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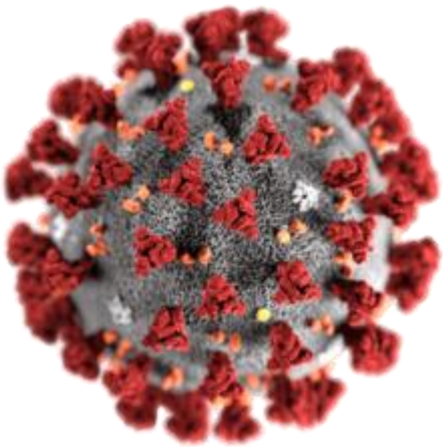

COVID-19 Science Report: Containment Measures

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Contents

Containment Measures

For regular readers of this report, the latest additions have been highlighted in green.

Some references were from preprints which are preliminary and yet to be peer reviewed, the results should be interpreted with caution.

During pandemics, medical countermeasures are usually not immediately available. Shortage of vaccines and therapeutics is highly likely, and their production and supply are typically hampered by the need for clinical trials, intellectual property concerns, regulatory hurdles and the fear of liability in the case of novel viruses. For novel diseases, like COVID-19, it will likely take at least six months to a year from onset of an outbreak before first doses of vaccine are available. Non-pharmaceutical interventions (NPIs) are therefore important and typically the only options available to governments to contain an evolving outbreak.

Governments have traditionally adopted a good range of NPIs to contain or mitigate the spread of a virus at the varying levels and points of its transmission pathway network into and within countries/regions. This report reviews the literature around NPIs and summarises the key measures taken in pandemics and outbreaks of respiratory viruses, evidence on their effectiveness and efficiency, and considerations and impact from their deployment. Works reviewed include mainly literature on general practices/recommendations and the guiding principles behind decisions, as well as research studies that evaluate effectiveness, model impact or analyse influencing factors/characteristics. (See also section on Search Method at end of report.)

Unlike vaccines, diagnostics and therapeutics which can be described as discrete entries, papers discussing the various containment measures are often prompted by specific outbreaks. For a systematic discussion therefore, we have divided up the containment measures into the following varying levels of containment.

Conceptual Overview of Levels of Containment

In a pandemic situation, an imported viral agent can enter a given country and ‘seed’ secondary transmissions and new epidemics, spreading the pandemic through exponential growth of new infected cases. Non-pharmaceutical containment and mitigating measures are usually built around key points in the virus’s transmission pathways, forming three key layers of defence and protection against spread of the disease, as described in the following table:

<table>
<tr><th colspan="6">Measures</th><th>Examples</th></tr>
<tr><td rowspan="3">1</td><td rowspan="3">Border controls</td><td>1a</td><td colspan="3">From source area, which may be extended over time.</td><td>From Wuhan, then Hubei</td></tr>
<tr><td>1b</td><td colspan="3">From source country (outside source area but administratively easily delineable).</td><td>From whole of China</td></tr>
<tr><td>1c</td><td colspan="3">From other countries or areas from which there have been incidences of infections.</td><td></td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">Active measures</td><td rowspan="2">2a</td><td rowspan="2">Detection of potential cases</td><td>2ai</td><td>Imported potential cases</td><td rowspan="2">Through screening at healthcare and other facilities</td></tr>
<tr><td>2aii</td><td>Suspected unlinked confirmed cases</td></tr>
</table>

Measures						Examples
				2aiii	Contacts of confirmed imported cases	By contact tracing
		2b	Isolation or quarantine	2bi	Healthcare facilities	Hospital infection control, protection of healthcare personnel
				2bii	Homes	
				2biii	Quarantine facilities	
		2c	Treatment, including financial support for treatment costs and loss of income			With Ritonavir/lopinavir
		2d	Release			Release after ascertainment of non-infectiousness
3	General measures (community measures, mitigating measures, others etc)	3a	Measures to reduce contact within the community			Reducing public gatherings, school closures
		3b	Public communications			Community sanitation and hygiene, mask use, self-isolation if unwell
		3c	Provision of necessities and other supplies			Masks, medical and food supplies
		3d	Others			Environmental cleansing, BCP etc

Border Controls

Border controls and travel restrictions are usually among the first response measures governments implement at the onset of a pandemic. They seek to prevent importation of a disease into the country and include entry or exit screening, health alert notices, collection and dissemination of passenger information, travel advisories/restrictions (both preventing/stopping entry or departures), physical examination or management of sick or exposed individuals, and border quarantine (including quarantine of ships and aircraft). With increasing globalisation and growing international air travel, transnational public health law has become increasingly important in global health and the impact of transnational containment measures can be far-reaching. [1]

Guiding Principles and International Regulations

Countries generally have legal provisions to guide, instruct and control the operationalisation of border control operations. These are usually incorporated under communicable disease control laws or maritime and aerial regulations, which include sub-sections on specific aspects of border control such as the quarantine of ships or aircraft. For example, Singapore’s Infectious Disease Act and CDC’s Interim Guidance for Ships on Managing

Suspected Coronavirus Disease 2019[1], and the likes in other countries/regions[2], list out the protocols for arriving ships with an infectious virus, including the need to pre-inform the port by a specified timing prior to arrival and to proceed to a quarantine anchorage. [2] [3] [4] [5] [6]

Given the transboundary nature and economic impact of travel advisories, the general consensus on guiding principles among governments, international law, academics and stakeholder communities are that:

- It should be left to the WHO to issue transparent and clearly justified travel recommendations in accordance with the International Health Regulations[3].
- It is the responsibility of individual countries to communicate relevant information on public health threats to the international community. [7]
- Pandemics will require solidarity among nations and collaborative approaches that set aside traditional values of self-interest and territoriality.
- Travel restrictions can severely disrupt travel, trade, and tourism, and decisions to do so should be balanced against the global economic impact.
- Border control measures such as entry and exit screening and quarantining of travellers crossing international borders are generally not recommended for influenzas, as they have not been shown to reduce the spread of influenza, and are also very expensive and disruptive. [7] [8]

Effectiveness of Border Control Measures

Impact on delay to outbreak. Modelling studies and case study research have shown that travel restrictions could delay the spread of an epidemic and reduce the impact from imported cases. A recent systematic review also concluded that travel restrictions were able to delay epidemic peaks and slow international spread. [9] Table 1 lists out projections of some of these studies, mostly focused on influenza pandemics but also including some recent studies on COVID-19. Length of delay is highly sensitive to the transmissibility of the virus (its reproduction number) and timing of restriction (how early in onset of the outbreak). High virus transmissibility translates to shorter delay periods, with projected delay of a few days (about 3) for an influenza virus with Rt of about 3.5 or H1N1's transmissibility. Recent modelling research studying the impact of border control on national (in mainland China) and international spread of COVID-19 yielded similar estimated delay periods (see Table 1). The travel quarantine of Wuhan was estimated to result in about 3-5 days delay in the national spread of the disease within China, and a study using Japan (with a large number of visitors from China) as a case scenario estimated travel restrictions to/from mainland China to result in 2 days to less than a day (for ROs 1.5, 2.2, and 3.7) of time delay to an epidemic in the 'seeded' country. [10] [11]. The same study projected that the probability of a major epidemic in the 'seeded' country (Japan) was reduced by 7-20% with the travel restrictions.

Impact on extent of outbreak. In terms of impact on magnitude of cases and outbreak, studies on travel restrictions to/from China quantified their impact as having averted 70-80% of exported cases (ranging from over 200 to 500 cases as at about mid-Feb) from mainland

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[1] This falls under CDC's Specific Laws and Regulations Governing the Control of Communicable Diseases.
[2] Such as Hong Kong's Administrative Measures for Entry and Exit Inspection and Quarantine on Ships of International Sails, and Quarantine (Maritime and Aerial) Regulations under Laws of Tuvalu.
[3] The International Health Regulations (2005) are a legally binding instrument of international law that aims to a) assist countries to work together to save lives and livelihoods endangered by the international spread of diseases and other health risks and b) avoid unnecessary interference with international trade and travel.

China. A study on Hong Kong also noted that travel restrictions reduced the number of imported cases, with very few detected during February. [12] A more recent study (see Constantino et al in Table 1) showed that Australia's travel ban on China was highly effective in reducing magnitude of the COVID-19 epidemic in Australia and averted a much larger epidemic (the epidemic would have continued for > 1 year with more than 2,000 cases and 400 deaths without travel ban on travellers from China effected on 1 Feb). [13] Another study on the US stated that while it is already too late for a wholesale traffic restriction to contain the spread (with virtually all US stated seeded with COVID-19 cases), earlier implementation of aggressive traffic controls (two weeks before 14-16 Mar) would delay national epidemic peak substantially and reduce peak magnitude by up to 30% (see page 102). Notwithstanding, the influence of mobility reduction on epidemic peak magnitude dwindles to a negligible level by March 16. Border controls are unlikely to contain the outbreak but could reduce importation of cases and subsequent scope of outbreak in other countries, especially at early stage of the epidemic. [14] [15]

The scope of increasing the delay period to epidemic spread with border controls appears limited, however. One of the earlier studies on influenza pandemic pointed to the need to increase effectiveness in travel restrictions from 80% to >99% to extend the delay interval from days to the order of weeks. [16] A recent modelling estimated on the impact of travel restrictions on COVID-19 spread in Spain presented similar findings where only an unrealistic 90% reduction of overall traffic will delay the epidemic peak by over 20 days. [17] Closure of highly connected hub airports, rather than a homogenous reduction in global air travel, also improves the effectiveness of slowing the epidemic. A stochastic metapopulation epidemic model which simulated and ranked border control strategies (by their efficiency levels) in the H1N1 pandemic scenario within the US found strategies that allocate screening resources to the most connected airports and airports with shortest path distances from epidemic source to be the most effective, while allocating screening resources to the most travelled and largest population airports performed the worst in the simulation. Notwithstanding, such strategies only have a major role when global case numbers are low at the very early onset of an epidemic. Once there are tens or hundreds of thousands of cases and multiple epidemics, travel restrictions have little impact even if optimally targeted. [16] [18]

Reasons why travel restrictions have little effect on preventing spread of global pandemics are the exponential increase of cases in outbreaks, and the usual fact that 'by the time awareness of an international epidemic crystallize', enough cases 'have been "seeded" in a given country to sustain transmission within national borders'. [19] A modelling study indicated that travel restrictions on a pandemic influenza strain may have a large impact only if implemented before there are thousands of cases at the source epidemic. [16] As such, only unrealistically drastic limitations on international movement can slow a pandemic that is already under way. These highlight the critical short timeline during which border control has the potential to play a substantial role, after which local control will be more impactful and little benefit will be derived from longer term implementation of travel restrictions. [19] [20]

Island nations. It should be pointed out that projection of longer periods of delay (in order of weeks) with travel restrictions in pandemic situations was possible for island nations or communities that are geographically remote (where alternatives to aircraft travel are difficult). A model computed positive net societal value for up to 12 weeks of border closure (after which the value turns negative) in a scenario of pandemic threat to New Zealand with a mortality rate of 1.5 times that of the 1918 influenza pandemic. Another modelling study recommended consideration of quarantine alone for 9 days or for 6 days combined with using rapid diagnostic testing (if available) for small island nations, which could contribute substantially to delaying the arrival date of pandemic influenza. [21] [22] [23]

For regions with very few infected travellers. A study on the COVID-19 outbreak found that for previously unaffected regions with extremely few infected travellers, air-traveller targeted interventions (without drastic travel bans/restrictions) implemented early in the outbreak can sufficiently delay a major outbreak in a by a magnitude of a few weeks to potentially even months. For such cases, traveller sensitisation[4], particularly in combination with syndromic screening, can delay a major outbreak by at least 23 or 111 days (at 97.5% and 75% of simulations respectively) for 1 infected traveller per week. Possible delay, however, decreases rapidly to a magnitude of days for more travellers (at least 4 or 9 days only for 10 infected travellers per week), lower effectiveness of sensitisation and higher R0. [24]

A more recent modelling study on Australia (see Adekunle et al in Table 1) showed that its progressive travel restrictions from 24 Jan followed by a travel ban of travellers from mainland China on 1 Feb (when confirmed cases was only 9) reduced imported cases by 79% (15 versus 70 cases) after 4 weeks and delayed onset of widespread local transmission by 4 weeks.

Other influencing factors. The studies modelling national spread of COVID-19 within mainland China pointed out that delay period brought about by travel restrictions is shorter for cities with larger populations and having more travellers from the source province, pointing to traveller volume and local population size/density as important influencing factors. One of the studies also found that the spatial spread of COVID-19 was more rapid than H1N1 (262 cities reported cases in 28 days for 2019-nCoV compared to 132 days for H1N1), likely due to degree of urbanisation and the development of modern transport systems, another contributing factor to speed of spread. [10] [25]

A recent study on COVID-19 importation and spread in Australia pointed out that the risk reduction potential of travel bans can be assessed through the relative volume of travellers from the respective countries, their seasonal variation and if travellers are residents or visitors. In the case of Australia, for example, it was noted that China and South Korea had a high number of visitors far exceeding returning citizens/residents while returning citizens/residents dominate return travel from Italy and Spain (slightly less for France and the UK) over the summer. Risk reduction from travel bans to/from China and South Korea is therefore substantial while that for Italy/Spain may be smaller. [26]

Economic impact and implications for policy. Some studies pointed out that economic impact of restrictions in major centres could be enormous, with severe consequences for service and travel industries. Considering that some benefits of reduced travel may also accrue without restrictions (with persons avoiding travel because of perceived risks), less drastic interventions such as outbreak-related communications for travellers at border entry points, together with effective communication with clinicians and disease control measures in the community, may be a more effective approach to the international control of communicable diseases. [27] [28]

The early emerging modelling studies on COVID-19 were generally of the view that drastic travel restrictions to/from mainland China may have yielded limited benefit to slowing international spread. One study pointed out that sustained 90% travel restrictions to/from mainland China only modestly affect the epidemic trajectory unless combined with public health interventions and behavioural changes that result in 50% or higher reduction of

[4] Sensitisation of arriving travellers to signs of illness.

transmission in the community. Citing the projected impact of delay to spread of COVID-19, another study stated that while a few days delay in spread within China would secure time for healthcare systems in cities that have yet been affected with case patients, the impact of such a delay outside China (as in the 'seeded country' scenario of Japan) is not substantial enough to accomplish meaningful prevention. [10] [11]. More recently, the WHO-China Joint Mission report pointed to the current decreasing risk of COVID-19 in China, the importance of its rapid return to economic productivity for itself and the world, and the world's urgent need to access to its experience and resources in responding to COVID-19. This meant the need to constantly reassess levels of restrictions on travel and/or trade with China. [29] However, the study projecting the effect of traveller sensitisation and syndromic screening pointed to how such less drastic interventions in UK and other parts of Europe may substantially delay major local outbreaks while the US's banned entry of foreigners who have visited China would likely further limit the number of infected travellers but come with substantial economic cost. However, the study qualified that under-reporting of cases in these regions is likely and the situation may change rapidly in the coming weeks with rising case numbers in Hong Kong, Singapore, Japan and Korea. [24]

More recent studies ascertained the value of travel restrictions in their reduction of imported cases and subsequent outbreak magnitude. The above mentioned studies on US and Australia pointed to how travel restrictions could be highly effective in reducing magnitude of COVID-19 spread in seeded countries (see page 4 and Constantino et al in Table 1). The study on Australia noted, however, that partial lifting of ban from 8 Mar by allowing 100K university students to enter had minimal impact and was a policy option. [13] [15]

Comprehensive pandemic plans by countries could also include ways of mitigating the negative economic impact from travel restrictions, such as planning contingency measures to support continuing export and import activities during such periods. [21]

Table 1: Projections from Modelling Studies

	Author/Source	**Description/Findings**
Earlier Studies	Wood 2007 [30]	Projected time delay between epidemics in two population centres computed an additional median delay in 20 infected cases to be 3 days at a Rt of 3.5.
	Bajardi 2011	Projected that a 40% travel reduction translated to 3 days of delay while a 90% travel reduction translated to 2 weeks of delay.
	Hollingsworth 2006	Projected that 80% of travel reduction increased the interval between exports by days only.
	Fergusen 2005 [31] Hollingsworth 2006	Indicated that travel restrictions preventing individuals travelling out of a source area and potentially seeding a new outbreak are feasible only when there are less than 50 cases.
	Boyd 2017	Computed a positive net societal value in the scenario of New Zealand in an influenza pandemic threat situation to last up to 12 weeks.
	Nishiura 2009	Predicted 95 to 99% effectiveness in preventing the release of infectious individuals into the community with border quarantine periods of longer than 4.7 and 8.6 days respectively for small island nations. Quarantine period

	Author/Source	Description/Findings
		could be shortened with combined use of rapid diagnostic testing.
	Hufnagel 2004 [32] Hollingsworth 2006	Simulation of severe acute respiratory syndrome outbreak indicated that closure of highly connected hub airports has the potential to slow the epidemic more effectively.
	Zlojutro, A., Rey, D. & Gardner, L (2019)	Using the scenario of the H1N1 pandemic within the US, strategies that allocate screening resources to the most connected airports and airports with shortest path distances from epidemic source to be the most effective, while allocating screening resources to the most travelled and largest population airports performed the worst.
COVID-19 Studies	Chinazzi et al 2020	A modelling study using a global metapopulation disease transmission model projects the impact of both domestic and international travel limitations – national spread is estimated to be delayed by 3-5 days and the effect on international spread is estimated to be a 80% reduction in number of exported cases from China until end February.
	Tian, H. et al 2020 [25]	The study, which combined epidemiological and human mobility data, found that the travel ban slowed the dispersal of the virus from Wuhan to other cities in China by 2.91 days on average.
	Anzai, A. et al 2020	The modelling study estimates travel restrictions to/from mainland China to result in 70.4% reduction in the volume of exportations from China (226 cases).
	Clifford, S. et al 2020	Found that early in the outbreak, traveller sensitisation, particularly in combination with syndromic screening, can delay a major outbreak in a previously unaffected region by at least 23 or 111 days (at 97.5% and 75% of simulations respectively) for 1 infected traveller per week and by at least 4 or 9 days for 10 infected travellers per week.
	Wells et al. 2020 [14]	Found that 779 cases would have been exported from mainland China by February 15, 2020. Border/travel restrictions enforced by the Chinese government averted 70.5% of these cases and reduced rate of exportation by 81.3% on average in the first 3.5 weeks of implementation.
	Constantino et al 2020 [13]	A modelling study showed that Australia's travel ban on China contributed to containing the COVID-19 epidemic in Australia and averted a much larger epidemic. Three scenarios – (1) no ban, (2) current ban effected on 1 Feb, and (3) current ban with partial lifting of ban from 8 Mar to allow only 100K university students to enter – were modelled based on Rt of 2.2 and assumed parameters of effectiveness of concurrent measures of contact tracing, quarantine and hospital isolation. Scenario (2) results in 57

	Author/Source	Description/Findings
		cases on 6 Mar (actual cases recorded was 66) while scenario (1) shows the epidemic would continue for > 1 year with more than 2,000 cases and 400 deaths. The impact of scenario (3) is minimal vis-à-vis (1), and may be a policy option.
	Adekunle et al 2020 [33]	The study using international flight data and models of disease transmission projected that the travel ban on individuals arriving from China reduced imported cases by 79% and successfully delayed the onset of widespread transmission in Australia by four weeks. Comparatively, up until mid-March, travel bans for South Korea and Iran (imposed on February 9 and March 5 respectively) were shown to have negligible impact likely due to the still much lower prevalence in these countries compared with China, and Italy having already placed itself on lockdown. However, travel restrictions are projected to become increasingly effective as cases in these countries rise. Local transmission is projected to outweigh imports by end-March.
	Brynildsrud and Eldholm 2020 [34]	Study on Norway observed an exponential increase in fraction of infected travellers (mostly those returning from Lombardy) between 21 Feb and 1 Mar (~1% on 21-25 Feb to ~9% on 1 Mar). Study recommends mandatory quarantine of returning travellers or suspension of non-essential international flights to control or suppress the COVID-19 pandemic.

On Specific Border Control Measures

Syndromic screening. Modelling and observational studies have indicated that syndromic screening is not effective at detecting infectious persons. Reasons include:

- Infected people may travel during the incubation period, which could be asymptomatic but infectious.
- People may be using antipyretics and may not exhibit signs of fever.
- Some screening tactics are easy to evade or circumvent (eg use of questionnaires and travelers concealing their origin by traveling to a non-barred location first). [35] [19].

