hubei province. It's not clear what is meant by the continuous and discontinuous line. So you mean that the entire territory of China adopted contact tracing and crowding NPIs by mid January including Wuhan, and then only Wuhan and other regions locally implemented additional NPIs? There are two solid orange lines, is that correct, it's a bit confusing, could you clarify this information by labeling accordingly?

The paper focuses mainly on social distancing and closures, not on hygiene measures or use of masks, which has been implemented also and there have been many problems as to availability of effective protective equipment worldwide. The title should reflect this fact, instead it mentions NPIs as a whole. Also there is no formal impact assessment in the results section, so it is misleading to see the term in the title.

Definitions for each social distancing measure (safety distance, stay-home, travel restrictions etc.) should be included in the Methods section. For example, the term Public communications is not clear as to what it refers to.

Table 2 gives the enforcement % as a whole in all the territories/countries included in the study, this is okay for 100% enforcement, but for the lesser it would be nice to have it broken down to each country /territory.

Only Wuhan implemented travel restrictions? Is this correct?

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Epidemiology of infectious diseases and outbreak prevention and control.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 27 April 2020

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Nancy Fullman

University of Washington, Seattle, WA, USA

Thank you for the opportunity to review this interesting and timely study. In the absence of an effective vaccine or pharmaceutical measures against COVID-19, policies that fall within the non-pharmaceutical intervention (NPI) are vital for slowing viral spread and (hopefully) reducing burden.

Each day brings updated and/or new knowledge to the COVID-19 evidence base, especially as more countries confront the virus and implement NPIs. Subsequently, any lapse of time between analysis, manuscript submission, and peer review inevitably involves a growing gap in what was initially included in any study. With this in mind, below are recommendations for improving the manuscript's current content and analyses; the main decision point for the study's authors is whether to expand this work to more accurately reflect the world's current "Adoption and impact of non-pharmaceutical interventions for

COVID-19” or to reframe the study’s content as a focus on a subset of locations within a certain time frame.

Main recommendation 1: Update results to cover more countries and policies to date, or clearly frame this study as focusing on locations which had the earliest epidemics. This submission provides an initial synthesis of NPIs adopted in a subset of locations (Wuhan City, Hong Kong, South Korea, Japan, Singapore, and Italy) initially affected by the novel coronavirus. It is not quite clear on when exactly this analysis occurred, and/or when the intake of new data was completed, but given the submission timing (April 2), and manuscript content (i.e., reference to cases as of 21 March 2020; Figure 1 having data through approximately March 10-15), it suggests that other locations – namely Spain, but also increasingly other countries in Europe (e.g., France, United Kingdom) and the United States – were also seeing rising COVID-19 cases and deaths at the time of analysis. Further, these locations had at least started implementing NPIs: in Spain, Madrid closed educational facilities on March 11 and non-essential services on March 13; many more communities in Spain saw similar closings from March 14-15. France had similar timelines at the national level, though initial mass gathering restrictions began on March 4. The US was much more fragmented at the state-level, but many types of NPIs were increasingly implemented after March 13 or March 16 (i.e., the time period at which national-level recommendations were more strongly endorsed by the US President). In sum, at the time of submission, it was likely that more locations (nationally and sub-nationally) had at least begun NPI implementation in response to COVID-19.

The focus on locations with earliest COVID-19 epidemics is an understandable one; however, this focus was not clearly discernable until the Methods section, and it was definitely not conveyed in the Abstract (i.e., based on its reading and timing of submission, I had expected at least some information on US NPIs). Again – this is not an inherent flaw of the study’s foundation or analytic approach. Going forward, it should either be much clearer on its intent (i.e., a focus on x locations that reached y COVID-19 cases or deaths before z date), or expand the review and synthesis to reflect the current state of countries’ adoption and impact of NPIs for COVID-19.

Main recommendation 2: More clearly define the types of NPIs included (and excluded) in this study. As the authors rightly note, there are many types of NPIs that have been deployed against infectious diseases and epidemics more broadly, and particular types that have been used to date against COVID-19. However, the consistency and clarity with which the latter are described could be substantially improved. First, the study appears to be primarily focused on social distancing measures (also referred to as physical distancing measures) rather than a broader set of NPIs; this should be made more clear in the Title and Abstract so as to not set different expectations for readers. Otherwise, the broader set of NPIs should be consistently considered throughout the analysis. Second, what is included in Table 1 (summary of social distancing measures considered and/or implemented in response to COVID-19) do not fully correspond with those in Figure 1. Notably “public communications” is not clearly defined (Figure 1), which is likely because it is not considered a social distancing measure (and is primarily discussed in supplementary tables and figures); however, “public communications” is then included in Table 2’s “Summary of social distancing interventions implemented...”.