A recent study pointed out that syndromic screening can detect a high proportion of infected travellers only when the rate of asymptomatic transmission is negligible and incubation period is short. Its simulation of thermal passenger screening for COVID-19 at airport exit and entry found that 46 of 100 infected travellers would enter a region/country undetected (using mean incubation period of 5.2 days). [36] Notwithstanding, another study on the COVID-19 outbreak (cited above) found that the combination of traveller sensitisation and syndromic screening could potentially delay a major outbreak in previously unaffected regions with very few infected travellers. [24]

A case study has shared on Taiwan's use of new technology – QR code scanning coupled with online reporting of travel history and health symptoms – to classify persons into risk categories. 'Cleared' travellers were sent a health declaration border pass via SMS for faster immigration clearance, while those with higher risk were quarantined at home and tracked through their mobile phones to ensure compliance. [37]

Case isolation at borders was highly effective in reducing onward transmission of SARS, and most imported cases were contained at their destination because infectiousness peaked well after the onset of clinical symptoms for the disease. In contrast, case isolation will be less effective for influenza infection, where considerable infectiousness can be associated with pre-symptomatic or mildly symptomatic infection and secondary influenza infections are likely to arise on international flights and from imported cases. [16]

Border quarantine. A modelling study (see above) recommended consideration of border quarantine for 9 days or for 6 days if combined with using rapid diagnostic testing for small island nations in the case of pandemic influenza. [23]

Quarantine of ships. A modelling study of empirical data of COVID-19 confirmed infections on the Cruise ship Diamond Princess found that the virus's Rt in the cruise ship situation of 3,700 persons confined to a limited space was around four times higher than its Rt in Wuhan (estimated at a mean of 3.7). As supported by previous research, Rt was dependent on population density (population per km^2 of 24,400 on the ship versus 6,000 in urban Wuhan). The public health measures taken (removal of all PCR positive passengers/crew from the ship and their isolation in Japanese hospitals, on-ship test-negative passengers quarantined in their cabins and allowed to come out for an hour per day) substantially reduced new COVID-19 cases (17% attack rate versus 79% without interventions) and prevented a total number of 2,307 additional cases by 19 February. A scenario of early evacuation at time of first detection of the outbreak would have resulted in only 76 latent infected persons during the incubation time. The study recommends early evacuation of all passengers on a cruise ship (or in a situation with confined spaces and high intermixing) as soon as an outbreak of COVID-19 is confirmed. [38]

A recent report from the CDC pointed out that the mingling of travellers from multiple geographic regions and closed nature of a cruise ship environment likely facilitate the spread of infectious diseases on cruise ships. SARS-CoV-2 RNA was also identified on a variety of surfaces in cabins of both symptomatic and asymptomatic infected passengers up to 17 days after cabins were vacated on the Diamond Princess. There is also risk of transmission from crew members across multiple consecutive voyages as in the case of the Grand Princess. In view of the extensive resources required of public health responses to cruise ship outbreaks, including coordination of stakeholders across multiple sectors, government departments and agencies, foreign ministries of health and embassies, hospitals, laboratories, and cruise ship companies, CDC has issued a level 3 travel warning on 17 Mar recommending that all cruise travel be deferred worldwide. Temporary suspension of cruise ship travel has also been partially implemented by cruise lines through voluntary suspensions of operations. [39]

Other measures. The International Health Regulations (IHR)[5] authorizes a variety of sanitary measures at borders and on conveyances, including inspection, disinfection, and destruction of infected or contaminated animals or goods. [40]

[5] The International Health Regulations, or IHR (2005), represent an agreement between 196 countries including all WHO Member States to work together for global health security.

Amidst the COVID-19 pandemic, several other general biosecurity measures (such as minimising contacts during boarding/deplaning processes, limiting movement within the cabin during flight, increasing frequency/quality of cabin cleaning, and simplifying catering procedures etc) have been proposed or implemented for airlines which continued to operate repatriation flights, and post-lockdown resumed flights. Several proposed preventive measures have raised feasibility and economic concerns for the airline industry. For example, the International Air Transport Association (IATA) recently endorsed mandatory face-coverings for passengers and masks for crew but opposed onboard social distancing in view of revenue impact.

A recent study examined passenger/crew responses to the Thai Airways International protocol adopted by Thai Airways' repatriation flights, which included classification of flights into risk score categories (depending on cases in the country of departure, proportion of seats occupied, flight duration, and if flight has the HEPA filtering system) and accompanying measures required (eg before boarding/inflight checking of passenger body temperature, extent of PPE required for crew and pilots etc). Passengers estimated varying physical distances at check-in (approx 1.59m), boarding (1.41m), and in-flight (1.26m). Physical distancing at 1.5 to 2.0 meters was viewed to be unfeasible during in-flight seating. On average, passengers moved around or went to the toilet during the flight approx 2 and 2.08 times. Physical distancing was also harder during disembarkation. [41]

Active Measures

Containment measures deployed at this juncture are taken when imported cases have been "seeded" within national borders. They are aimed at preventing disease spread from known infected persons and persons who have been exposed to the virus into the community.

Isolation and Quarantine

Quarantine is the restriction of the activities of asymptomatic persons who have been exposed to a communicable disease (ID contacts) to prevent disease transmission. In contrast, isolation is the separation of known infected persons so as to prevent or limit transmission of the disease. Quarantine and isolation can be done by various means, including confining people to their own homes, restricting travel out of an affected area, and keeping people in a designated facility. [7] Use of quarantine zones may be limited for smaller nations as these do not have the benefit of space.

Typically, quarantine is comparatively more controversial as it involves restricting the liberty of individuals who might pose a danger to public health as opposed to individuals who actually pose a danger.

For purposes of clarity, isolation and quarantine addressed in this section pertains to physical containment measures within a country/region (as opposed to border quarantine). Notwithstanding, it should be noted that certain studies/literature referred to in this section included border quarantine operations in their coverage.

Guiding Principles and General Consensus

Techniques for quarantine and isolation can vary, but it is important to treat symptomatic, potentially infected, and non-exposed populations differently. For example, it would usually be deemed inappropriate to place infected individuals in the same room as those who are only possibly exposed. [7]

Coercive public health powers such as quarantine and isolation are generally considered to be legitimately justified if the public health interests of society are carefully balanced against the freedom of the individual. [22] The broad international consensus is that each country should comply with the Siracusa principles[6], a set of internationally agreed-upon legal principles that establish the conditions under which restrictions on civil liberties are justified. [42] [7]

Measures as coercive as quarantine and isolation are thought to be acceptable when a disease is known through extensive scientific study to be contagious the measures limited to people who have in fact been exposed to the disease. [7] It is important that decision on such restrictive measures be made in an open, fair, and legitimate manner, and that public health authorities fully and honestly disclose, as well as allow community participation on, their reasons for action. [43] [44]

Effectiveness versus Cost

Economic cost. Quarantine operations are resource heavy. Services and costs for quarantine operations during the SARS outbreak in Singapore, for example, amounted to a total of $5.2 million USD. [45]

Social cost. Recent studies have also confirmed that quarantine imposes some serious financial and psychological hardships on the affected individuals. About 30 percent of individuals quarantined for SARS, for example, suffered from posttraumatic stress disorder and depression [7] [46], and in Singapore, some quarantined individuals reported problems associated with stigmatisation by their neighbours during the SARS period [45] [46]. A recent review of the psychological impact of quarantine reported wide-ranging and substantial effects that can be long-lasting. [47]

Quantifying effectiveness. Considering the significant social, psychological and economic costs resulting from quarantine, several studies have questioned the merits of the practice and pointed to experiences where actual infected cases out of large numbers quarantined were either nil or minimal. For example, during the SARS outbreak, only 0.22% and less than 0.5% of quarantined contacts were infected cases in Taiwan and Singapore respectively. There were also no confirmed cases of quarantined Canadians actually developing SARS. Most of the SARS cases in these countries were acquired in hospitals. Quarantine operations in the US during the Ebola outbreak in 2014 were also widely criticised as being overly aggressive in approach and achieving little to contain disease but at great expense to civil liberties. Quarantine exercise of travellers during the outbreak amounted to $1.9 million USD but not a single infected person was identified. [48] [49] [45] [50] [51]

Several studies, using a variety of modelling approaches, attempted to examine the extent to which quarantine contributed to control of infectious disease (ID) spread. These generally conclude that quarantine (accompanied with effective isolation) is likely to be effective if the asymptomatic transmission period of an ID is neither too short or too long. (Too short an asymptomatic period reduces the probability that the individual gets placed into quarantine before he/she develops symptoms and too long a period makes it extremely difficult to identify individuals likely to have been infected.) This condition usually results in a high proportion of identifiable infections generated by asymptomatic individuals, hence making quarantine effective. [52] [53]

In certain situations, such as when an ID's proportion of asymptomatic infections is low, the ID is likely to be contained in the absence of quarantine if stringent and effective isolation measures are in place. Hospital-wide case isolation can therefore be more important, and

[6] The Siracusa principles are set out in the provisions under the International Covenant on Civil and Political Rights, a multilateral treaty adopted by the United Nations General Assembly and in force from 1976.

simply informing suspected asymptomatic individuals, and telling them to report to a hospital at the first sign of symptoms, can possibly reap comparable benefits of quarantine in such situations. [52] [53] [51] [54] [55]

Effectiveness with COVID-19. While the effectiveness of quarantine measures may have been questionable for SARS, which was likely contagious only upon symptom onset, recent studies have cited some evidence of asymptomatic or mildly symptomatic transmission for COVID-19. [56] [57] [58] At the same time, while the virus's incubation period typically range from 3 to 6.4 days, it could potentially extend beyond 10 days. [59] (A recent study cited the incubation period range to be 0-24 days.) [60] [61] Two recent studies noted a likely shorter serial interval (the time between symptom onset of infector and infectee) than incubation period for COVID-19, indicating substantial asymptomatic transmission cases. [62] [63] [64]

One of the studies (Peak et al, preprint) compared the relative effectiveness of quarantine versus active monitoring of individuals and found that the former is substantially more effective than the latter (reduces the median Rt to 0.55 versus 1.55) in the scenario where serial interval is short (4.8 days) and intervention performance is high where at least three-quarters of infected contacts are individually quarantined (virus incubation period of 5.2 days was used). The other study (Xia et al, preprint) observed a serial interval of 4.1 days and incubation period of 4.9 days based on an analysis of 124 first- and second-generation cases in Wuhan and with reference to some earlier studies. This verified some of the qualifying conditions for a feasible scenario where quarantine effects substantially greater impact over active monitoring. Xia et al also noted that the majority of secondary cases (73%) were infected 1-2 days before symptom onset of first-generation cases, recommending for the tracing back to all close contacts within at least three days prior to symptom onset of infected cases.

Notwithstanding, Peak et al had pointed out that as the COVID-19 outbreak grows, achieving the intervention performance of having more than three-quarters of infected contacts individually quarantined may become unrealistically high in view of administrative burden and cost. In such circumstances, resources can be prioritised for scalable interventions such as social distancing, where selective individual quarantine (eg of family members of patients) or active monitoring can contribute synergistically with social distancing. The study simulated such a scenario and found that tracing 10%, 50% or 90% of contacts on top of social distancing resulted in a median reduction in Rt of 3.2%, 15% and 33% respectively (for active monitoring) and 5.8%, 32% and 66% respectively (for individual quarantine), assuming reduction of 50% of person-to-person contact with social distancing for infected individuals in the community who are not quarantined/isolated.

Influencing Factors

A recent rapid review found that adherence to quarantine ranged from as little as 0 up to 92.8%. Main factors influencing compliance were people's knowledge about the disease and quarantine procedure, social norms, perceived benefits of quarantine and perceived risk of the disease, and practical issues such as accessibility to necessities or consequences from absence from work. [65]

Trust and communication. Studies have shown that societal understanding and trust of the government's isolation and quarantine management plans is important as it helps resolve possible misgivings and improve community cooperation. Conversely, quarantine compliance in major epidemics is lower when the public does not support its use. [66] [47] For example, during the SARS outbreak, there were cases in Hong Kong and China where groups of ID carriers or contacts fled their premises upon hearing rumours of quarantine, accelerating the spread of the disease nationally. [49] Comparatively, the transparent provision of information, advocacy for social responsibility, and engagement and health education by visiting nurses to quarantined persons were cited to have contributed to the low rate of noncompliance with quarantine in Singapore. [45] [67]

Provision of regular and timely information can also help improve people's knowledge and perceived risk of the disease, ensuring that they understand the magnitude of negative societal impact from noncompliance. [65]

Other stressors and forms of support. A recent review on quarantine's psychological impact noted that longer durations of quarantine were associated with poorer mental health outcomes. Restricting the length of quarantine to the scientifically reasonable known incubation period rather than adopting an overly precautionary approach can therefore help minimise the negative impact.

Other stressors include boredom and sense of isolation, concerns on accessibility to basic supplies and healthcare/prescription drugs, financial loss from time of absence from work, and social stigma. Access to communication networks and forms of media, prompt and adequate provision of supplies, financial compensation and support groups can help make the quarantine experience as tolerable as possible for people. [47] [66]

Attitudes. Notwithstanding the negative impact, research in the aftermath of SARS showed that people understood and accepted the need for restrictive measures. Many perceived it as their civic duty and were willing to sacrifice their right to freedom of movement. [7] [68] Communications emphasising such attitudes as altruistic can further improve community acceptance of quarantine measures. [65]

Variation in such acceptability of restrictive measures was observed across cultures and countries. In a SARS case study, strong majorities in Singapore, Taiwan, and Hongkong favoured quarantine while lower acceptability was registered in the US. Support for quarantine was also affected by the level of concern about the ID as a potential health threat, with higher levels of concern registered for the participants from Asian countries where SARS was of stronger perceived threat. The same majorities continued to support quarantine even when told that people could be arrested for refusing to comply. [66]

Preference on monitoring methods. The study also surveyed respondents' preference for the different monitoring methods (see Table 2). Respondents across all four regions supported monitoring of quarantined people through periodic telephone calls, with citizens in Hong Kong less likely than other regions to support this measure. Periodic video screening was comparatively less preferred, with respondents from Singapore and Taiwan comparatively more supportive of it than those from US and Hong Kong. Majorities in Hong Kong, Singapore, and Taiwan favored using electronic bracelets and stationing guards outside quarantine stations to monitor quarantined people, compared with only 40 over percent in the United States. The majority of US respondents and slightly more than half of Singapore respondents preferred home quarantine for themselves and family members, while the majority in Hong Kong and Taiwan preferred off-site quarantine.

Other considerations. Internet connectivity and e-commerce services can facilitate ordering and delivery of necessities and good contact with the workplace/family/friends for people under quarantine, making the experience less inconvenient and resource intensive. Singapore, for example, benefits from its compactness and relative maturity of e-commerce services, where it is relatively easy and inexpensive to order cooked food and other items online. [69]

Table 2: Preferences for monitoring quarantine compliance and where quarantine period should be spent, four countries, 2004 [66]

	U.S.	Hong Kong	Singapore	Taiwan
Favor or oppose public health officials monitoring quarantined people by				
Periodic telephone calls				
Favor	75%[a,b,c]	60%[b,c]	85%[c]	90%
Oppose	24[a,c]	35[b,c]	14	7
Periodic video screening				
Favor	31[b,c]	31[b,c]	50	52
Oppose	67[b,c]	66[b,c]	46	44
Daily visit to check the health of those who are quarantined				
Favor	84[a]	97[b,c]	84	88
Oppose	16[a]	3	14	11
Electronic bracelets				
Favor	40[a,b,c]	56[c]	54[c]	68
Oppose	57	36	43	23
Guards stationed outside the place where people are quarantined				
Favor	43[a,b,c]	74[b,c]	52	55
Oppose	57[a,b,c]	25[b,c]	44	40
If a family member had to be quarantined				
Prefer that they be quarantined at home	71[a,b,c]	36[b,c]	59[c]	48
Prefer that they be quarantined in a separate facility	25[a,b,c]	59[b,c]	36	43
If YOU had to be quarantined				
Prefer to be quarantined at home	70[a,b,c]	28[b]	55[c]	37
Prefer to be quarantined somewhere else	30[a,b,c]	70[b,c]	42[c]	59
Still want to be quarantined at home if you were required to wear a mask at all times	60[a,b,c]	22[b]	40[c]	28
Would rather be quarantined somewhere else if you were required to wear a mask at all times	7	4	14	8
Very worried about infecting healthy family members if quarantined at home	42[b,c]	47[c]	54[c]	68

SOURCE: Harvard School of Public Health/TNS Survey in Four Regions, 18 November–16 December 2004.

[a] Significantly different from Hong Kong; $p \leq .05$.

[b] Significantly different from Singapore; $p \leq .05$.

[c] Significantly different from Taiwan; $p \leq .05$.

In the recent COVID-19 crisis, some literature have pointed to China's 'largest and most draconian quarantine in history', and Singapore's 'strict hospital and home quarantine regimen' and accompanying punitive actions, which have drawn praise from WHO and helped contained spread but may not be replicable in other cultures and parts of the world. Some concerns have also been raised about US's quarantine measures being excessive and infringing on individual liberties. [70] [71] [72] [73]

Guidelines

Taking into account the various influencing factors and considerations, WHO recently developed an interim guidance for quarantine of individuals in the context of COVID-19. The document covers issues such as appropriateness of quarantine facilities, necessary provision of necessities/information to quarantined individuals, minimum infection prevention/control and health monitoring measures, and minimum distance from household members for home quarantine etc. [74]

Detection/Contact Tracing

Detection facilitates accurate identification of infected and potentially infected persons, so as to promptly separate them from the non-exposed population. It also allows the government to monitor and assess the degree of transmissions taking place within national borders. Governments typically set out suspect case criteria (involving clinical symptoms, travel history, and close contact with previous confirmed cases) and referral protocols (management of qualifying cases) to which screening points and clinics nationwide can reference to and act on to refer cases for diagnostic testing (PCR, or preferably, serological, for COVID-19, if available). Such criteria are revised periodically according to new information about the virus and developments in its epidemic spread. [75] [76] Sometimes, governments may make a decision to outreach to a specific and particularly at risk population group. South Korea (Daegu), for example, is currently planning to diagnostically test all 200,000 members of the Shincheonji Church of Jesus linked to a COVID-19 cluster. [77] Governments may also have a sentinel surveillance system to test patients with respiratory symptoms from a selected network of primary care clinics as well as cases of pneumonia in acute hospitals to pick up signs of widespread community transmission of SARS-CoV-2, as with Singapore and Scotland currently. [78]

Detection capacity usually varies across countries depending on their suspect case criteria, timely revisions to it upon new developments, level of adherence by practitioners to national guidelines, and government approach.

Effectiveness Studies

Detection capacity. A study which sought to project the true number of imported COVID-19 cases outside of China noted discrepancies between various countries' reported cases and projected cases under the predictive model. The study also pointed out that actual imported cases reported in Singapore exceeded their projected number, indicating a higher case-detection capacity than assumed in the model. A local study also noted detection effectiveness in Singapore from the significant decline in the 7-day moving average of interval from symptom onset to isolation of the first 100 patients in Singapore, while experts have also pointed to the country's statistic of having 40% of its infections detected through contact tracing while still asymptomatic. Another study estimated that the global ability to detect imported COVID-19 cases as at Feb 2020 was at 38% of Singapore's capacity. Some studies indicated that an increase in flight volume by 14 passengers per day is associated with one additional imported case. [79] [80] [81] [69]

Two studies revealed that COVID-19 mortality rate was negatively associated with COVID-19 test rate, a likely result of its facilitation of early detection and treatment, and transmission via asymptomatic patients. [82] [83]

Testing/surveillance methods/strategies. Effectiveness studies have emerged on the efficacy of testing/surveillance methods and strategies.

Surveillance. A Beijing study found that with 1,600 tests per day, the probability that a surveillance strategy exclusively targeting fever clinic patients and healthcare workers can detect more than one COVID-19 case on a given day is 1.1% and 1.2% respectively, whereas the probability of detection is only 0.5% and 0.7% for respiratory department patients and healthcare workers respectively. The surveillance system can attain a 50% chance of detection among fever clinic patients 3 days earlier than among respiratory department patients, while patient-based surveillance in respiratory departments would require more than twice the daily testing capacity (i.e. 3,600 tests/day) to achieve the same results. It was also estimated that there will be 598 and 1373 cases in the population by the time the first COVID-19 case is detected at fever clinics and respiratory departments respectively. Surveillance strategies should prioritise testing among fever clinic patients and healthcare workers, which record the highest surveillance sensitivity. [84]

Multi-stage and pooled testing. In view of the shortage of SARS-CoV-2 test kits in many countries, a recent study proposed multi-stage group testing which could lead to a major reduction in number of kits required and improve large-scale population testing. In multi-stage group testing, samples are tested in groups of various pool sizes and over multiple stages (negative group samples are eliminated after a single test while positive group samples are split into smaller pool sizes before eventually performing individual tests).

It was found that three-stage testing schemes with pool sizes of 16 samples at maximum can test up to three and seven times as many individuals with the same number of test kits for prevalence rates of around 5% and 1%, respectively. Group testing is more efficient than individual testing for prevalence rates under 30%, and large pool sizes and more stages are preferable for lower prevalence rates, while small pool sizes and fewer stages are preferable for higher prevalence rates. Compared to two-stage testing, multi-stage schemes are more efficient than two-stage schemes for prevalence rates < 12%. [85]

There is evidence to support that pooled testing is possible with using even rapid automated molecular test. [86]

Screening test using raw saliva. A preprint study presents a community-deployable SARS-CoV-2 screening test using raw saliva (a rapid and simple-to-perform RT-LAMP assay for SARS-CoV-2 RNA detection). The test takes approximately 45 minutes from sample to answer and requires only simple equipment, like pipettes and a heating source. With its swift turnaround time, non-invasive nature, low-complexity and potential portability, and the comparative short supply of swab-based sampling kits, this saliva testing method can support real-time community screening, especially for asymptomatic populations. It can enable more frequent testing to be done in diverse settings such as factories, meat-packing plants, office buildings or schools, as well as on people who face the risk of transmission daily but who would not have the time or resources to undergo tests in a clinical environment. [87]

Multi-tiered screening and diagnosis strategy. While PCR is the gold standard for confirmatory diagnosis of SARS-CoV-2 infections, it can be ineffective due to poor early sensitivity, long turnaround time, reagent shortages and possibly aerosol generating risk in obtaining of samples. A study proposed a strategy of conducting a quick screening to differentiate viral and bacterial infection (10-minute fingerstick test to determine elevation of Myxovirus resistance protein A (MxA) protein and C-Reactive Protein (CRP) which has a 90% positive predictive value to confirm viral infection, and a 99% negative predictive value to exclude bacterial infection). Thereafter, IgM/IgG serology testing can be used to determine disease time course. Patients who are IgM/IgG positive would benefit from quarantine, while those tested IgM/IgG negative may need further testing or therapeutics if symptoms persist. [88]

Targeted testing of higher risk settings. A study evaluating the results of mass screening of residents and staff in long-term care facilities in Fulton Country (Georgia) revealed that a total of 1,085 (out of 5,672 screened) infected individuals were diagnosed with 18% requiring hospitalisation and 12% dying. The majority (97% and above) were from facilities that were screened in response to reported cases (versus those screened as a preventive measure). These “response” facilities had an infection prevalence of 28.9% while the “preventive’ facilities had a prevalence of 1.6%. Notwithstanding, 7 out of 13 “preventive” facilities had at least one resident tested positive and 4 of them had at least one infected staff. The study supports the role of active screening. [89]

A recent UK study comparing different strategies of testing key workers in terms of absence duration from work and transmission risk to others pointed out that the optimal testing strategy is context-specific and dependent on factors such as risk of workplace exposure, availability of testing capacity and resources, and transmission risk. The study recommends testing key workers in quarantine as the strategy had the largest reduction in absence days and minimal increase in transmission risk. Testing of all key workers can be carried out in the context of sufficient resources and high workplace transmission risk. [90]

Wastewater testing. A number of research groups worldwide (including Singapore and the Netherlands) have started using wastewater analysis as a method to detect SARS-CoV-2 in communities (see Table 3). Australia has also used piloted using SARS-CoV-2 RNA wastewater surveillance from airline and cruise ship sanitation systems in Australia. There is evidence supporting the potential use of wastewater surveillance in the monitoring for viruses during pandemics. Wastewater testing and clinical swab testing can be employed together to maximise detection and minimise false negatives. [91]

Environmental surface testing for case detection. A recent study evaluated the effectiveness of coronavirus environmental surface testing at work location and frequent clinical testing in detecting asymptomatic and symptomatic SARS-CoV-2 employees. Only several employees who volunteered to be clinically tested received positive results (none of them were symptomatic), and rate of positive surface detections was positively associated with infected employees while locations with no infected employees have very few positive surface detection. Common touch points tested positive for the virus were break room chair and door handle, workbench surface, equipment control panel, log book, door handles, and elevator buttons. Positive coronavirus environmental surface samples may be a predictive tool to inform the presence of SARS-CoV-2 positive employees. [92]

Contact tracing. Earlier modelling studies have shown that highly effective contact tracing and case isolation is enough to control a COVID-19 outbreak, with required levels of effectiveness of contact tracing - requiring 50% to 90% of contacts to be traced for ROs ranging from 1.5 to 3.5, or for all symptomatic individuals to be isolated within one day from symptom. [93] [17] These, however, did not take into account or account for significantly asymptomatic transmission.

With emerging evidence on asymptomatic transmission playing a significant role in epidemic spread, [94] [95] [96] [97] [98] [99] [100] [101] [102] more recent studies have indicated that that rapid diagnosis and isolation alone cannot control outbreaks of SARS-CoV-2 but can contribute to reducing the growth rate and doubling time of epidemics, buying time, spreading severe cases out over a longer period of time, potentially reducing the total infected cases, and reduce peak healthcare demand. One study showed that a high-quality, rapid contact tracing system with strong support systems can reduce Rt by at most 60%. Another found that the potential for containment will be seriously jeopardized when incubation period exceeds 4-6 days and when asymptomatic cases comprise more than 40% of infected cases. [103] [104] A more recent study pointed out that when 17.9% and 30.8% of infections are asymptomatic, 33% and 42% isolation of silent infections is needed to suppress the attack rate below 1%. There is therefore the need to combine isolation of symptomatic cases with rapid contact tracing to identify and isolate presymptomatic and asymptomatic individuals prior to their infectious period, and to complement such efforts with some accompanying level of moderate social distancing. [102] [104]

Time to quarantine. A study on Hong Kong found that a time to quarantine of half a day before symptom onset of an infected individual is able to reduce the Rt from 2.32 to 0.76, whereas a quarantine time of more than a day after symptom onset results in Rt of more than 1. Timing to quarantine also plays a role in determining detection efficiency. The model estimates that a 1-day delay and 6-day delay in quarantine reduces daily detection ratio from 71% to 60% and 31% respectively. [105]

Coupling with testing or random sampling. Some studies showed that contact tracing coupled with random sampling brought infection numbers down remarkably. Sampling based on population's geographical distribution and travel behaviour aids identification/isolation of infected individuals missed by the contact tracing process. A study also pointed out that testing efficacy can significantly affect contact tracing outcomes. Poor test sensitivity of 65% greatly undermines contact tracing effectiveness with the release of false negative cases from quarantine. Introducing a seven-day isolation for all individuals with negative results can lower the risk of a large outbreak from 27.2% to 15.3% when Rt is less than 1.5, and adding on a two-day delay in testing following exposure further reduced the risk to 13.1% under similar conditions. [106] [107] [108]

Digital contact tracing. As delay in isolation/contact tracing can cause the measures to be ineffective, studies have modelled the effectiveness of use of mobile phone applications to notify individuals of close contacts diagnosed with COVID- 19 and alert them to start self-isolation. Such instantaneous contact tracing assisted by a mobile phone application can be a solution to the interventions delay to more effectively contain COVID-19. [99] [109] [110] [111] (See also 'Mobile Positioning Data contact Tracing' in Table 3.)

Some studies found digital contact tracing to be insufficient, being dependent on mobile app adoption, people self-reporting, missing out on asymptomatic individuals, and both persons (infected and his/her close contact) being required to have the app installed. Most models projected an uptake of at least 60% to suppress the epidemic, and some involve other concurrent social distancing measures. [109] [110] [111] One model predicted that an app adoption of 60% and 80% translates to contact tracing efficiency of around 35% and 60% respectively. [109] Another report by the Oxford Big Data Institute estimated that the epidemic can be suppressed with 80% of smartphone users (56% of the population) using a contact tracing app, with certain assumptions held. [110] An Australian study projected that if uptake reaches a possible maximum of 61%, and with a monthly 50% reduction in social distancing (from lockdown scenarios) until pre-lockdown contact levels are resumed, and a 5% decline in testing, the projected number of new cases over a 9 month period could be reduced by more than half. [111]

Digital tracing should therefore be complemented by a traditional manual tracing policy as well as simultaneous additional measures such as randomised testing. Contact tracing and quarantine criteria focusing on long exposure (even for weak links) was found to outperform approaches that prioritised close-range contacts for shorter periods of time. Definition of what represents a high-risk contact can be fine-tuned accordingly.

Current contact tracing app uptake. On estimations of likely app uptake, a UK study on NHS Care Information Exchange users (Bachtiger et al) found that 60.3% of respondents were inclined to participate in a national app-based contact tracing programme. The study cited two other estimations: 53% in an online poll by Opinium which surveyed 2,002 participants in the UK and 73% in a non-representative poll of 730 Dutch participants. The app uptake in Australia is approximately 27% as at 20 May. [111] Studies have also cited privacy concerns as reasons for indicating reluctance (67.2% of those who indicated reluctance in Bachtiger et al, and 64.8% in a study on Dutch adults). Unwillingness to participate based on privacy was found to be inversely related to age. In the Dutch study, respondents were slightly more willing to use the application for symptom recognition/monitoring (45.3%) as compared to the one for contact tracing (41.2%). Fear of COVID-19 was a strong predictor of acceptance of these mobile applications. [112] [113] A study on uptake of COVIDSafe app in Australia cited concerns about technical limitations of their phone as a reason for inaction in downloading the app, apart from privacy concerns. [114]

Contact tracing criteria. In view of the substantial demands contact tracing places on public health authorities, a study reviews the implications of applying a less strict definition of ‘close contact’ for COVID-19 which can reduce the burden on contact tracing services. The UK currently defines a close contact as 15 minutes within 2 metres over two weeks before detection. The study, which utilises data on social encounters in the UK from a survey, found that stricter definitions shorter than 1 hour had relatively little impact on the mean number of untraced cases (remains at 2 for definitions 10 mins to 1 hour). Mean untraced cases and probability of at least one untraced case increase significantly after definitions are relaxed beyond 1 hour. [115]

Comparing methods. A study estimating the transmission reduction under different contact tracing/isolation methods found that combined testing and tracing strategies brought Rt down more than mass testing/self-isolation alone. Transmission reductions observed were:

a) 2% for random mass testing of 5% of population (assuming that infected individuals identified will immediately self-isolate).

b) 29% for self-isolation of symptomatic cases within the household.

c) 35% for self-isolation of symptomatic cases outside the household

d) 37% for self-isolation and household quarantine.

e) 64% for self-isolation and household quarantine, combined with manual contact tracing of all contacts.

f) 57% with the addition (to point e above) of manual tracing of acquaintances only without manual contact tracing.

g) 47% with addition (to point e above) of app-based tracing alone with 53% coverage. [108]

New Methods

Methods to enhance or improve the efficiency of detection and contact tracing have evolved amidst the COVID-19 outbreak. Most of these seek to relieve the workload of hospitals and public health services, while improving detection rate and operational efficiency. (See Table 3)

Table 3: New methods in detection for COVID-9

Project	Description
Home testing pilot launched to reduce unnecessary ambulance use and hospital visits in the detection process (London)	Potential cases referred from GPs, National Health Service’s (NHS) hotline or local emergency departments are triaged over the phone to ensure that they are well enough to remain at home and self-isolate. A healthcare professional with PPE training is then sent to their homes to perform the test within 24 hours of referral, after which those who are found to be infected are admitted to hospital Such a practice reduces the downtime for ambulances which can be out of service for up to eight hours for decontamination after carrying potential cases to hospital for testing. [116]

Project	Description
	Other NHS trusts have begun piloting the method. [117]
"Drive through" scheme to relieve pressure on hospital and ambulance services (London, Community Healthcare NHS trust; Edinburgh, Scotland, South Korea, Canada)	Patients referred by NHS 111 will be sent to the "drive thru" service, with pregnant women and those seriously ill excluded under its protocols. Nurses based at the centre will put on PPE before travelling outside to collect swabs from patients in their cars. There has been some concern that those unable to drive may end up having someone bring them to the centre, potentially putting another person at risk of infection. [117] A "drive through" testing centre has recently opened in Edinburg. [118] "Drive through' coronavirus testing facilities are also open to the public in South Korea. [119] On 21 Mar, Canada started its first drive-thru test centre in Winnipeg. [120] 68 of South Korea's testing centres adopted 'drive through' testing as of 12 March. These are located in less populated areas in preferably large parking lots with a process flow as illustrated in Figure 1. Features include: - All communication made by mobile phone except for specimen collection, with use of contactless thermometers and electronic payment systems. - Open tents of temporary buildings used for work booths. - PPE of inner and outer gloves, N95 respirator, eye–shield/face shield/goggles, and hooded coverall/gown required for HCWs with direct contact with testees. Additional disposable apron gown and gloves are changed for every testee with hand disinfection with 70% alcohol. - Nasopharyngeal and oropharyngeal swabs taken by HCWs at the specimen collection booth through opened car window. Car ventilation mode should be kept as internal circulation. - Sputum samples collected in the testees' cars by themselves with windows closed. Advantages and disadvantages: - 10 minutes per test (one-third shorter than conventional screening, which requires 30 mins for cleaning of specimen collection rooms) with 100 tests per day being able to be done. - Excludes risk of cross-contamination between testees - Possibility of specimen contamination by HCWs' PPE as HCWs do not change PPE for every testee. - Protection of HCWs from outdoor atmosphere during bad weather conditions - Dehydration from long working time wearing PPE

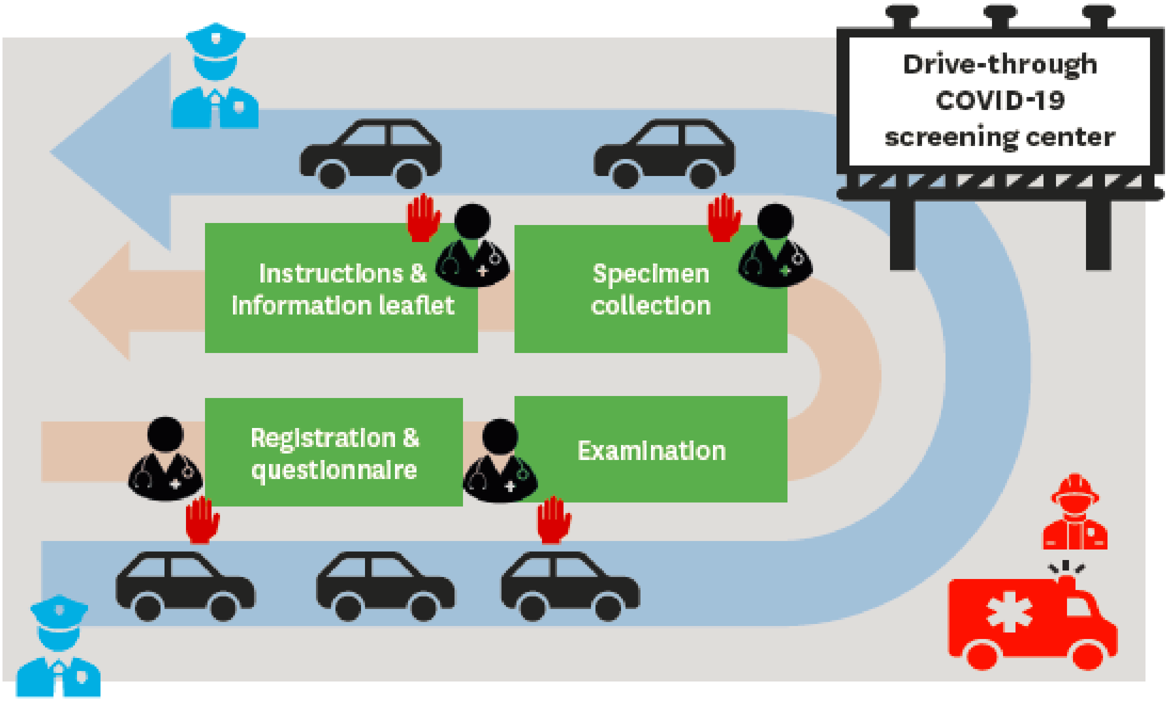
Project	Description
	- Limited prompt management of medically unstable testees with hospitals located some distance away. [121]
Activation of Public Health Preparedness Clinics (PHPCs)[7] with subsidised services to encourage patients with respiratory symptoms to come forward (Singapore)	Singapore's Ministry of Health has activated its network of 900 PHPCs to provide subsidised treatment, investigations and medications to patients with respiratory symptoms. The PHPCs do not conduct diagnostic tests but have been guided on the risk assessment protocols for referrals to hospitals for diagnosis. PHPCs have noticed an increase in patients with respiratory symptoms and it is hoped that the move will cast the detection net wider and improve its rate and accuracy. [122] [123]
Verifying case claims in contact tracing. (South Korea)	Use of the following information collection methods to verify case claims in contact tracing by the COVID-10 National Emergency Response Center of KCDC: - medical facility records to identify clinical symptoms, date of symptom onset, and specify facilities visited - Global Positioning System and credit card transactions to identify route and location of case and verify case claims - CCTV to identify case symptoms and evaluate explore risks of contacts. [124] [125]
Leveraging on the National Health Insurance system to aid case identification. (Taiwan)	Taiwan leveraged its NHI database to quickly mobilise case identification. It integrated the database with its migration/customs database, which facilitated the generation of real-time alerts during clinical visits based on travel history and clinical symptoms to aid case identification. The database integration was accomplished in one day. [37] [126]
Chang and Chiu (Taiwan)	Taiwan's effectiveness in surveillance, detection, quarantine and isolation is in part due to its tiered primary healthcare model: - **Tier 1: Walk-in clinics** provide general care including for chronic diseases and mental health. Clinics are equipped with standard protection and general diagnostic equipment. - **Tier 2: Community Healthcare Groups Prepared Clinics** (CHGPC) accepts patients from walk-in clinics with upper respiratory symptoms, fever and possible COVID-19 cases. Government provides these clinics with protective equipment and subsidies to recruit more CHGPCs as they are the first responders to public health emergencies. - **Tier 3: Community screening stations** (CSS) are equipped with x rays, testing and quarantine facilities. They

[7] A network of private primary care clinics assigned the responsibility to perform roles (such as dispensing medications, administering vaccinations etc) during public health emergencies.

Project	Description
	- take in suspected COVID-19 cases from CHGPC and can treat mild cases. - **Tier 4: Medical centers**/ Designated hospitals treat serious cases referred by CSS. 90% of Taiwan's clinics participate in National Health Insurance, allowing for rapid response via education, diagnosis, isolation and referrals. Through this tiered model, COVID-19 management will ideally not be at the expense of other acute and chronic care functions. [127]
Virology surveillance system (UK, Singapore)	The Royal College of General Practitioners Research and Surveillance Centre and Public Health England had worked together for years on the surveillance of Influenza and other infectious diseases. They established a virology surveillance system with the help of 100 General Practices (GPs) to monitor the effectiveness of the containment strategies on COVID-19. GPs assisted in the collection of nasopharyngeal swabs and blood for COVID- 19 and a coding system was established to stratify patients' risks and identify COVID-19 spread areas. The virology surveillance system had managed to detect 2 COVID- 19 cases in low risks patients with no travel history. The system could be extended to monitor the temporal and geographical distribution of COVID-19 infection in the community as well as measure containment strategies and pre-empt any potential outbreak. Singapore has a similar surveillance system involving selected clinics from its network of 900 PHPCs. [128]
Cloud-Based System for Effective Surveillance and Control (Hubei, China)	Use of the Honghu Hybrid System by hospitals in the city of Honghu to carry out syndromic surveillance and to follow up on potential COVID-19 cases. Data is inputted by residents via WeChat questionnaires (on symptoms and contact history) and from hospitals' electronic medical record and labs. Data was also used to monitor the disease trends, evaluate the effectiveness of disease management, and identify high risk clusters that warrant home visits. The hospital and labs data were also used to predict mortality based on a scoring system so as to prioritise limited medical resources and improve clinical care. The system also allowed for follow up of discharged patients, requiring them to report their symptoms daily for 2 months post discharge. Such a system's success requires the deep involvement of multiple stakeholders including healthcare institutes, social media companies and the government. [129]
Mobile Positioning Data Contact Tracing (China, South Korea, other countries looking	Similar to South Korea and China, Nigeria is looking into using location data from telecommunication providers to trace a positively tested individual's historical movement and notify its close contacts via interactive voice response technology. However, proximity accuracy of 50-300 meters is far greater than the 2m definition for

Project	Description
into/scaling up on this)	contacts and the method has to be complemented with other strategies. [130]
Use of natural language processing (NLP) and artificial intelligence (AI) based methods (US, South Carolina)	NLP and AI methods were used with unstructured patient data collected through telehealth visits at the Medical University of South Carolina Health system. Text analytics revealed that concepts such as “smell” and “taste” were more prevalent than expected in patients testing positive and screening algorithms were adapted to include these symptoms. The model which improved predicting positive results was applied to prioritise testing appointment scheduling. The model categorised patients into High, Medium and Low risk categories, with High and Low risk categories having positive rates of 60.84% and 2.6% respectively, comparing against the overall positive rate of 5.6% and showing the acceptable accuracy of the model. [131]
Wastewater testing (research groups/pilots worldwide, including the Netherlands, Singapore)	A number of research groups worldwide have started using wastewater analysis as a method to detect SARS-CoV-2 in communities. Testing wastewater is one way to track if the virus is excreted in urine or faeces. Singapore has been sampling wastewater from water reclamation plants and migrant worker dormitories (where major outbreaks have been detected). This facilitated a more targeted swabbing strategy in the testing of migrant workers in worker dormitories in Singapore. It can also provide surveillance information on communities, allowing monitoring of large groups, and subsequent clinical testing for specific communities with positive signals from their wastewater. [132] [133] [134]

Figure 1: Illustration of DT COVID-19 screening center provided for the public.