Third, at least one key distancing measure appears to be omitted: stay-at-home orders, or the equivalent of ‘lockdowns’ and shelter-in-place as they were framed in many locations. Whether the policies expressly banned any kind of departure from an individual’s residence (or only during certain times and/or for certain types of essential activities), this type of social distancing policy was considered one of the most strict – and potentially impactful – for many of the locations included in this study. Isolation and quarantine are different than more blunt mandates to remain at home and not interact with others; isolation and

quarantine are, in theory, supposed to be on the basis of confirmed or suspected infection (isolation), and then exposure to infected individuals (quarantine). Given the authors' separation of the different types of educational facility closure, it also could be useful to consider mandates to close certain types of businesses (e.g., entertainment venues, recreational facilities) and then more broadly sweeping non-essential business closures. These policies were generally more focused on reducing contact and exposure of customers within business settings rather than the employees (which was the primary focus on workplace closures and advisories to work from home). Restaurant and bar restrictions, whereby such businesses had to ease in-person services but could provide food and/or drink for off-site consumption if proper public health measures were in place, are another type of social distancing policy that is not expressly included in the current manuscript. Last, it would be helpful to hear more about why the authors did not include travel restrictions as a type of social distancing policy. Depending on what the restriction aims to achieve, it could squarely fall within a social distancing measure definition (i.e., a policy or measure that aims to reduce mixing and rates of close human contact with each other). Based on the three-point definition of social distancing measure on page 3, it seems as if travel restrictions (e.g., banning on non-essential travel outside of your state or community of residence; requiring quarantine for all travelers arriving in location x , irrespective of points of origin) would fall under "community containment".

Main recommendation 3: Remove impact from the study's title or conduct a more formalized synthesis of NPI/social distancing policy impact. Because the manuscript's title indicated that this was a study of "adoption and impact" of NPIs for COVID-19, there was an expectation that a more formal quantification of impact would be included. Of course such an analysis is fraught with challenges, especially when more stringent distancing policies may be implemented in response to worsening epidemic trajectories in many places (i.e., issues of endogeneity), and widespread gaps or delays in testing (i.e., issues with properly quantifying COVID-19 outcome measures). Increasingly more pre-print studies are using changes in human movement based to approximate the impact of social distancing measures and how changes in mobility might be related to subsequent changes in transmission and infection. Further, other studies are increasingly considering which types of social distancing policies have been related to larger changes in mobility (and thus potentially transmission) – a crucial step to understanding what combinations of measures may be most effective for a given setting and epidemiologic context. To most accurately retain "impact" in the study's title would require at least some kind qualitative, and preferably quantitative, synthesis of the different types of studies conducted to date on the impact of social distancing measures in response to COVID-19.

Other minor recommendations and queries:

- Introduction: broader types of NPIs are discussed here (e.g., personal protective measures), but are not really revisited in the Discussion. Strengthening the ties between the different types of NPIs and when they might be best used throughout an epidemic's course could be beneficial for this study.
- Results: Table 2: What does "Enforced" mean? By law, or by physical force (e.g., police, military)? Means of enforcement could certainly vary across the included locations.
- Discussion (page 4, right-hand column, second paragraph): even by mid-late March, the US had markedly expanded its social distancing policies beyond local school closures. Statewide orders started accelerating in mid-March, and various types of business closures increasingly occurred. California had the country's stay-at-home order and non-essential business closure issued on March 19, followed by New York State. Discussing COVID-19 responses in other European countries (Spain, France, UK, among others) would be helpful in this section and elsewhere in the

Discussion.

- Final paragraph (page 8): consider including information on the role of social distancing measures alongside the scale up of containment strategies (i.e., widely available testing, case-based isolation and contact tracing), especially in locations looking to ease distancing policies. Further, given the resurgence of cases in many of the places covered in this study post-easing of social distancing policies, what the implications of longer term use of NPIs?

Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Population health measurement, health systems, infectious diseases.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.