Release (After Treatment/Quarantine)

Evidence-based Consensus and General Practice

Quarantine period should be based on incubation of the ID virus. Incubation period for COVID-19 typically range from 3 to 6.4 days, but could potentially extend up to 13 or 24 days. [59] [60] [61] [135] WHO's interim guidance on individual quarantine for COVID-19 recommends a period of 14 days from the last time the individual was exposed to a COVID-19 patient. [74]

Isolation. The general rule for duration of isolation precautions for hospitalised patients with acute respiratory tract infections is that isolation for such patients should be continued for 24 hours after resolution of fever and respiratory symptoms. [136] With COVID-19, some variation is noted across countries on the discharge criteria for isolated patients. Canada, for example, discharged a patient upon resolution of fever, with subsequent full recovery under home isolation discontinued following two negative swab tests. [137] For others, such as the UK, China and Singapore, isolation precaution practice includes repeated tests for Sars-CoV-2 on patients confirmed to have COVID-19 infection to show viral clearance before hospital discharge. [138] [139] [140]

Several instances of patients who tested positive after discharge or recovery from COVID-19 raised concerns on possible risk of virus transmission after discharge. [141] [142] [143] [144] [145] This risk was considered by China and additional precautions after discharge were added to China's latest Diagnosis and Treatment Guidelines for COVID-19 – health monitoring and medical observation with home quarantine required for another 14 days after discharge. The authorities in Wuhan recently introduced 14 days' mandatory quarantine for recovered patients. Studies have also recommended that discharged patients should be tested for viral nucleic acid again after two weeks of isolation, or have a throat swab test for SARS-CoV-2 every day or every other day, for at least five times. [142] [145] (See COVID-19 Science Report: Clinical Characteristics for information on prolonged viral shedding.) More recent evidence has pointed out that the risk of secondary transmission of COVID-19 is unlikely by Day 14 of onset of illness (even though PCR tests may be positive, the virus is no longer viable). Various countries such as South Korea, the UK, the US, and Ireland, and more recently, the WHO, have also adopted or recommended a time-based discharge criterion rather than a test-based one. In Singapore, MOH revised (wef 29 May) the discharge criteria to a time-based one where COVID-19 patients assessed to be clinically well by Day 21 of onset of illness can be discharged from isolation without the need for further PCR tests. They will be given leave to remain at home for a further 7 days after that. [146] [147] [148]

A study (virological assessment of nine hospitalized cases in Germany) pointed out that in a situation characterised by limited capacity of hospital beds, early discharge with ensuing home isolation could be considered for patients beyond day 10 of symptoms with less than 100,000 viral RNA copies per ml of sputum. Both criteria predict that there is little residual risk of infectivity, based on cell culture. [149] Another study highlighted the urgent need to develop evidence-based risk stratification of COVID-19 patients to determine those best managed at home rather than in hospital. [137] Other studies have pointed out that clinical characteristics and outcomes of patients with mild COVID-19 infection had a stable disease course and recommend that these cases be managed outside of hospital setting to optimise utilisation of healthcare facilities and resources. [150]

Alignment to national guidelines. It is important to note that in terms of isolation discharge criteria, and diagnostic criteria[8] as well, healthcare facilities should align with MOH guidelines. A stricter approach than what is proposed by national guidelines can undermine the national position, change the pick-up specificity, and create a culture of mistrust in MOH's information sharing.

Flexibility built into operational processes/design and IT systems should be considered as well. For example, in terms of IT, backend reprogramming should not be required each time an adjustment is made in the criteria.

Hospital Infection Control and Protection of Healthcare Personnel

Active measures to identify and separate infected persons and potentially infected persons should accompany infection control and preparedness measures within healthcare facilities, which are central to the effective treatment of cases and highly susceptible to nosocomial outbreaks in an epidemic situation. The experience of SARS was marked by numerous nosocomial outbreaks reported in affected countries. One of such cases, coupled with late detection of the outbreak, led to the closing down of an entire hospital's operations in Singapore, further straining healthcare capacity at a critical period. Similarly, with COVID-19, a large number of healthcare workers (HCWs) have been reported to be infected in China, with a study on 138 hospitalised patients pointing out that 29% were HCWs. [151] [152] [153] [154] A cross sectional study of 2,457 infected HCWs in Wuhan found that case infection rate was higher for nurses than doctors (2.22% versus 1.52%), for generalised hospitals than specialised and community hospitals (89.26% versus 5.70% and 5.05%), and for HCWs than non-HCW workers (2.10% versus 0.43%). [155]

Existing Guidelines, Recommendations and Best Practices

General and more specific guidelines on hospital infection control (IC) and protection of healthcare personnel have been made available by expert committees and international health or disease surveillance organisations, such as the National Infection Prevention and Control Guidelines for Acute Healthcare Facilities by the National Infection Prevention and Control Committee, Guidelines on Core Components of Infection Prevention and Control Programmes at the National and Acute Health Care Facility Level and Handbook on Managing Epidemics by WHO, and Guideline for Isolation Precautions by the CDC.

More recently, WHO has developed and interim guidance on Infection prevention and control during health care in relation to COVID-19. [156] CDC has also developed an Interim Infection Prevention and Control Recommendations for hospitals on COVID-19. [157] Johns Hopkins Bloomberg School of Public Health's (JHSPH) Center for Health Security has also published recommendations on what US hospitals and other healthcare facilities can do in terms of infection control and capacity preparedness for the COVID-19 pandemic. [158] Zhejiang University School of Medicine has also come up with a Handbook of COVID-19 Prevention and Treatment, compiled according to clinical experience, which includes infection control measures such as isolation area management practices and personal protection management. [159]

These guidelines/guidance documents address measures across the different levels and layers of control via healthcare personnel education/training and compliance, ongoing surveillance mechanisms within hospitals (for detecting healthcare-associated infections), hospital environment measures (eg frequent cleaning and disinfecting of surfaces, spatial

[8] For a more detailed understanding of diagnostic test criteria, one can refer to the COVID-19 Science Report: Diagnostics by Saw Swee Hock School of Public Health, NUS. Available at: https://sph.nus.edu.sg/covid-19/research/

planning with triage areas and segregation of patient types) and procurement/manpower/bed capacity planning preparations (eg need for activation of licensed bed capacity upon short notice, and need for additional cleaning staff/materials, PPE etc). Healthcare personnel precautions include standard infection prevention control behaviours in care of all patients (such as hand hygiene, cough etiquette, use of PPE) to additional transmission-based precautions (eg prevention of needle stick/sharp injury prevention and blood/body fluid exposure, droplet and airborne precautions, and proper handling of textiles and laundry) and use of personal protective equipment (PPE). [160] [161] [162] [22] [163] [164] [157] [158] [165] In terms of capacity preparedness, and using a spreadsheet based model from the CDC, JHSPH Center for Health Security projected the need for 30% of licensed bed capacity for COVID-19 patients on one week's notice for US hospitals. [158]

Specific to practices. Academic literature has emerged with IC precautionary measures for COVID-19 specific to particular practices, such as dental practice and ophthalmology.

<u>Ophthalmology.</u> In view of evidence on possible risk of infection through conjunctival secretions and tears from patients, the American Academy of Ophthalmologists and the UK's Royal College of Ophthalmologists recommend generic measures to protect ophthalmologists from infection, including thorough disinfection practices, protective plastic slit-lamp breath shields, limiting time spent at slit lamp, and avoidance of certain procedures. [166] [167] [168] A case study on Hong Kong's experience shared on the various levels of control measures adopted in an ophthalmology clinic in a hospital. It pointed out the heightened risk of cross-infection between patients and HCWs in ophthalmology clinics. The measures adopted were based on risk assessment by local ophthalmologists and infection control experts and include reducing outpatient attendances, triage stations, suspension/avoidance of certain procedures and PPE protocols (see Table 4 for details). [169]

<u>Dental practice.</u> Similarly, participants in dental practice are more susceptible to risk of COVID-19 infection due to its procedures involving face-to-face communication, frequent exposure to saliva and other body fluids, and handling of sharp instruments. Airborne spread of SARS-CoV-2 in dental settings is also a concern as it is hard to avoid the generation of large amounts of aerosol and droplet mixed with patient's saliva/blood during dental practice. Salivary glands also act as a reservoir for COVID-19 asymptomatic infection due to large presence of aCE-2 receptors. A number of review articles recommended several infection control measures and management protocols in dental practice, including:

- Establish precheck triages on patient symptoms and travel/contact history (an Italian workflow management triaged patients remotely via phone/text/website before their visits)
- Postponement of nonemergency dental practices in areas of COVID-19 outbreaks
- Use of preoperative antimicrobial mouth rinse
- Avoidance of coughing inducing procedures (eg intraoral x-ray) or aerosol-generating procedures (eg 3-way syringe) where possible. Extraoral dental radiographies can be used as alternatives instead.
- Use of rubber dams, anti-retraction handpieces, 4-handed technique, and saliva ejectors
- Use of absorbable suture, and rinsing wound slowly with use of saliva ejector
- Strict disinfection measures in clinic settings (thorough disinfection of all surfaces, good hand hygiene etc)

- Risk-stratified PPE usage (including face shields and goggles) for staff, dental professionals and when in contact with patient suspected/confirmed with COVID-19 infection.
- Staff members should only treat one patient at a time.
- Scheduling patients with higher transmissibility risk procedures as last patient in the day.
- Proper sanitization and ventilation of operating rooms with surgeries equipment protected with disposable films, especially in those with aerosol-generating procedures.
- In life-threatening oral and maxillofacial compound injuries, chest CT is done to rapidly diagnose for COVID-19 and environmental disinfection done after treatment. [170] [171] [172] [173]

One of the review articles was partly based on IC measures practiced in The School and Hospital of Stomatology, Wuhan University, which treated >700 patients and involved 169 staff since 24 Jan despite the outbreak situation in Wuhan. No COVID-19 infection was reported among the hospital's staff, substantiating the effectiveness of the IC measures taken. [171] One review focused mainly on recommendations on the use of masks and PPE for dentists in the prevention of COVID-19. [174]

Anaesthetists, operating rooms and emergency HCWs. A case study on outbreak response measures of an anesthetic department in an academic tertiary level acute care hospital in Singapore also pointed to the susceptibility of staff in anesthetic departments, whose routine work involves aerosol-generating procedures, and the challenges of IC in the operating room (OR), where preparations involve multiple stakeholders. The case study describes the range of measures taken, their implementation in relevant contextual phases, and corresponding levels of effectiveness (see Table 4 for details of some of the measures taken).

Other articles, mostly supported by or based on recommendations from the Anesthesia Patient Safety Foundation, describe recommended steps for perioperative infection control amidst the COVID-19 situation. Some of the steps are based on empirical evidence characterising the epidemiology of perioperative transmission and infection development. Recommended steps include measures related to IC in operating room management (such as environmental cleaning with UV-C for 20-30 mins for high risk work areas, patient decolonisation and vascular care steps, use of precautionary equipment during patient transfers, and equipment management after endotracheal intubation). It also includes steps on management protocols regarding suspected cases, and on optimising staff or case assignments in situations of PPE shortage (such as longer shift hours, dedicating > 1 room for anesthesia so that anesthesia/nursing teams can work in on thorough/deep cleaning in between cases, recovery of patients in the same rooms). [175] [176] [177]

It also pointed out that HCWs in the emergency department were easily exposed to infection risks before appropriate PPE usage. Early recognition of suspected patients, early preparation, and strict adherence to protocols on management of suspected patients at all times are crucial. [178] Guidelines/recommendations have also emerged on surgical practice with higher transmission risk, such as head and neck surgical oncology practice. [179]

Radiology. Two articles highlighted challenges faced by radiology teams in their institutions during the COVID-19 outbreak and steps taken by the team to ensure business continuity and patient safety (see Table 4).

Another provided evidence-based measures to protect healthcare workers from COVID-19 transmission for Interventional Radiology. Measures include:

- Limiting patient cases, segregating patients, maximal barrier and designated disposal for COVID- 19 patients.
- Level 1 procedures such as punctures, aspiration and biopsy should be conducted in an isolated radio diagnostic room.
- Level 2 and 3 procedures such as angiography, drainage and neurointervention should be conducted in an isolated environment compatible to ISO 7 level performance.
- Airborne Infection Isolation Room (AIIR), respirators and face masks should be used for confirmed COVID-19 patients and procedures that are likely to induce cough.
- Disinfection should be done 4 times a day such as before and after each team's use. Ideally, there should be 2-unit teams for 1 site for work continuity purposes. [180]

Others. A systematic review was done to provide recommendations for PPE in **orthopaedic.** It was found that high speed cutters used in surgery can create an area of up to 3-8m of spray around the operating field, resulting in contamination to everyone's face and body and production of aerosol particles of body fluids and pieces of body tissue <5µm. With COVID-19 known to be present in all body fluids, the recommended PPE for orthopaedic surgeons include level 4 surgical gowns; N95-99 respirator masks; face shields or goggles; and double gloves with frequent outer glove renewal to reduce risk of glove perforation and blood exposure. An alternative to mask and face shield/goggles is a powered air-purifying respirator especially in poor fit of respirator masks or in long procedures. Telemedicine can also be explored. [181]

Another review listed out recommendations on aerosol generating medical procedures in **otolaryngological procedures** during the COVID- 19 pandemic. The upper and lower airways have the highest SARS CoV-2 viral load and nasal and oropharyngeal cavities are high viral shedding areas. Surgical procedures such as CO2 laser vaporisation, electrocautery or high speed powered rotating instruments and endotracheal procedures were considered to be aerosol generating medical procedures. Healthcare workers should also be cautioned of small aerosols from sneezing and coughing induced by nasal endoscopy, epistaxis management and in-office sinonasal procedures. Level 3 PPE such as Powered Air Purifying Respirators or N99 or FFP3 respirators should be used in suspected COVID- 19 patients. [182]

Review was also done on possible COVID-19 transmission **during Minimally Invasive Surgery (MIS)** such as laparoscopy and laser procedures. Concerns over the unknown risk of presence COVID- 19 in CO2 plume from MIS was surfaced. Cautionary measures should be taken to protect HCWs: 1) testing of patients prior to surgery, 2) limit cautery plume creation and CO2 release, 3) full PPE, 4) negative pressure operating room and CO2 filtering with the smallest filter, 5) minimum operating staff deployment and 6) consideration of Rapid Sequence Intubation. [183]

A review also pointed to precautions in **autopsy practice**. It is known that viruses such as HIV can persist in cadavers for up to 16.5 days after death, even though the risk of exposure is highest a few hours after death and decreases over time. Organisations carrying out autopsy should create dedicated COVID-19 paths with insulated ventilation systems and Biosafety level 3 autopsy rooms dedicated only to COVID-19 cadavers. A 5 phase autopsy protocol was proposed, involving steps such as risk assessment (testing of cadavers with suspected COVID-19), cadaver storage (1-time use body bags, specific cold rooms etc), and samples collection and preservation (limited use of oscillating saws, formaldehyde fixation for certain specimens etc). [184]

HCW rights and roles. In view of HCWs' critical role in the response to the COVID-19 outbreak, WHO has also developed a guidance document on their rights, roles and responsibilities, including key considerations for occupational safety and health [165], and a risk communication package (toolkit) for healthcare facilities simplifying IC measures into a series of key messages and reminders for HCWs with illustrations for sharing/posting as appropriate. The messages/reminders are based on WHO's more in-depth technical guidance on IC in healthcare facilities. [185]

Amidst the COVID-19 pandemic, the UK government's suggestion that retired NHS staff may be activated to supplement patient care in the situation of escalating COVID-19 cases placed HCWs' right and choice to remove themselves from an unsafe situation at the core of its contingency plan. The majority of 120 former NHS employees who responded to a newspaper survey were resistant to the idea. While doctors' freedom of choice is protected in international law, arguments can be made that it represents abdication of duty. The concept of an unsafe situation is also debateable and subject to whether such situations are viewed as inherent to the occupation of HCWs. Earlier surveys have shown that 28% of German healthcare professionals agreed that it would be "professionally acceptable" for HCWs to abandon their workplace to protect themselves and their families during a flu pandemic). In the UK, 37.9% of survey respondents agreed that HCWs should be able to refuse to work with infected patients during a flu epidemic. [186] [187]

Notwithstanding, with reference to UK's case, some experts have pointed out that the advanced age of retired doctors and their heightened susceptibility to the illness makes the plan ethically problematic. [187]

HCW stress and job satisfaction. A recent academic commentary highlighted that pressure on the global healthcare workforce will intensify with COVID-19 developments and the need for transparent and thoughtful communication with them to build trust and a sense of control in them. Topics to be addressed and measures taken include:

- Redeployment of HCWs with conditions that elevate risk of severe infection/death from the highest risk sites. New sites for consideration can include telemedicine services, patient advice lines, and telephone triage services.
- Alleviation of HCW's concern about heightened risk of infection by their family members. This could be done through priority testing/vaccination/treatment for HCW family members and support in protective planning for the homes.
- Ensuring HCWs get adequate rest and are able to tend to critical personal needs – provision of food, rest breaks, decompression time, adequate time off, PPE etc. [188]

A study conducted on COVID-19 infected HCWs in a Wuhan hospital on perceived transmission routes and psychosocial changes found that 84.5% believed they were infected in the hospital working environment, with swabbing and physical examination perceived as the most common or likely transmission method by nurses and doctors. A sizeable proportion (41%) of HCWs perceived problems with PPE as the cause of infection. 88.3 % of HCWs experienced psychological stress and emotional changes during isolation. [189]

Another cross-sectional survey on 2,707 HCWs revealed that 51% reported burnout, with various reasons including work impacting household activities, feeling pushed beyond training, COVID- 19 patient exposure and having to make life prioritisation decisions. It was noted that PPE was protective against burnout. The study also pointed out that HCWs should be well supported to ensure good healthcare quality during the pandemic. [190]

A survey conducted to assess HCW's job satisfaction levels during the COVID-19 pandemic season found a negative correlation between office work days and job and life satisfaction for younger workers, and a positive correlation between the same variables among older workers. Office days predicted turnover intention among younger workers as well. Other factors such as job deployment and daily exercise hours are also associated with life satisfaction. Healthcare organisations can focus their efforts on younger workers working many days each week and older workers with very few work days. Notwithstanding, the study qualified that HCW's job and satisfaction levels may differ across countries and healthcare systems. [191]

Research/Evidence on Measures' Effectiveness

The more recent outbreaks of SARS, MERS-CoV, and H1N1 have prompted some studies evaluating the effectiveness of hospital infection control measures in outbreak situations. The experience of SARS, marked by numerous nosocomial outbreaks reported in Singapore and other affected countries, also prompted several case studies sharing key takeaways and useful experiences on hospital infection control. Increasingly, observational studies and case studies from the evolving COVID-19 situation are also being shared.

Cost-effectiveness. A cost-effectiveness analysis was conducted on different levels of hospital IC response in simulated outbreak scenarios of Pandemic (H1N1), SARS and the Spanish influenza. The study found that protection measures targeting only infected patients yielded the lowest incremental cost per death averted of US$23,000 for the simulated outbreak scenario of the Pandemic (H1N1) 2009 disease. Enforced protection in high-risk areas and full protection throughout the hospital averted deaths but came at an incremental cost of up to US$2.5 million per death averted. Better cost-effectiveness was noted for more stringent measures for SARS and the Spanish influenza scenarios. High case-fatality rates, virulence, and high proportion of atypical manifestations impacted cost-effectiveness the most. Notwithstanding, the study pointed to the unquantifiable psychological impact of secondary transmission to and fatality of HCWs and how draconian approaches seeking to ensure the protection of all HCWs can provide intangible gains that exceed the economic costs involved. [160]

A recent study measured the net cost savings and increment cost benefit ratio of 4 clinical best care practices (hand hygiene, hygiene and sanitation of surfaces and equipment, admission screening, additional precautions) when used against 4 pathogens (CDAD, MRSA, VRE, and CR-GNB) in medical and surgical units in Canadian hospitals [192]:

Infection Control Practices	**Annual savings ($CAD)**	**Amount saved for every dollar invested ($CAD)**
A MRSA hand hygiene campaign	1.2 - 2.5 million	> 9.3 saved for every dollar invested
MRSA screening	870,000 - 1.7 million	> 2.9 saved for every dollar invested
MRSA contact precautions	At least 42,000 and > 564,000 if precautions only include the use of gloves	Not available

A MRSA prevention and control programme (screening with a nasal swab, additional contact isolation precautions, basic precautions with gloves and gowns, eradication treatment, nasal mupirocin and chlorhexidine body wash)	More than 252,000 - 369,000	> 2.5 saved for every dollar invested
A MRSA search and destroy intervention(screening, additional isolation precautions, basic precautions with gowns, gloves and masks, and cleaning and sanitation)	More than 891,000 - 1.6 million	4.1 saved for every dollar invested
A VRE prevention and control programme(screening, basic precautions with gloves and gowns, patient education by nurses, and antimicrobial control using nurse monitoring)	More than 527 000 - 1.6 million	6.7 saved for every dollar invested

IC preparedness. A descriptive study described the bundle approach of IC preparedness adopted by public Hong Kong hospitals in the first 42 days of the outbreak from Wuhan (from official announcement of a cluster of pneumonia of unknown etiology in Wuhan). The approach involved active and enhanced laboratory surveillance, early airborne infection isolation, rapid molecular diagnostic testing (with a turnaround time of 4 to 8 hours during the initial phase of preparedness) and contact tracing (followed by 14-day quarantine and then 14-day medical surveillance) for HCWs with unprotected exposure in the hospitals. Early preparedness involved, in particular, inclusion of a patient who had visited a hospital in mainland China under epidemiological criterion for surveillance on day 17 even though SARS-CoV-2 was still confined to Wuhan until day 20. A total of 1,275 patients fulfilled the epidemiological criteria upon presentation at public hospitals over the 42 days, of which 42 (3.3%) were confirmed as cases of SARS-CoV-2 in the country; and with all the preparedness measures, no nosocomial transmission of SARS-CoV-2 has been reported since importation of the country’s first confirmed case in day 22. The study observed that early and appropriate hospital IC and surveillance measures could prevent nosocomial transmission of SARS-CoV-2. [193]

HCW protection IC practices. Another descriptive study provided evidence of effective IC practices against MERS-CoV transmission to HCWs in a healthcare facility. All identified contacts who were exposed to a MERS patient and had 100% compliance to a list of infection control measures during their entire working period were tested negative for MERS. Their list of IC measures was hand hygiene, using N95 respirator, performing respirator fit test, wearing gown, gloves, eye protection, and cap. [194] Another study suggested that a significant fall in symptomatic and asymptomatic SARS-CoV-2 infection among HCWs and absence of nosocomial transmission in a hospital in Cambridge, UK, reflects the combined efficacy of HCW testing, stringent infection prevention and control measures, and social distancing among the HCWs. [195]

A study looking into environmental contamination by SARS-CoV-2 in a designated hospital took air and environmental samples from the “medical zone” (including the patient room and nurses’ station) “living quarters” (including offices, restrooms and PPE buffer rooms). None of the air samples tested positive but 38 out of 200 environmental samples tested positive, with 2 form “living quarters” and the rest from “medical zone”. Beepers, water machine buttons, elevator buttons, computer mouses, and telephones were the top 5 positive samples from the “medical zone”. A more recent study investigating SARS-CoV-2 surface and air contamination in a hospital in London detected viral RNA on 52.3% of surfaces and 38.7% of air samples. These include >80% of samples from computer keyboards/mouse, alcohol gel dispensers, chairs, and >50% from toilet seats, sink taps and bedrails. Detection of SARS-CoV-2 in air and surface samples was also more likely in areas occupied by COVID-19 patients (63.8%) than other areas (45.3%). All samples had a high Ct value >30, suggesting the virus is not culturable, possibly due to low RNA levels or extended length of time since deposition. [196] Notwithstanding this, the wide contamination of COVID-19 shows the importance of PPEs in patient care, especially when handling high touch surfaces. [197]

Similarly, in another study, a DNA oligonucleotide surrogate for contaminated bodily fluid based on the Cauliflower Mosaic Virus was inoculated into a bed rail in an isolation room. Swabs were taken from 44 sites including the bed space environment and from outside the isolation room. The virus transferred to 41% of all surfaces in the ward within 24 hours and peaked at 52% on Day 3. The virus also persisted throughout the 5-day sampling period. This implies a combination of poor cleaning, patients and carers not adhering to hand hygiene protocols and re-inoculation of surrogate DNA following patient movement. Hand hygiene protocols and effective surface cleaning are especially crucial. [198]

Compliance. Staff perception of control measures were associated with compliance. A survey study of medical staff near the onset of SARS outbreak found that perception of an IC measure’s effectiveness was positively linked to its reported compliance. Concern of SARS as a public health threat rather than perceived effectiveness of IC measures appears to have a greater impact on compliance. [199]

A study identifying the barriers and facilitators to HCW’s adherence to infection prevention and control guidelines for respiratory infectious diseases noted the following:

- Organisational factors: Supportive behaviours facilitate a safety climate while unrealistic workloads are barriers to adherence. Communication of guidelines which are concise, consistent and coming from a single source, and mandatory training and education also facilitate adherence.
- Environmental factors: Insufficient space and facilities (eg isolation rooms, shower and handwashing facilities et) are barriers to achieving adherence. Lack of sufficient supplies (eg surface decontaminants, PPE etc) are other barriers.
- Individual factors: Individual’s low risk perception and inaccurate opinions about transmission or PPE effectiveness, perceived duty of care to patients’ emotional and medical well-being, and discomfort of wearing PPE are barriers to adherence. Workplace culture can be a barrier or facilitator due to peer pressure. [200]

Another cross sectional online global survey conducted on 533 responders to analyse sickness presenteeism and behaviours of HCWs and non HCWs when experiencing influenza like illness (ILI) found that 58.5% of responders would continue to work when sick. 26.9% of HCWs and 16.2% of non-HCWs would work with fever alone, while a large majority (89.2–99.2% of HCWs and 80%-96.5% of non-HCWs) would work with “minor” ILI symptoms such as sore throat, sinus cold, sneezing, mild cough, reduced appetite or fatigue. Common reasons include perception of not being infectious, lack of understanding in severe and mild ILI symptoms, sense of obligation, logistics and cultural factors. Such behaviour is worrisome as it could compromise quality of care and the safety of patients and other HCWs. [201]

Other learnings. Academic literature have also shared some key takeaways and useful IC and capacity planning methods amidst constraints faced during epidemics, mostly from the SARS experience and the COVID-19 experience (see Table 4).

Table 4: Key lessons and shared experiences in academic literature

Country / Region	Key Takeaway/Shared Experience on Effective Method
Non-country specific	Early detection was crucial in containment of the transmission, with early detection defined as detection within one incubation period and no evidence of secondary transmission on careful contact tracing.
Singapore	Another key factor was complete assessment of movements and follow-ups of patients, healthcare workers, and visitors who were contacts.
	A hospital preparedness plan should have, minimally, the following 3 components: (1) Use of PPE and early isolation of cases, (2) Early detection of cluster through surveillance of febrile HCWs or patients, and (3) An established and tested system to rapidly generate a complete list of potentially affected HCWs, patients and visitor contacts. [152]
Hong Kong	Active surveillance of patients with community or nosocomial acquired pneumonia was also conducted in general wards to identify and isolate any unrecognized cases. Standard, contact, and droplet precautions were enforced in all clinical areas in the hospital. [202] [203]
	Risk-stratified IC measures were proposed in acute pediatric wards. Clinical areas were stratified into ultrahigh-, high- and moderate-risk areas, according to different risk levels of nosocomial SARS transmission and the implementation of different levels of IC precautions. There was no nosocomial transmission of SARS in the pediatric service. [202] [204]
	In a hospital in Hong Kong, when the demand for PPE was high in an outbreak setting in a hospital in Hong Kong, the provision of PPE to healthcare workers was stratified according to the risk of exposure to SARS patients. [205]
Taiwan	An integrated IC approach was implemented at a SARS designated hospital where airborne infection isolation rooms were not available. Fever screening stations, triage of fever patients, separating SARS patients from other patients, separation of entrances and passageways between patients and healthcare workers, and increase of hand-washing facilities all demonstrated a protective effect for healthcare workers. [202]
	Construction of standard negative-pressure isolation rooms was expedited in a hospital in Kaoshiung, and the emergency room moved outside the hospital complex for patient triage. [202]
Toronto	In addition to droplet and contact precautions and caring for SARS patients in airborne infection isolation ward, healthcare workers wore double gloves, double gowns, goggles, cap and shoe covers in the isolation ward, intensive care unit and emergency room [206]

Country / Region	Key Takeaway/Shared Experience on Effective Method
Non-country specific	Responses to nosocomial outbreaks included temporary closure of wards, outpatient clinics, inpatient admission, and both inpatient and outpatient services. Home quarantine of healthcare workers with SARS contact was also mandated in some centers. The median time between admission of index patients and closure of hospital services was 18.5 days (range, 3–21 days), whereas the median time between admission of index patients and termination of nosocomial outbreaks of SARS was 30 days (range, 17–40 days) [202] [152] [207] [208] [209]
Guangdong (COVID-19)	Setting up a real-time monitoring system with cameras covering negative pressure isolation wards and IC observers with computer monitors in a separate area. Observers will prompt, soothe, guide or send another staff member in to assist medical staff in situations of missed steps or occupational exposure. The hospital plans to incorporate artificial intelligence image recognition into the system to enhance its sensitivity and accuracy. [210]
Wuhan (COVID-19)	Zhongnan hospital implemented several measures to prevent COVID-19 transmission in their radiotherapy department. 153 patients with 1,752 visits underwent radiotherapy from 28 Jan to 10 Mar and 39 staff were tested for COVID- 19. None of the staff were tested positive. Implemented measures included: • Scheduled treatment times to reduce waiting room density and patient screening prior to radiotherapy treatment. • Daily staff temperature check • Donning of biosafety level 3 protection for high risks procedures. • Strict following of hand hygiene and decontamination measures. • Patients being instructed to wear surgical masks at all times. [211]
Hong Kong (COVID-19)	Approach taken by intensive care unit of a hospital with aerosol-generating procedures to manage risks to HCW while maintaining optimal care: - All aerosol-generating procedures should be done in airborne infection isolation room with double-gloving. - Does not recommend use of non-invasive ventilation and high-flow nasal cannula until patient is cleared of COVID-19. - Airway devices providing 6 L/min or more of oxygen are considered high flow and use is recommended only in airborne infection isolation room. - Endotracheal intubation by only by an expert with backup airway plans ready. - Delaying bag mask ventilation and optimising preoxygenation with non-aerosol-generating means (such as bed-up-head-elevated position, airway manoeuvres, airway adjuncts etc). Use of

Country / Region	Key Takeaway/Shared Experience on Effective Method
	supraglottic device for manual bagging instead of bag mask ventilation. [212]
Hong Kong (COVID-19)	IC precautionary measures for COVID-19 adopted by an ophthalmology clinic in a hospital. These include: - reducing outpatient attendances through rescheduling of appointments and suspension of non-urgent elective services/operations (SMS was sent to patients one week prior with number to call for rescheduling with 23.5% response rate and reduction of 24.6% of patient attendance) - triage stations at entrance of clinic to screen out potential cases (symptomatic urgent cases were treated at A&E or isolation wards after admission and non-symptomatic suspect cases were treated at a separate waiting area and special room) - inpatient consultations from other specialties were seen in respective parent wards instead of the outpatient eye clinic. - suspension of routine aerosol generating procedures and non-contact tonometry (use of alternatives such as i-Care tonometry instead) - avoid nasal endoscopy - staff IC training, environmental control and use of PPE (universal masking, eye protection equipment for ophthalmologists, surgical masks by patients) - Ophthalmologist attending to higher risk patients at designated - areas wore full PPE, including isolation gown, gloves, cap, eye protection. [169]
Taiwan (COVID-19)	Proposing adjusted use of Traffic Control Bundling (TCB) for IC control in hospitals during the COVID-19 outbreak, a tool that was used by hospitals in Taiwan during SARS. The tool involves triaging of patients in outdoor screening stations and directing them to clearly delineated zones (contamination, transition and clean zones) separated by checkpoints. HCWs must gown-up PPE and engage in hand disinfection before moving from the clean zone to the intermediate or hot zones, and de-gown in the transition zone. Daily environmental disinfection is recommended in clean and transition zones. Each zone is clearly delineated with signage, doors, painted lines on floors, and include prominently posted descriptions of steps to be taken in the zone. HCWs are trained in TCB protocols prior to implementation. No HCWs and only two patients developed nosocomial infection in the 18 hospitals implementing TCB during the SARS experience, while 115 HCWs and 203 patients developed SARS in the 33 control hospitals. The modified TCB model is proposed for implementation by public health authorities in the COVID-19 situation. [213]

Country / Region	Key Takeaway/Shared Experience on Effective Method
Singapore (COVID-19)	Outbreak response measures of an anesthetic department in the largest academic tertiary level acute care hospital in Singapore. These include: • Engineering controls (eg an OR complex with individual ventilation system and designated for survey of COVID-19/suspected cases, all OR doors (except for one) sealed while patient is inside, use of single use of medical equipment/OR technicians etc) • Administrative measures (eg reduction of elective surgery, staff to refrain from unnecessary travel to certain destinations, separation of staff caring for COVID-19 patients from those caring for other patients, communication channels to all staff) • Guidelines on anesthetic management (eg local anesthesia over GA where possible, attachment of circuit extensions prior to starting a case, preference of definitive airway with an endotracheal tube over a supraglottic airway, preference of video-laryngoscope, full expiration into face mask before lifting off patient's face, avoidance of awake intubation procedures etc) • Practices for PPE use • Simulation to evaluate feasibility of practices/measures [214]
Singapore (COVID-19)	Steps taken by the Department of Radiology in Sengkang General Hospital: • To ensure business continuity (the team is small and any outbreak can cripple the department), the department was divided into 4 geographically-separated teams and prevented from coming into any contact with each other. After the local outbreak, the ministry initiated a 'Swab-Chest Radiograph- Go' screening process with round-the-clock reporting within 1 hour. To achieve this, staggered shifts and designated "on-call" overnight radiologists have been rostered. • On patient safety, radiographers are split into teams based on location with a designated radiographer at the isolation area for suspect cases. Mobile digital radiographic units are also redeployed to the ED to reduce patient movement. Pre-designated CT and MRI machines are set aside for suspected or confirmed COVID-19 cases and are cleaned (takes up to 60 mins) between each patient. • Maintaining of staff morale was done by through regular and clear communication. Staff have to perform daily temperature taking, donning of PPE correctly, and mask fitting. • Education for residents (medical students) was maintained via video conferencing of clinico-radiological rounds and interprofessional education, sharing of images via PACS workstation and interactive tutorials via Webex. [215]

Country / Region	Key Takeaway/Shared Experience on Effective Method
Singapore (COVID-19)	The Singapore General Hospital introduced a respiratory surveillance ward (RSW) which admitted all suspected patients presenting with respiratory syndromes, including those who developed respiratory syndromes after admission. Heightened IC measures (such as beds spaced 2 metres apart in cohort rooms, HCWs in full PPE, patients with viral pneumonia given priority to single rooms etc) were implemented in the RSW and patients were transferred out only after 2 consecutive negative tests. Over this 6-week period, 1178 patients were admitted to the RSWs, with mean length of stay 1.89 days and 5 tested positive for COVID-19. No patient-HCW transmission was detected and only 1 patient who overlapped with the 5 positive cases developed COVID-19 subsequently. This resource intensive method of utilising a RSW successfully helped to avoid patient-HCW transmission and cluster formation in the hospital. [216]
Singapore (COVID-19)	A staff protection and staff temperature and sickness surveillance system adopted by Tan Tock Seng Hospital Singapore comprised the following processes: • Isolation of suspect patient cases in negative pressure isolation rooms and use of PPEs (N95 masks, eye protection, long sleeved gowns and gloves) in such rooms • Universal masking in hospital premises with compliance monitoring • Twice daily temperature and symptoms reporting for staff. • Close surveillance of staff working in COVID-19 lab/clinical areas or with travel history to/from China with testing (and then discharged with 5 days leave) for cases of low suspicion and hospital admission for further investigation for clinically suggestive cases. Of 10,583 staff, 1,524 were under close surveillance, 266 developed symptoms, 167 were tested and 29 admitted. SARS-CoV-2 was not detected in all these cases. [217]
Singapore (COVID-19)	A study validated the effectiveness of contact tracing of HCWs and patients using real time locating systems (RTLS) and electronic medical records (EMRs) in a hospital in Singapore. The 2-day study involved 796 staff patient contacts with 17 COVID-19 patients. RTLS. RTLS yielded a sensitivity of 72.2 % and specificity of 87.7 % while EMR yielded a sensitivity of 47.2 % and specificity of 77.9 %. Highest sensitivity was obtained by including all contacts identified by either RTLS or EMR (sensitivity 77.8%, specificity 73.4%). The time taken for data extraction from RTLS and EMR was 2 to 3 minutes and 20 minutes per patient respectively. EMR yield lower results likely due to the lack of clarity in documentation of specific staff performing certain tasks. To improve contact tracing effectiveness, RTLS would require technical adjustments and measures to increase user compliance. [218]

Country / Region	Key Takeaway/Shared Experience on Effective Method
South Korea (COVID-19)	2 community acquired COVID- 19 cases were identified in a university hospital in Eunpyeong-gu northwest Seoul. A 2-week hospital closing was carried out as per the 2015 Middle East Respiratory Syndrome (MERS) guidelines. Contact tracing and isolation of close contacts at single rooms was done. Repeated testing was also done on all hospital staff and suspected cases prior to discharge to prevent delayed positivity. While measures were effective to control spread, hospital shutdown was deemed unreasonable as it deprived patients with other diseases of care. Repeated testing was also questionable as it came with high costs. Instead, disinfection and removal of air contaminants was emphasised as a more practical measure. The study recommends that the guidelines be revised. [219]
Shenzhen, China (COVID-19)	A paper shares about infection control measures in a hospital's outpatient clinics: • Entrance and exit were strictly controlled with temperature screening, and everyone's epidemiological history and clinical symptoms taken down. Suspected COVID-19 cases are sent directly to the fever clinic via a designated route. • Patients will be screened again by a nurse, and then by the doctor inside the outpatient clinic. • Within the fever clinic, those with positive epidemiological history will be assigned to Fever Clinic 1 and those without to Fever Clinic 2. Each of the 2 fever clinics operate separately with different equipment and staff For the period of 24 Jan 24 to 1 Mar, 1,408 were admitted to Fever Clinic 1 and 56 tested positive while 732 were admitted to Fever Clinic 2 and 2 tested positive. The difference in positive rate between the two fever clinics was statistically significant, showing that the method effectively prevents cross infection. [220]
Italy (COVID-19)	A reporting system was set up in the University Hospital of Bari to monitor HCWs' contact with SARS-CoV-2. HCWs with close contact with confirmed cases when without PPE will be temporarily suspended from work and isolated at home for 7 days. A swab will be done and they are allowed to return to work if there was double molecular test negativity in a 24-hour period. HCWs in close contact with confirmed cases but with PPE and HCWs with casual contact with confirmed cases continue working but will be told to self-monitor for 14 days and will be suspended and isolated if symptoms were to develop. The system contributed to good transmission control in the hospital: the hospital received 1,065 COVID-19 positive patients, 1,303 swabs were done among HCWs, and only 23 tested positive. [221]
UK (COVID-19)	The effectiveness of using a hospital-onset COVID-19 infection (HOCI) surveillance system to target prevention interventions in 5 hospitals in London was assessed. A total of 90 HOCI cases out of 907 COVID-19-

Country / Region	Key Takeaway/Shared Experience on Effective Method
	positive cases were reported, while a rise in COVID-19-positive inpatients was observed but the proportion of HOCI cases remained low. Network analysis of patient movements revealed a broader pathway involvement, highlighting the importance of patient pathway network analysis in surveillance. The study recommends use of this surveillance system in combination with the national surveillance system and infrastructure for the rapid identification of HOCI clusters and targeted IPC activities. [222]

On Specific Measures

Face masks. Most risk factor studies performed during or after epidemics emphasized the importance of the appropriate use of surgical mask or an N95 respirator, which was protective and significantly reduced risk for HCWs. [223]

N95 (or respirators) and surgical masks. There are mixed results from studies on the efficacy of use of surgical masks versus N95 masks by HCWs. Two studies found that use of a surgical mask compared with an N95 respirator resulted in non-inferior rates of laboratory-confirmed influenza. Studies have observed that effectiveness varies and depends on the setting. [224] [225] A recent systematic review and meta-analysis showed that there were no statistically significant differences in preventing laboratory-confirmed influenza, laboratory confirmed respiratory viral infections, laboratory-confirmed respiratory infection and influenza-like illness using N95 respirators and surgical masks. N95 respirators, however, provided a protective effect against laboratory-confirmed bacterial colonisation. [226]

On the other hand, several studies have found that N95 masks were more effective in reducing influenza infection rates and their use associated more strongly with protection from infection than that of disposable surgical masks. A more recent systematic review of observational studies on COVID-19, SARS and MERS in healthcare and non-healthcare settings across 16 countries noted that use of N95/respirators associated more strongly with protection from infection than use of disposable surgical masks or cotton ones. [227] One recent study based on results of pre-existing RCTs concludes that N95 respirators can halve the risk of any respiratory infection compared to surgical masks. Another narrative review pointed out that surgical masks have a reported failure rate of 10-90% and a pilot study using a human exposure model observed that they only protected 1 in 4 participants against influenza while N95 respirators protected 4 in 5 participants in the same human exposure model. Notwithstanding this, a study qualified that use of N95 masks needs to be continuous (instead of intermittent). [228] [229] [22] [227] [230] [231] It was noted that the similar effects of both types of masks noted in some studies may be related to low compliance with wearing N95 respirators, although N95 respirators confer superior protection in laboratory studies with 100% intervention adherence. [226] A review study noted that breach of protocol such as adjusting N95 respirator, touching the respirator or under it, face, or eye has been found to be 25.7 times per 12 hour shift, with the likelihood increasing for those with higher BMI. Excessive body movement also increases risk of seal leakage. [231] Use of N95 has been associated with impaired mental performance, headaches, inappropriate fitting and perceived to be difficult to tolerate, and could be counter-productive.

The decision is divided on use of N95 for novel MERS-CoV or SARS prior to COVID-19 - airborne precautions have been cited to be unnecessary for MERS-CoV and SARS. [223]

[232] [233] However, some professionals and authorities recommend use of N95 and airborne precautions for novel respiratory virus for more stringent protection of HCWs. [233]

On respirators. A review on the performance and impact of respirators for HCWs amidst the COVID-19 pandemic yielded the following main findings:

- Respirator performance standards are applicable across industries and repurposing respirators to healthcare from other industries is appropriate provided practice needs are met.
- Proper fit testing is required for safe use.
- Carefully worn well fitted facepiece respirators can provide good protection up to 8 hours. Notwithstanding, some clinical procedures (such as chest compression) may impact fit.
- All respirator types compromise user comfort and ease in communication. Organisations can consider flexible policies providing more than one respirator model type (or reusable respirators which a substantial proportion of HCWs preferred over disposable designs). [234]

It has been pointed out that flexibility and awareness of limitations of respirator types in different scenarios are important for HCWs. For example, while the European Resuscitation Council recommended Personal Protective Equipment (PPE) of FFP3 respirator masks (FFP2 or N95 if FFP3 is unavailable), N95 may not provide a tight face seal and its mask shape and vigorous movements might decrease its ability to protect healthcare workers during Cardiopulmonary Resuscitation (CPR). Powered Air Purifying Respirators (PAPRs) provide better protection (assigned protection factor of 25 and filtering 99.97% of particles (0.3µm)) but donning of PAPR is more difficult and time consuming which might not be appropriate during resuscitation. [235] [231] A recent study also pointed out that prolonged hours of N95 mask wearing exposes risk of mask-induced hypoxia, and recommends dividing an 8-hour shift into 2 teams where one team works in an infected area with mask wearing while the other works in a clean area without mask for 4 hours. [236]

On comfort/convenience when using respirators, a recent study found that 62% of respondents reported that respirators and PPE did not affect their ability to perform patient care and 51% did not find their use inconvenient (51%), but most felt that compliance to their use will be affected should they affect their ability to perform care. PAPR users were most likely to feel that respirators affected their ability to perform patient care (27%), followed by N95 (17%), and Elastomeric (16%) users. Nurses (22%) and doctors and medical practitioners (28%) were also more likely to find that respirators interfere with patient care than respiratory therapists (9%) and support staff (10%). [237]

Another study pointed to the current worldwide shortage situation with COVID-19 (especially for FFP2 respirators) and how the untraceable origin of respirators supplied to hospitals meant the need for quality check of supplies. A protocol was developed in the Catharina hospital in the Netherlands to test a minimum Total Inward Leak (TIL) of 8% for FFP2 respirators (based on EN149+ A1:2009 standard). Only 33 % of tested respirators met the test requirements. The result shows that it is crucial to test received respirators before use to ensure that the safety of HCWs is not compromised. [238]

On aerosol transmission. Two studies indicated that N95/facepiece respirators provide more adequate protection against inert airborne particles. However, one study indicated that N95-certified respirators may not provide the expected 95% protection level when filtering airborne virions in the nanosize range (maximum penetration was observed for particles up 40 to 50 nm), and at higher inhalation rates. The efficiency of surgical masks is significantly lower than that of respirators. Surgical masks generally do not reduce exposure to aerosolised agents. However, surgical masks with an integrated visor provided overall better protection. [239] [240]

A study sought to identify the escape of small particle aerosols from patients' airways. It simulated breathing conditions with 0.28µ aerosols and a fixed cadaver head and evaluated a novel Negative Airway Pressure Respirator (NAPR) System made via an Ambu mask fitted with suction tubing attached to a HEPA filtration system. The NAPR was tested and almost no aerosolised particles were detected (88 pixels), as compared with a cadaver without a mask (27,486 pixels), with a standard surgical mask (21,379 pixels), and with a modified Ambu anesthesia mask (3,835 pixels). Local negative-pressure environment around the patient's nose and mouth is critical to minimise the risk to HCWs associated with procedures of upper and lower airways. [241]

<u>Global shortage with COVID-19 and mask reuse/extended use</u>. WHO has recently pointed out that severe global shortage of face masks for HCWs is affecting the ability of countries to respond to the outbreak, and that hoarding and misuse was exacerbating the problem. [242] Extended use or reuse of face masks is increasingly being considered or recommended in this situation. Recommended guidance for extended use and limited reuse of N96 masks have been made available by CDC and some academic papers. The guidance states that extended use is favoured over reuse, and provides recommendations on when an extended use mask should be discarded (eg following contamination by body fluids or after aerosol generating procedures etc), accompanying engineering controls to limit transmission risk (eg use of cleanable face shield over mask, masking of patients etc), and how mask reuse should be managed (handling of masks, storage before reuse etc). [243] [214]

A recent review article also pointed out inconsistencies between guidelines from different agencies regarding how and when different masks should be used in relation to COVID-19. While WHO recommends using surgical masks for routine care and respirators during aerosol generating procedures, the US CDC and European CDC recommend using respirators during both routine care and high-risk situations. Some countries align with WHO guidelines (eg China, Australia etc) while some countries align with the CDC (eg UK and China). In addition, while all organisations recommend using N95/P2/FFP2 or equivalent respirators, Public Health England recommends using filtering facepiece 3 and Australian guidelines recommend powered air purifying respirators.

The article recommends:

- Use of N95 or higher respirators by HCWs in both routine care and high-risk situations, considering transmission dynamics for COVID-19 are still unclear.
- Extended use should be balanced against risk of infection and wearer should not remove masks between patient encounters, considering that extended use/reuse are high risk practices and there are currently no clinical studies supporting these practices and their safe application.
- Implementation of a program that includes selection of certified respirators, training and fit checking and testing, and inspection, maintenance and storage. For eg. the National Institute for Occupational Safety and Health regulates the certification process under regulation 42 CFR 84(44) in the US and similar regulations are in place in Australia and Europe. [244]

A recent 1-day sampling study suggested the possibility of safe extended use of N95 and goggles if with strict adherence to environmental and hand hygiene (see section on 'PPE' below). Another narrative review noted that reuse of masks should be limited to a maximum

5 uses, unless alternative manufacturer guidance is available. Filtration efficiency for filters is also observed to be reduced to below 95% after 9 and 13 weeks of simulated reuse. [231]

Another recent review article debates the need for universal masking in hospitals at a time of shortage and where preventing wastage is important. The positives from universal masking is that it may prevent asymptomatic and minimally symptomatic healthcare workers from spreading COVID-19 unknowingly. However, the paper points out that risk of such transmission is likely low. In addition, mask wearing may paradoxically lead to increased transmission if it results in other infection control measures (eg full PPE use, screening and isolation, having a low threshold for testing) not being carried out. Mask wearing also serves as visual reminder to everyone regarding infection control measures, and most importantly increases HCWs' perceived sense of safety, well-being and trust, thus reducing their anxiety. [245]

A narrative review on use of PPE noted that surgical mask overlay may act as an additional barrier protection against contamination and attrition. [231]

Sterilisation of masks. There is evidence that hydrogen peroxide plasma works as a viable disinfectant for FFP2 and N95 respirators without affecting their physical characteristics of protection, and supports their reusage in shortage situations. [246] [247] Another study was conducted to evaluate the effectiveness of using Gamma irradiation as a sterilisation method for N95 masks (gamma irradiation has been shown to be effective in inactivating viruses, including SARS-CoV, and has the added benefit that the process can be done on soiled masks when they are sealed). It was found that irradiated masks performed much more poorly than unirradiated masks in terms of particulate matter filtration, especially for 0.3 μm particles. Irradiated masks also have a slight unrecognisable odor, which the study authors suspect is caused by the discharging of their electrostatic barrier. The study suggests against irradiation as a sterilisation method. [248]

A study was also conducted to assess the efficacy of a simple steaming decontamination method. Medical masks were contaminated with vaccine strain avian infectious bronchitis virus H120 to mimic SARS CoV-2 and steamed on boiling tap water in the kitchen pot. The virus was completely inactivated when medical masks were steamed for 5 minutes. The blocking efficacy of the medical masks (99 % viruses in aerosols) remained even after steaming for 2 hours. The steaming method proves to be safe but appropriate handling of medical masks was emphasised to ensure its blocking efficacy. [249] There is evidence supporting the use of dry heat and microwave-generated steam (MGS) for reprocessing of FFP2/N95 type respirators. Reductions in the viability of dry *S. aureus* was observed after treatment by dry heat 37°C for 90 minutes at 70°C or by MGS in 90 seconds. [250] Another study pointed to the possibility of heating N95 respirators to 85℃ for 40 minutes with relative humidity of 60-85% for five cycles as a method of decontamination. The method is scalable to a range of health services with simple equipment used (such as convection ovens, containers, paper towels, pipette, and low cost sensors). [251]

Pretreating solutions. There is evidence that pretreating various household materials (kitchen paper towel, laboratory paper towel and surgical mask filter) with NaCl solution (a salt-based solution) improves their filtration efficiency and prevents penetration of COVID-19 sized viral particles with similar efficiency as medical grade surgical masks. NaCl treated readily available material (eg household paper towel) can potentially be used as additional protection to/prolong the lifespan of homemade masks, surgical masks, and/or N95 respirators for HCWs in the pandemic situation. The efficacy reduces after 2 hours of exposure to viral particles and should be replaced after 2 hours. [252]

Homemade masks. The CDC recently suggested nurses and other HCWs use homemade masks (eg bandana, scarf etc) for care of COVID-19 patients as a last resort. It explained, however, that the capability of such masks to protect against COVD-19 is unknown. The National Nurses United (the largest nurses' union in the US) objected to the move, pointing to the risk for HCWs and the risk of infection to patients in hospitals. [253]

A randomised control trial study comparing the efficacy of cloth masks to medical masks in HCWs in secondary/tertiary level hospitals in Hanoi showed significantly higher rates of infection outcomes in the cloth mask group as compared to the medical mask group and control arm (usual practice, which included mask wearing). Penetration of cloth masks by particles was almost 97% while that for medical masks was 44%. Postulated reasons for increased risk of infection in the cloth mask arm were moisture retention, reuse of cloth masks and poor filtration. The results caution against use of cloth masks. It was qualified that the study lacked a no-mask control group and that quality of cloth masks varies widely around the world so results may not be generalizable to all settings. [254]

Mask utilisation projections. A modelling study projected the mask shortage numbers for different facemask policies in China with different user groups assumed to use different mask types: healthcare workers (N95 mask), infected cases (N95 mask), suspected cases (non-N95 face mask), observational cases (non-N95 face mask) and the general population (non-N95 face mask):

- If a universal facemask wearing policy was implemented, there would be 132 days of total facemask shortage with the largest daily shortage predicted to be 539.5 million masks.
- If a universal facemask wearing policy was implemented only at the epicentre, there would be 7 days of total facemask shortage, with a peak shortage of 49.3 million masks.
- If no universal facemask wearing policy was implemented, there would be 4 days of total facemask shortage, with a peak shortage of 37.5 million masks.

In all scenarios, there will be N95 masks shortage and it is predicted to occur on Day 4 (23 Jan) of the simulation, and lasts till the end of the simulation period (30 Jun), with 2.2 million N95 masks lacking daily. The study pointed out that universal facemask wearing policy can cause panic throughout the country leading to more severe shortages that will affect healthcare workers. [255]

Protective eyewear. Recent academic literature drew attention to growing evidence of possible ocular involvement in early manifestation and human-to-human transmission of COVID-19, pointing to the inclusion of one ophthalmologist amongst the deaths of HCWs in mainland China and case experience of a HCW who was infected despite being fully downed with protective suit and N95 respirator and reported unilateral conjunctivitis as the first symptom. Reviews recommend use of protective eyewear as a precaution and the need to stay vigilant to recognising viral conjunctivitis as a possible presentation. [256] [166] [231] Another study discovered that effectiveness in transmission prevention increased to 90% when N95 respirators were used together with goggles. [231]

PPE. A cross sectional study on frontline HCWs who provided care for COVID-19 patients with appropriate PPE in Wuhan recorded that all participating HCWs did not report any COVID-19 related symptoms and tested negative for SARS-CoV-2, suggesting the protective effects of PPE. [257] A recent narrative review pointed out that there is low-certainty evidence showing that PPE which covers more parts of the body was found to provide better protection. [258]

Risk-stratified use. With supply shortage of PPE, a common problem in outbreaks, risk-stratified use of PPE is usually applied in hospitals to conserve and maximise their use. Examples of instructions for risk-stratified use of PPE can be found in Cheng et al's descriptive study of enhanced IC measures applied in Hong Kong public hospitals for COVID-19 and PPE use recommendations available at the College of Radiologists website. These include appropriate levels of PPE protection at specified clinical settings and situations and accompanying extended/reuse recommendations. [193] [259] (See also face masks section above for CDC's mask extended/reuse guidance.)

On risk stratified use of PPE, a recent study proposed a third tier PPE use for high risk Aerosol Generating Medical Procedures (AGMPs) for both anesthesiologists and other airway managers. Further measures such as head and neck protection and second pair of gloves overlapped with gown sleeves were advised for these high-risk procedures. The study also highlighted the neck area as a high contamination zone and could be a further contamination source during removal of clothes. PPE doffing should be taken seriously with more attention paid to preventing self-contamination. [260]

Specific procedures. An international multicentre cohort study was conducted on 1,718 HCWs who performed tracheal intubation on patients with suspected or confirmed COVID-19. While all participants responded that they did so in PPE that conformed to WHO's recommended minimum standards for aerosol- generating procedures, specific PPE combinations differed across participants. Approximately 10% of HCWs were diagnosed with new COVID-19 infection or isolated/hospitalised with new symptoms following involvement with tracheal intubation of suspected/confirmed COVID-19 patients. More efforts should be channelled to screening and identifying interventions to reduce risk to HCWs providing such care. [261]

Re-use. A recent 1-day sampling study was conducted in the National Centre for Infectious Diseases (NCID) in Singapore to determine the risk of PPE contamination with SARS-CoV-2 in HCWs caring for COVID-19 confirmed patients. PPE samples such as goggles, front surfaces of N95 respirators and shoes of HCWs were collected, and duration of time in contact with patient, specific activity done, and patient clinical information were noted. All samples from doctors, nurses and cleaners were negative for SARS-CoV-2, suggesting the possibility of safe extended use of N95 and goggles if there is strict adherence to environmental and hand hygiene. [262]

Plastic drapes, gowns, aprons. A study was conducted to evaluate clear plastic drapes in minimising droplets contamination during aerosol-generating medical procedures such as intubation and extubation during COVID-19 treatment. The author used a tracheal intubation model and added fluorescent resin powder to simulate secretions while a medical air gun was used to simulate a cough.

Wide distribution of droplets contaminated the surrounding areas in a set up with no clear plastic drape, aerosolisation and droplet spraying was limited in a set up with a single clear plastic drape applied over the head and endotracheal tube, and contamination was only found on the patient's face and head in a third set up with a 3-layer plastic drape configuration - 1. Under the head, 2. Covering the upper torso, 3. Over-head top drape. The final set up was the most effective. [263]

A narrative review on PPE concluded that gowns are more protective than aprons against contamination (MD -1.36, 95% CI -1.78 - -0.94). [231]

Gloves. A narrative review on PPE concluded that double gloving is more protective as compared to single gloving (RR 0.36, 95% CI 0.16- 0.78). [231]

Others. The same narrative review pointed out that hypochlorite base solutions are better in preventing contamination than alcohol-based hand rub during doffing (MD 4, 95% CI 0.47 – 34.24). [231]

Side effects. Frequent use of PPE (and frequent washing of hands) can result in skin damage such as burning, itch, eczema, acne, maceration and skin indentations (eg from goggle use). A recent cross-sectional study surveyed 330 HCWs working at fever clinics and inpatient wards of COVID-19 cases found that 71% of respondents reported self-perceived skin barrier damage. Guidelines on Consensus of Chinese experts on protection of skin and mucous membrane barrier for HCWs in relation to COVID-19 were published recently. These were based on consensus of Chinese clinical experts, and include advice on application of moisturizer (urea-containing emulsions recommended) after hand hygiene before donning of gloves/other PPE, additional protections for eczema (eg use of gauze layers inside the mask), and treatment/alleviation of eczema/skin indentation conditions (eg use of glucocorticoids of varying potencies for different severity of conditions). [264]

A recent study with 10 participants suggested possible use of a repurposed silicone-based dressing underneath a N95 mask in reducing facial injuries while maintaining mask's seal. Pronounced improvements in facial condition, improved nose comfort and absence of facial irritation were observed. Mask movement and seal's stability also improved, but the possible risk of slight localised sweating underneath the mask with the improved seal was pointed out. [236] However, another study assessing the impact of use of skin protectants on the N95 qualitative fit-test (QLFT) and user comfort noted that their use may interfere with mask fit (only 36% of participants passed the QLFT for 5 protectant types). Protectant types with higher QLFT also tended to score lower on user comfort ratings. [265]

Hand hygiene. Approved alcohol-based products for hand disinfection are preferred over antimicrobial or plain soap and water when there is no visible soiling of hands. [164] [22] Hand hygiene with the use of an alcohol-based hand rub has become a key infection control measure in hospitals. [202]

Frequent hand washing can result in skin barrier damage and eczema conditions. See above for guidelines on protection of skin and mucous membrane barrier for HCWs in relation to COVID-19.

Another journal article pointed to the often-neglected recontamination of hands by touching unclean surfaces after hand rubbing/washing. This can be mitigated by applying the following principles for behavioural change:

- Create a mental model: Give clear guidance on what surfaces are clean within the patient zone
- Create social norms: Having managers lead by example in terms of hand hygiene protocols
- Create the right emotions: Emphasize the importance of stopping recontamination for everyone's safety
- Replace one behaviour with another: “Keep hands off unsafe surfaces” vs “Do not touch unsafe surfaces”
- Make the behaviour easy: Create a user-friendly environment based on the workflow for patient management and with hand hygiene cues to reduce opportunities for recontamination. [266]

Temperature monitoring of HCWs. Daily temperature monitoring of all HCWs in hospitals was useful for early identification of HCWs with SARS during the SARS experience. [267]

Ventilation. Hospital design with augmented air changes may be protective against nosocomial transmission of SARS. In Hanoi, Vietnam, during the SARS outbreak, a hospital with designated isolation wards of large spacious rooms with high ceilings, ceiling fans that were kept running, and large windows kept open for natural ventilation, registered no transmission. [202] [268] The infection rate of SARS among healthcare workers was also found to correlate with the ratios of ventilation window to room areas. [202] [269]

Sufficient ventilation in makeshift hospitals that are converted from public buildings in the event of limited hospital capacity in an outbreak is important. The multiple makeshift hospitals for COVID-19 patients converted from large-scale public places in Wuhan had exhaust air volume approximately at 150 m^3 per hour per person, much lower than WHO's guideline of 288 m^3. Insufficient ventilation in these makeshift hospitals may increase infection risk of opportunistic airborne transmission. To increase ventilation rates in makeshift hospitals, low outdoor temperature will increase the need for heating inside the hospitals and air conditionings and electric blankets. There may however be challenges in energy consumption to exhaust such high-volume air a large number of people. The use of air purifiers to increase dilution of contaminated air and reduce possible virus-laden aerosols is an alternative. All the filters should, however, be collected and disposed as medical waste or disinfected thoroughly to prevent secondary contamination. [270]

Staff scheduling. A recent study highlights the potential benefits of ICU staff scheduling based on the epidemiology of the disease. While a typical routine staffing of 5 x 8h shifts per week and 2-day rest requires 84 HCWs per week, a pandemic staffing of 7 x 12h shifts in every other week and 1-week rest requires 40 HCWs per week. The pandemic staffing includes 1 week of quarantine/rest to reduce probability of infection and requires 5% less staffing as compared to the typical routine. Assuming a 3-week quarantine period after infection, workforce savings for the pandemic staffing increased with infection probability (17% for probability of 0.10 and 8% for probability of 0.40). [271]

Capacity preparedness

Overwhelming of capacity. Capacity preparedness has important implications for IC and protection of HCWs. The COVID-19 outbreak in Hubei province, and in places such as prisons or cruise ships [272], has shown how infections can rapidly spread in confined spaces. Insufficient beds and overcrowding in hospitals can pose additional risk for HCWs. A recent modelling study on the epidemic situation in France projects ICU capacities to overrun by 14 April in all regions in the worst-case scenario and to overrun in seven regions in the mild scenario. While drastic social distancing measures mitigate extent of cases, a massive reorganization leading to an expansion of French ICU capacities has been highlighted to be necessary to manage the upcoming wave of critically affected COVID-19 patients. [273] Similarly, another modelling study estimated that hospitals in half of the states in the US are expected to exceed capacity even if less than 0.2% of state population requires hospitalization in the COVID- 19. (Median 0.2% of state population is estimated based on Wuhan where 1 in 5 of 1% of the affected population required hospitalisation.) [274]

Emergency responses. A case study shared on Italy's early experience and emergency response to the initial surge in COVID-19 patients. In Lombardy, the pre-crisis ICU capacity was approximately 720 beds and the decision to cohort patients in 15 first-responder hub hospitals within 48 hours where cohort ICUs for COVID-19 patients, triage areas and triage protocols were created, brought in an additional 482 ICU beds over the first 18 days. [275]

Resource allocation and ethics. Notwithstanding, limited ventilators and ICU beds in the face of overwhelming surge of patients and long intubation period requirements means that scarce resources will need to be allocated and decisions made on which patients receive the ventilation support. In Italy, the Italian College of Anesthesia, Analgesia, Resuscitation, and Intensive Care (SIAARTI) issued recommendation for such decisions, urging clinical reasonableness and 'a soft utilitarian' approach. An ethical framework for such resource allocation (titled "Too Many Patients . . . A Framework to Guide Statewide Allocation of Scarce Mechanical Ventilation during Disasters") was also created by Lee Biddison, an intensivist at Johns Hopkins, based on focus groups on community members' preferences. Both these guidance value saving people with the greatest chance of survival most. The general consensus was to utilise clinical factors to evaluate a patient's likelihood of survival and to determine the patient's access to ventilator therapy.

Rosenbaum 2020 also stressed the need for a process to accompany ethical frameworks or guidelines. These could include separation of the decision making from clinicians providing the care. A triage officer, backed by a team of experts in nursing/respiratory therapy, would make resource-allocation decisions and communicate them to the clinical team, patient, and his/her family. These decisions should also be reviewed regularly by a centralized state level monitoring committee. [276] [277]

General Measures

Most of the measures taken at this juncture are preventive and seeks to slow disease spread rather than contain or stop its initiation. This is because the disease has usually already "seeded" itself in the community at this point, and infected and infectious persons are unknown to the government. Measures to segregate these individuals from non-infected groups are no longer possible.

Community Hygiene

Guidelines and General Practice

Community hygiene measures include hand-washing, disinfection, the use of PPE in the community, and respiratory hygiene, such as the use of proper etiquette for coughs, sneezes, and spitting. These are broadly accepted and widely used in influenza pandemics. [22] [278]

Guidelines on community hygiene have been made available in documents such as MOH's Pandemic Readiness and Response Plan For Influenza and Other Acute Respiratory Diseases and WHO's Handbook on Managing Epidemics. In broad, these provide guidance on community engagement and encouragement to follow recommended practices in the various aspects of live animal market hygiene, animal handling and consumption practices, cleansing/disinfection of homes/work/public places, and personal hygiene, especially frequent hand washing and respiratory hygiene. [161] Singapore's National Environment Agency has also recently published a list of cleaning agents to disinfect for viruses. [279]

Research/Evidence on Effectiveness

General community hygiene practices. Much of our knowledge of community hygiene comes from reports of infection outbreaks where hygiene procedures have been defective or from case control studies. Concurrently, there is growing evidence that a significant proportion of respiratory viruses are spread via hands and surfaces such as handkerchiefs and tissues, tap and door handles, telephones and other surfaces touched by an infected person. [280] A review of studies on coronaviruses found that they can persist on inanimate surfaces like metal, glass or plastic, but can be efficiently inactivated by surface disinfection procedures with 62-71% ethanol, 0.5% hydrogen peroxide or 0.1% sodium hypochlorite within 1 minute (SARS-CoV-2 was not included as it was a review of historical studies). [281] A recent study observed significant environmental contamination of a hospital room by a SARS-CoV-2 patient with mild upper respiratory tract involvement through respiratory droplets and fecal shedding. Post-cleaning samples from the environment were negative, suggesting that current decontamination measures in hospitals are sufficient. Other studies have pointed out that SARS-CoV-2 can remain viable on plastic and steel surfaces for up to 72 hours, and on copper and cardboard for up to 8 hours. These studies suggests potential COVID-19 transmission through the environment and the need for strict adherence to environmental and hand hygiene. [282] [198] [283]

While a recent systematic review on RCTs did not find definitive quality evidence on PPE, environmental measures and respiratory etiquette in reducing influenza transmission, [284] an earlier review of infection outbreaks and hygiene intervention procedures concluded that there is convincing circumstantial evidence to suggest that improved standards of hygiene can have a significant impact in reducing rates of respiratory, intestinal and other viral infections in the community. [280] A recent study analysing "SARS-CoV-2 infections in young, healthy soldiers in two spatially separated groups" noted that stringent social distancing and hygiene measures (when implemented prior to detection of first case) results in reduced COVID-19 infection rate. These measures are also effective in the case of asymptomatic infection. [285]

<u>Population behaviour and compliance.</u> Several studies noted strong adherence (over 70%) or increased uptake to community hygiene practices in the COVID-19 pandemic (see Table 5). Most of these studies addressed countries who have successfully contained an initial outbreak situation such as China, Korea, and Vietnam. The studies also noted the role of public communications in influencing population behaviour in some of these countries. Some of the studies also noted that women were more likely to practice such behaviours than men. One of the studies noted that perceived risk towards COVID-19 infectivity, which is likely to motivate compliance with self-protective behaviours such as personal hygiene, was positively associated with females, higher income groups, and people living with children. A study in Taiwan also shared its practice of distributing sanitizer and alcohols to different organisations according to their priority level, concurrent with its public communications/education on community hygiene instructions. [126]

Apart from compliance, governments should also note unsafe practices due to incorrect knowledge of appropriate practices. A survey study in the US found that while participants practiced more home cleaning/disinfection to prevent COVID-19 transmission, a sizeable proportion had limited knowledge of safe preparation of cleaning/disinfectant solutions.

Table 5: Studies on population behaviour regarding community hygiene practices.

Author/Source	Description/Findings
Huang et al [286]	An internet-based cross-sectional survey study of 10198 responses (via a questionnaire disseminated using WeChat) conducted in China on addressed population's compliance with hygiene practices during the COVID-19 crisis. It was found that 92.4% opened windows for ventilation more frequently; 97.9% used masks in public; and 97.9% washed their hands more (95.7% also stayed at home as much as possible). Women were more likely to practice these behaviours than

Author/Source	Description/Findings
	men, and 80% of participants also tried to positively influence their families and friends. However, when compared with SARS (2003), there is a lower frequency of covering one's mouth when sneezing or coughing (57.8% vs 70.6%), and a lower frequency of hand washing (66.5% vs 75.9%). The study deduced that more hygiene education could be effected.
Jang et al [287]	A cross-sectional population-based study in Korea which compared community hygiene practices during the current COVID-19 crisis and the MERS outbreak found that wearing a face mask increased by more than 5-fold, while the hand washing rate increased by 1.3-fold. Social distancing behaviour increased as well. Females were more likely to practice transmission preventive behaviour, as well as those with higher perceived risk of infection and those living in cities.
Nguyen et al [288]	An online questionnaire study evaluated adherence of Vietnamese adults to COVID-19 preventive measures through questions and scoring on personal preventive measures (such as wearing face masks outdoors, coughing/sneezing etiquette, hand hygiene etc) and community preventive measures (such as avoiding gatherings/public transport, usage of individual spoons/plates when eating with family members etc). The mean adherence scores for personal and community preventive measures were 7.23 (range 1 to 9) and 9.57 (range 1 to 11) respectively, with high adherence rates likely due to prompt and intensive measures by the government, and its emphasis on countering fake news. The strong preventive behaviour of the Vietnamese population could be reason for the low number of COVID-19 infections and nil mortality up to first week of May 2020.
Muto et al [289]	A study evaluating behavioural changes of 11,342 Japanese in response to COVID-19 noted high compliance to social distancing and community hygiene practices: • 80% avoided closed spaces with poor ventilation, crowded places, and close-contact settings. • Over 85% avoided mass gatherings, with higher compliance observed amongst females and older adults. • 86% practiced frequent handwashing, with 91% being females and 88% aged>40. • 77% practiced coughing etiquette and many avoided going out when ill with a cold. However, only 40% had prepared consultation and transportation methods when they fell ill. The Diamond Princess cruise ship incident was cited as the most significant event influencing respondents' behavioural changes, and TV news programmes and internet news sites were cited as the main sources of COVID-19 information, marking the importance of perception of transmission severity and public communications in influencing community hygiene compliance (see also section on 'Rick Communications').

Author/Source	Description/Findings
Gharpure et al [290]	A recent online panel survey in the US found that while 60% of the respondents practiced more home cleaning/disinfection to prevent COVID-19 transmission, a sizeable proportion had limited knowledge of safe preparation of cleaning/disinfectant solutions: only 23% responded that bleach should be diluted with room temperature water, and that bleach should not be mixed with vinegar (35%) and ammonia (58%). A substantial proportion (39%) also engaged in at least one high risk practice not recommended by CDC (eg bleaching of food items (19%), use of cleaning and disinfection agents on bare skin (18%), misting of body (10%)) Public health messages should stress on both safe and effective use of cleaning and disinfection agents.
He et al [291]	A web questionnaire survey among 476 residents living in Chongqing, China found that perceived risk towards infectivity of COVID-19 were positively associated with females, higher income groups, and people living with children. Respondents who used WeChat contacts as their main information source have a lower risk perception towards infectivity while those who relied on television and community workers as media sources have a higher perceived risk of pathogenicity. Perceived risk also increased by 4.9% for every one-year increase of age.

Hand hygiene. There is consistent evidence supporting the use of hand hygiene in all settings. Evidence also suggests that while handrub and handwash products may have good activity against bacterial pathogens, activity against viral contamination is variable and depends on the type of virus. Alcoholic handrubs are effective against enveloped viruses (coronaviruses are enveloped viruses), but activity against non-enveloped viruses is limited. Similarly, agents such as triclosan and chlorhexidine have some activity against enveloped virus but are not considered effective against non-enveloped viruses. [280] [22] [166]

A study (using a model-based framework) pointed out the determinants influencing effectiveness of hand hygiene on respiratory tract infection transmission:

- The longer the duration of virus survival, the more effective increasing hand-washing frequency will be in reducing infection.
- Event-prompted hand washing (washing 1 minute after contamination event) was more effective than fixed-time hand washing (every 15 minutes). Probability of infection was 6% with fixed-time hand washing and 2% with event-prompted hand washing (at virus half-life of 5.4 minutes).
- The higher the hand contamination rate, the higher the increase in frequency of hand washing needed (for eg washing least 5 times per hour was needed to reduce 50% of transmission when hand contamination rate was high (> 10 times per hour) at virus half-life of 36.1 minutes.

The study highlights the effectiveness of hand hygiene, particularly event-prompted hand washing, in reducing transmission of respiratory tract infections. [292]

Use of masks. A systematic review on use of masks and respirators to prevent transmission of influenza included studies on efficacy in community settings. While none of the studies were found to establish a conclusive relationship between mask/respirator use and protection against influenza infection, some evidence suggests that mask use is best undertaken as part of a package of personal protection, including especially hand hygiene. The effectiveness of masks and respirators is also likely linked to early, consistent and correct usage. [293] A separate review study noted that the effectiveness of facemasks in containing the spread of airborne diseases in the general population is diminished largely due to improper use and lack of user compliance. [294] [233] [295] Another more recent review demonstrated the protective effect of masks on HCWs and other populations but pointed out the there was a lack of adequately designed and high-quality prospective studies on this issue, especially on wearing masks by the general public, and especially during an outbreak, and that more evidence is needed in this area. [296]

H1N1. A more recent review of studies done on the efficacy of public facemask use during the H1N1 pandemic found that facemask use demonstrated mixed results. Notwithstanding, it pointed out that a cluster randomized control trial found a significantly protective effect of facemask use. The broader conclusive finding was that facemask use was not significantly protective compared to regular hand hygiene (which was significantly protective). However, the review recommends an optimal intervention strategy that combines broad recommendations for frequent hand hygiene with targeted facemask use among high-risk populations (healthcare workers, schools-age children, the elderly) or in situations with high risk of exposure. It suggests that in view of the evidence, this is likely to contribute to preventing pandemic influenza infection. [297] [298]

Based on laboratory studies on mask effectiveness in protecting against inhalation of nanoparticles, a modelling study analysed use of N95 in the pandemic H1N1 situation. The study found that if 10% of the population wears facemasks and they are 20% effective in reducing susceptibility and infectivity, potential net savings are high. With the adult population group being the largest and contributing most to the economy, only 25% of the adult population would have to wear masks in order to achieve significant net savings. [299]

SARS: A small number of observational studies evaluating community-based mask and respiratory use following the outbreaks of SARS in 2003 reported that wearing masks and/or respirators appeared to provide protection from acquiring SARS. [300] [202] [293] [233]

COVID-19: A recent regression study noted that societal norms and government policies emphasising on the wearing of mask are associated with low mortality from COVID-19. [301] A systematic review of observational studies on coronaviruses in healthcare and non-healthcare settings across 16 countries provided best available evidence on optimum use of masks in the context of COVID-19. While direct evidence was limited (all studies were non-randomised), use of face masks is associated with protection from infection, with N95/respirators associated with more pronounced protection than disposable surgical masks or reusable 12–16-layer cotton ones. Eye protection, typically unconsidered, may confer additional benefit in community settings. [227] An analysis of the effect of face masks on in Germany found that the cumulative number of cases reduced between 2.3% and 13% over a period of 10 days after public use of face masks became compulsory. [302]

A number of statistical studies noted the association of mask-wearing with lower mortality. A regression study evaluating potential predictors of COVID-19 related mortality found that extensive mask usage as a part of cultural norm in some Asian countries (Thailand, Japan, South Korea, Taiwan, Hong Kong, Vietnam, Malaysia, Cambodia, Philippines, Mongolia and Laos) was associated with a fairly lower mortality rate. Mortality rate in a mask wearing population increases by 5.4% each week, as compared to 48% each week in a non-mask wearing population. [83] A statistical study also noted significant decline in daily COVID-19 growth rate with increasing effects after face mask mandate was issued in 15 US states and DC, decreasing by 0.9, 1.1, 1.4, 1.7, and 2.0 percent within 1-5, 6-10, 11-15, 16-20, and >21 days respectively. Mandates for face mask use may have prevented up to 230,000-450,000 cases by 22 May. [303] One study noted stronger association between mask wearing and lower mortality in the earlier phase of the pandemic, suggesting that mask wearing should be encouraged early in the early stages of an outbreak. [304]

Simulations. Modelling studies were conducted to simulate the benefit of wearing masks in the context of COVID-19. One study showed that when 2 people wore masks, the protection is multiplicative, not additive (when a surgical mask was used on both an infectious and non-infected person, there is a 2.8x improvement when compared to only the non-infected person wearing a mask, and a 17x improvement when compared to no mask at all). [305] Another modelling of the potential for face mask use in the COVID-19 pandemic by the general public was done based on varying adoption and levels of efficiency based on the following efficiency range gathered from earlier studies, and the inclusion of asymptomatically infectious persons.

On inward mask efficiency -

- 20– 80% for cloth masks, ≥50% typical
- 70–90% typical for surgical masks,
- >95% typical for properly worn N95 masks.

On outward mask efficiency -

- 0-80% for homemade masks, 50% typical
- 50-90% for surgical masks
- 70-90% for N95 masks

Key findings are:

- The product (in terms of mask effectiveness) and coverage level strongly predicts the effect of mask use on epidemiologic outcomes.
- Increasing coverage of mask-wearing is generally more effective than increasing effectiveness of masks (eg If a low effectiveness mask (homemade cloth mask) were used en masse, the population at large will benefit.)
- If mask adoption is delayed, a point of no return can rapidly be crossed, thereafter there will be no effect on mask adoption outcomes. Point of no return is further for a smaller effective transmission rate.
- Mask use has a strong non-linear effect on cumulative death and peak hospitalization.
- In severe epidemics, masks alone have a small effect, but its effect is non-trivial in terms of absolute lives saved, and mask use has a synergistic effect on outcome when it is coupled with other measures (e.g. social distancing).
- The level of protection masks afford against acquiring infection is slightly more important than the level of protection against transmitting infection. [306]

A more recent modelling study found that Rt in the COVID-19 pandemic can be reduced with the use of non-professional face masks if they were systematically deployed in the entire social network. Deployment in the early exponentially increasing stage can lower the Rt and lead to a subsequent linear increasing stage. [307]

Policy and General Practice: There is general consensus in the literature that professionals and the public must use masks properly and sustainably to be effective, and masks that are not well fitted or become blocked by moisture from breathing may be ineffective. [22] In some countries (eg Japan and Hong Kong), surgical mask wearing at times of health threats has been socially embedded as a general protective practice. [308] [309] Some national authorities recommend public use of masks in combination with other interventions (hand hygiene measures, avoiding crowded places and large gatherings etc) during pandemic influenza. [310] In the case with COVID-19, WHO's interim advice is that use of medical masks in community settings is not required as evidence is not conclusive on its protection of non-sick persons, and in view of unnecessary cost, procurement burden, inappropriate usage and the creation of a false sense of security. It states that masks might be worn in some countries, according to local cultural habits, but best practices on usage should be followed. [311] An updated interim guidance asked that decision makers on use of masks for healthy people in community settings consider the risk of exposure for and vulnerability of the population/person, feasibility (mask availability) and mask type. Appropriate usage and prioritisation for HCWs should be emphasised. [312]

Policies on mask usage should also allow for organisations and individuals to make common-sense exceptions and prohibit dangerous situations of usage. For example, cases of student deaths while taking physical education or gym lessons with mask usage in mainland China has stirred controversy over the rule of mask use during physical education lessons in schools. There has also been evidence that exercising with face masks induces physiological responses that affect muscle/brain metabolism, cardiorespiratory stress, and even immune responses that can increase chances of infection from COVID-19 or other respiratory infections, and social distancing while exercising is recommended as a less risky alternative. [313] [314] [315]

<u>Global shortage.</u> In the face of increasing global shortage of face masks with the evolving COVID-19 outbreak, alternatives, such as use of cloth masks (used by surgeons successfully during operations before disposable masks were available) are being suggested for consideration. Policy decisions on whether to adopt mass masking will also need to be carefully considered. [316] [317] Further into the pandemic, scientists and health experts are increasingly advocating for mass masking in public/crowded places, even with homemade/cloth alternatives, to lower the rate of COVID-19 transmission. [318] In Taiwan, mask supply was allocated to prioritised user groups, such as healthcare workers, patients and staff working in medical institutions, while the public were restricted to buy a predefined number of medical masks per week or could pre-order them online. Different types of cloth masks were concurrently scientifically tested by the government to better understand their filtration efficacy. [126]

<u>Homemade/cloth masks.</u> The few studies comparing the effectiveness of homemade/cloth facemasks against medical masks in non-healthcare specific settings conclude that homemade/cloth masks provide lower degrees of protection as compared to surgical masks or respirators (one study quantified homemade cotton masks as one third as effective as surgical masks). The studies also show that homemade/cloth masks provide some level of protection vis-à-vis a no mask scenario and can be used as a last resort or if a patient has no respiratory symptoms. [319] [320] [321] [322] [323]

A study examined homemade masks as an alternative to commercial face masks. Filtration efficiency and pressure drop (a useful measure of resistance to breathing) were compared across homemade masks using materials such as cotton t-shirt, tea towel, pillow case and vacuum cleaner bag and surgical masks. Surgical masks had the highest filtration efficiency while homemade masks had lower filtration efficiency across materials. Filtration efficiency of some materials (eg vacuum cleaner bag and tea towel) is comparatively better than other homemade materials but their high pressure drop rendered them unsuitable. Cotton t-shirt and pillow case with lower pressure drop were more suitable materials but had comparatively lower filtration efficiency versus other homemade materials. Similarly, a separate study found that masks made of cotton and towers provide better protection than those made of gauze.

Lower filtration efficiency of homemade masks was also partly due to greater variation in methods of fitting among users versus more consistent usage of surgical masks with their looped elastic straps. The studies suggest that a homemade mask should only be considered as a last resort to prevent droplet transmission from infected individuals, and that it would be better than no protection. Homemade masks are also not recommended for use in reducing transmission from aerosols. [319] [323]

A more recent study compared three cloth masks (commonly commercially available in the developing world) to respirators. While all cloth masks were only marginally beneficial in protecting individuals from particles < 2.5 micrometres, one of the cloth masks (one with an exhaust valve) had the highest efficiency for 30 and 100nm particle sizes. The other two types of cloth masks were simple rectangles with loops, allowing for leakage of a significant fraction of particles. [321]

Population behaviour and usage. A study on public compliance with face masks during the COVID-19 pandemic in Brazil observed that only 45.1% of study participants were found to wear their masks correctly, while 15.5% did not use masks at all. The remaining 39.4% wore their masks improperly, with 12.9% exposing their mouth and nose, 12.0% exposing their nose only, 17.8% touching their masks during use, and 6.5% wearing poorly fitted masks. This suggests that many mask-wearing individuals who believe they are protected are actually not in reality [324].

A 2020 study done on 345 online responders in Vietnam analysed the association between mask wearing and risk perception of COVID-19. It was found that people who chose to buy masks have higher risk perceptions than those who did not, and are likely to maintain such behaviours. There was also a change in the behaviour of the elderly who were more likely to wear masks after the COVID-19outbreak. The study also found that mask characteristics made no difference to people’s decision to mask or not. [325]

While some studies have pointed to mask wearing in community settings giving wearers a false sense of security, some have also pointed out that it could help increase awareness of other NPIs and prevent individuals from self-contaminating their nose or mouths with their hands. [326] [245] A Thai study found that those who wore masks were more likely to wash their hands often. [327]

A study examining the responses of the public to face mask mandates in the US found a reduction in time spent at home by 20-33 minutes (3-5%) after implementation of face mask orders, suggesting that face mask orders may provide a sense of security and that risk communications should accompany masking orders to prevent such a sense of security from undermining the effect of the measure or the effect from other social distancing practices. [328]

The Thai study (see above) also observed that inconsistent mask wearers also tended to have more physical contact and not practice social distancing adequately. Targeted delivery of public communications on consistent/correct usage of masks to this group can help extend the protective effect of masks to higher risk transmission situations/settings. [327]

Face shields. A recent preprint study evaluated the protection efficacy of face shields against cough aerosol droplets using breathing and cough simulators. Face shields showed a higher blocking efficacy as compared to medical masks, especially for finer particles of less than 2μm in diameter, blocking 10 times more of otherwise inhaled particles than medical masks. Face shields also achieved a higher blocking efficacy than medical masks when the breathing simulator was located directly in front of the cough simulator. However, face shield's blocking efficacy dropped to 40-60% when a vertical distance (30cm above and below) between the simulators was introduced. Total number of arriving droplets also dropped in such configurations. The study concluded that face shields performed best in protecting central and upper parts of the face while extension of shields may improve their protection for the cheeks and neck. Face shields can also protect the surrounding from exposure as no particles were identified in the vicinity of the coughing simulator. The study points out that the efficacy of face shields is comparable or even higher than that of medical masks, and policymakers can consider their use as an alternative for the general population. [329]

Other community hygiene measures. The recent COVID-19 outbreak has seen the widespread adoption of environmental cleansing and disinfection measures by governments worldwide. An interesting observation is the quarantining and disinfection of bank notes by some governments such as South Korea and China, considering that they change hands frequently and can facilitate virus transmission. In China, for example, the government stopped transfer and allocation of old bank notes across provinces/between cities most affected by the outbreak. Money from key virus-affected areas were sanitised with ultraviolet rays, heated, or locked up for at least 14 days before redistribution. Commercial lenders were also told to separate cash from hospitals and food markets. WHO concurrently encouraged use of contactless payments amidst the COVID-19 outbreak. [330] [331] [332]

Use of UV-C light. A recent article suggests use of UV-C light as a short term, easily deployable, and affordable way to limit virus spread in the current SARS-CoV-2 pandemic. UV-C light can inactivate both airborne viruses in aerosols and viruses deposited on actively used surfaces. While UV-C light at certain wavelengths may cause eye damage, carcinogenic effect on the human body as well as generating harmful ozone, studies have found that using UV-C light at a wavelength of 200-230nm presents a low risk on human health and maintains a low ozone production. Ways of use include placing UV-C light sources in ducts of ventilation systems, standalone systems with UV-C elements and fans to produce airflow through them (these can be placed in offices, classrooms and restaurants), UV-C radiation exposed to smaller spaces with high turnover of people (eg toilets, office pantries, transportation) when they are not in use. [333]

Luminore CopperTouch surface coating. A preprint study points to some evidence on the potential of Luminore CopperTouch™ copper and copper-nickel surfaces in inactivating filoviruses and SARS-CoV-2. SARS-CoV-2 viral titers on copper surfaces were reduced by more than 99% after 2 hours and Luminore CopperTouchTM copper-coated surfaces can shorten the viral particle survival time significantly compared to plastic or metal surfaces. This could be an effective and cost-friendly tool for mitigating the presence, growth and spread of the aforementioned pathogens on frequently-touched surfaces, as well as for enhancing infection control in highly trafficked areas like healthcare or long-term care facilities, public transportation, schools, hotels and airports. [334]

Mitigating possible fecal transmission. A review of case analysis on patients with COVID-19 and Gastrointestinal Tract (GIT) manifestations in China noted that viral particles were able to survive in the GIT longer than in the respiratory tract and possible faecal transmission. Viral shedding might last for more than a month with possible faecal transmission (see also COVID-19 Science Report: Clinical Characteristics). Another review noted possible viable viral spread through fecal transmission (eg fecal-oral, fecal-fomite, or fecal-aerosol/droplet), with observation of live virus in a few attempts to culture SARS-CoV-2 from patient stool samples, one of which after about 15 days after onset of disease. It is advisable to follow strict hand hygiene and regular disinfection of toilets. It was also recommended that patients not share toilets with their families even after being discharged. Notwithstanding, findings from attempts to culture the virus were based on very small patient numbers and additional studies are required to ascertain if prolonged fecal shedding of virus has significance. [335] [336] [337]

Mitigating transmission via wastewater plumbing system. In 2003, a SARS superspreading event was found in a Hongkong housing block, due to a wastewater plumbing system defect resulting in a virus laden droplet contamination. A study in 2017, which used Pseudomonas putida as a model organism to test for the presence of droplet contamination in wastewater plumbing systems, showed positive droplet fallout contamination and cross contamination of air from wastewater plumbing systems. Concerns were raised over high concentration of self-isolation or quarantine individuals as higher concentration of suspected infected individuals could contribute to higher viral load in wastewater plumbing systems and lead to increased spread of infection. Recommendations to ensure tight seal of leaks and monitoring of whole wastewater plumbing system performance were mentioned to decrease risk of viral transmission. [338]

Risk Communication

Risk communication in use of containment measures has been emphasised as misinformation has been rampant in past epidemics, leading to substantial public anxiety, reliance on word of mouth for knowledge, and purchase of ineffective and expensive products. [339]

Studies have also demonstrated that the general public do not uniformly adopt basic hygiene practices, and greater variability in adherence is observed for community hygiene practices than quarantine orders. A survey study revealed that respondents were less receptive to legal coercion to comply with such measures than quarantine orders [66], and literature has pointed to acceptability and perceived effectiveness of such measures as being vital to community adherence.

As such, guiding principles in the literature have emphasised that public education campaigns should be grounded in the science of risk communication, and that information disseminated through these campaigns should be accurate, clear, uncomplicated, not sensationalistic or alarmist, and as reassuring as possible. It is also best to start with such public communications before an epidemic. [22] [70]

In the evolving COVID-19 situation, various governments have prioritised the management of communications. In Taiwan and Singapore, for example, frequent press briefings and public announcements are made by ministers and even the vice president or prime minister (for Singapore) on developments on the outbreak and issues such as mask usage and handwashing. Concurrently, efforts are being made to tackle the propagation of misinformation in social media. [340] [29] [126] A recent UK survey study showed that worsening mood, fear and anxiety due to changing government rules as well as a poor understanding of state regulations were associated with decreased propensity to participate in enforced measures, such as being part of a national app-based contact tracing programme. [112]

Another recent study using data social media discussion forums (Reddit, Twitter, YouTube) explored the reasons for non-compliance with control measures and the inability of authorities to produce a “shared sense of inclusion” regarding protective measures. Key themes identified were misleading advice/information by various parties, persistent uncertainty regarding the rapidly spreading virus, perception of infringement to personal freedom, distrust of government/politicians in view of their conflict of interest, lack of economic support from the authorities, lack of concern by the younger generation for the more vulnerable older generation. [341] Another study pointed out the association between greater social responsibility/greater social trust and positive pandemic-related behaviours (news monitoring, social distancing, disinfecting) as well as less hoarding among adolescents in the US. Greater self-interest was associated with less social distancing and more hoarding behaviour. [342]

An interesting study which evaluated the vicarious traumatisation scores of the general public and nurses in Wuhan found that scores for front-line nurses were significantly lower than those of non-front-line nurses and the general public. Likely reasons for this are the stronger work experience and better psychological preparation/capacity of front-line nurses who were selected for the jobs, and their being more knowledgeable about the epidemic than the general public and non-front-line nurses. Non-front-line nurses also bear the additional burden of sympathy for front-line colleagues. The study suggests that propaganda strategies should be well-organised and effective to address this, coupled with early intervention measures to alleviate psychological issues faced by the general public and members of the medical team. [343]

Physical Distancing

Decreased social mixing/increased social distance has been a consistent response in past epidemics and are incorporated in the pandemic response plans and guidelines available today. [344] This includes restrictions on mass gatherings and voluntary or imposed social separation.

In the COVID-19 pandemic crisis, multiple countries have gone into lockdown situations and these have effectively curbed spread of the epidemic across the world and within the countries (see page 87). Social distancing comprises a large component of lockdowns, effected through measures such as stay-at-home orders, closure of non-essential businesses (eg certain shops, dine-in services, sports facilities etc), and closure of schools.

Emerging evidence has sought to evaluate which physical distancing measures worked best, through understanding influencing transmission dynamics, and studies on contact volumes, mobility, and outbreak risk in different settings. These can inform policy on targeted physical distancing measures at specific ‘higher-risk’ settings in the community, as universal measures involve substantial economic/societal costs. [166]

Evidence and Effectiveness Studies

Transmission dynamics. Factors influencing transmission rates are important considerations when identifying ‘high-risk’ situations. [345] (See also COVID-19 Science Report: Exit Strategies) These include:

- Pathogen-specific factors: Current evidence points to key transmission via respiratory droplets, possible transmission via aerosols, [346] [347] possible faecal transmission, [335] [348] [337] and possible transmission via surfaces with potential viral viability up to 72 hours on certain surfaces. [282] [198] [349] [350] [351] [283]
- Host factors: Median incubation period of about 5-6 days, [352] and emerging evidence that asymptomatic/presymptomatic transmission plays a significant role in epidemic spread. [94] [95] [96] [97] [98] [99] [100] [101] [102]

- Environmental factors: Population density, [353] [345] [354] [355] [356] sanitary conditions, and weather conditions. Emerging data suggests that cold and dry conditions aid spread of SARS-CoV-2. [357] [358] [283]
- Behavioural factors: Including personal hygiene and health-seeking behaviour.

Safe distance. A recent systematic review of observational studies noted that physical distancing of 1 metre or more was associated with significantly lower risk of infection, with added benefits likely with even larger physical distances (eg 2 metres or more). [227] A more recent paper re-examining the results of this systematic review noted physical contact (reducing infection risk by more than half) as the key factor behind the association of infection risk with physical distancing of less than 1 metre, rather than distance. The paper references to other data suggesting that the bulk of infection occurs through direct transfer of material rather than aerial route, and suggests that social distancing measures should focus on the prevention of physical contact rather than physical distance. [359]

Contacts reduction. A number of studies tracking contacts made after the recent implementation of physical distancing measures in COVID-19 lockdowns (see pages 87 and 99) noted clear association between decrease in cases and increasing social distancing. The studies also found that contacts per person generally reduced by about 70% or more to less than 4. (See Table 6)

The extent of household and external contact influences the outcomes of intervention, with social distancing measures least effective when both have approximately equal weight and delay to peak cases longest (taking about 5.5 weeks with mild symptoms). In situations where ether household or external contact hold a much higher weight, social distancing measures are most effective with interventions blocking transmissions into households (when external contacts have high weight) or with very few households seeded with infections to begin with and weakened inter-household contacts further preventing spill-over between households (when household contacts have high weight).

Individual risk of infection is also affected by household size and the nature of occupation. This varies from <0.2% for individuals who live alone to 5.4% for a household of 7. In situations where "essential workers" continue to work when social distancing measures are in place, their relative risk to the population average is 1.6 under strict social distancing measures while those in the same household as them have a heightened relative risk of infection of 1.4 versus 0.8 for individuals in a household with no continuing worker. [360] Another US study reported a significantly higher than expected health-related workplace absenteeism among workers in several occupation groups defined as essential/critical (healthcare support, personal care and service and production occupations etc) and which mostly did not have the option to work from home. Health-related workplace absenteeism in other occupations, on the other hand, saw a reduction or remained unchanged. This highlights the increased risk of SARS-CoV-2 transmission and the importance of working from home where possible. [361]

A study also pointed out that secondary infection was higher among household contacts than non-household contacts, estimated at 12.4% for household contacts (when defined as close relatives), 17.1% for household contacts (when defined as individuals living at the same address), and 7.9% for non-household contacts. [362]

Physical distancing can also be applied in a targeted rather than universal manner, to alleviate the societal/psychological impact of large-scale distancing measures. A modelling study on the UK projected that allowing and limiting contact clustering in social bubbles to families with young children and single occupancy households (those most in need of additional contacts) only increases Rt by <15% from its lockdown state. [363] Another study, which modelled scenarios where people are separated into close-knit groups (households) with a high rate of contagion and contacts between people across households are uniformly reduced, found that Rt increase was linear for scenarios with relatively small households but was less steep for scenarios with larger households. Establishment of bigger social circles can be considered instead of a uniform reintegration of all contacts during reopening from lockdowns. [364]

'Higher-risk' settings. Emerging studies have also identified settings or situations involving larger contact volumes and transmission risk (see Table 6).

Populations contained in high density accommodation (PCHDA). Considering the above transmission dynamics, PCHDA (such as cruise ships, correctional facilities, army barracks, worker dormitories, and nursing homes) have been potential epicentres for COVID-19 and other infectious diseases, for reasons of most of these involving unavoidable close contact in often overcrowded, poorly ventilated, and unsanitary facilities, as well as concentration of individuals likely to have comorbidities and poor health-seeking behaviour. [365] [366] [367] [368] [369] [370] A separate section in this report (see page 77) addresses the key concerns and suggested preventive/containment measures for PCHDA and PCHDA outbreaks.

Schools. Several studies have pointed to the comparatively larger volume of contacts recorded in school settings and the significant transmission reduction impact from school closures in COVID-19 lockdowns, with extent of attributable Rt reduction quantified to be as high as 58% in one study (Brauner et al). This aligns with the higher volume of contacts or higher proportion of contact reductions noted in school age groups (around 5 to 20 years) noted in other studies. While some studies (such as Guo et al and Leclerc et al) have suggested that the contribution of school contacts/clusters to epidemic impact was not apparently determinable, a few attributed this to their longer transmission path length (chain of successive cases), and the age group being less affected by COVID-19 or likely asymptomatic.

Retail and recreation. Several studies also assign the highest level of transmission risk to the retail (particularly grocery and pharmacy spheres) and recreation spaces (mostly shopping settings, religious gatherings, singing related (eg choir practice), weddings, sports related (eg gyms), and bars). One modelling study (Leeuwen et al), however, suggests that a large proportion of close-contact transmission occurs in schools, social visits, and workplaces and less so with visits to parks, bars, restaurants, and non-essential shopping.

Workplace. While most studies assign mid-level importance to workplace contacts and transmission, a few pointed to their significance with one review highlighting higher transmission risks in workplace meetings lasting about an hour and open-concept office settings.

Food processing plants. A review study and other COVID-19 related reporting have pointed out food processing plants as sources of clusters, likely due to the colder settings, proximity of workers and need to communicate loudly over the noise of machines. [371] [372] This has extended to similar concerns regarding distribution centres and warehouses. [373]

Public transport. While public transport has not been highlighted specifically in studies as sources of clusters or involving high transmission risk, a study on the Philippines pointed out need for a protection level of >90% in mass transportation systems where the disease is prevalent (when the number of infected individuals boarding the vehicle is possibly >1). Modelling projected the lowest rate of spread under the following parameters: passenger capacity can go up to 50% of maximum seating with ≥1m distancing practiced or only 10% of maximum seating without. Buses tend to generate more infections than trains due to their greater capacity, but trains facilitate faster transmission due to their smaller dimension. The study recommends a decrease in crowd density on larger vehicles or a decrease in travel time on smaller vehicles. [374]

Gatherings. Several studies noted the effectiveness of gathering bans. A study comparing effective contact rate (ECR) across 7 European countries (Post et al) noted that Germany achieved a similar ECR to Spain and Italy's (after a full lockdown) with a gathering ban only. A gathering ban is also among the three mitigation policies shown to be effective in Guo et al. (See also section on 'Monitoring mass gatherings' below (page 71)

Mass gatherings have been observed to exacerbate the scope of pandemics, especially that of respiratory diseases. A review of the evidence for mass gatherings (by Oxford COVID-19 Evidence Service) suggested that the effect of restricting and cancelling mass gatherings and sporting events on respiratory disease rates during pandemics needs further assessment. A UK study (Brooks-Pollock et al) also found that policies restricting large-scale gatherings have a comparatively smaller impact on an epidemic (result in a lower reduction rate to Rt) than policies restricting smaller group gatherings. The review pointed out that the best available evidence suggests multiple day events with crowded communal accommodations are most associated with increased risk of transmission of respiratory infections.

Cluster size. A review study noted that PCHDA settings (including eldercare settings), schools, religious gatherings and food processing plants involved larger clusters (more than 100 cases) while sport, bar, wedding, work-related settings involved comparatively smaller clusters (50 to 100 cases). [371]

Interaction type. Another review study noted that high quality person to person interactions (eg involving breathing out more particles such as speaking loudly or singing) have a > 60% risk of transmission. Such interactions include workplace meetings, group singing practices lasting about two hours, car travel with family members and family dinners. [375]

Transmission path length. A South Korean study pointed to religious gatherings and gym facilities as major cluster types with the longest transmission path length, likely due to their consisting of active young/middle aged adults who can subsequently spread the virus across multiple settings. [376]

Gender and other demographic factors. The same study observed that female-to-female transmissions occurred more than male-to-male transmissions, with women shedding more virus over time than men. A possible explanation provided was that females were likely to be less sick and could carry on the transmission path.

A few other studies suggest that children and younger adults are likely drivers of transmissibility. One of the studies, which evaluated behavioural changes of 11,342 Japanese in response to COVID-19, noted that participants who do not adhere to social distancing were associated with factors such as males, <30 years of age, lower-income households, drinking and smoking habits. Females and older adults were also more compliant in avoiding mass gatherings. [289] [377] [378] Another US study also associated health behaviours, older adults and higher socioeconomic status/education level with greater compliance to social distancing behaviour. [379]

Indoor and air-con settings. The vast majority of clusters were associated with indoor or indoor-related (mixture of indoor and outdoor spaces) settings, with air-con likely creating favourable transmission conditions. [371] Air conditioning airflow has been shown to prompt droplet transmission and direction of spread in a restaurant in Guangzhou. [380]

Identifying Potential Risk Areas

Based on what is known about transmission dynamics and 'high-risk' settings/conditions, Table 7 lists specific risk areas. Understanding the key influencing factors for clusters can aid accurate and continued identification of emerging risks. The following considerations can help guide identification of specific locations at risk. (See also section on ''Vulnerable Groups/High Risk Settings' on page 77)

'Hidden' settings. Consideration of situations with high quality interactions, a large number of younger or active people, and taking place in sectors not habitually visible to society, can help identify unanticipated outbreak sources. The commercial sex sector, for example, can be a potential source of clusters, with likely poorer health-seeking behaviour and overcrowding conditions in unlicensed brothels/rented rooms. Illicit activity spheres like drug using networks, gangs and triads are also potential sources of risk, for similar reasons.

Dating apps, which involve extended chains of contact points as well as group gatherings, but are typically obscure to the public eye due to privacy concerns, can also evolve large and unexpected clusters.

Disability settings and mental health institutions have also been cited as potential but obscured spaces of infection spread. Apart from the confined nature of their environments, caregiving in these settings necessitates frequent physical contact and pronounced vocal communication. [381] [382]

Super spreaders. Super spreaders play a significant role in amplifying transmission, with cases of single infected persons infecting an especially large number of people reported in Wuhan, South Korea and the US. Potentially, 80% of transmission is caused by only 10% of infected individuals. [371] [383] [377] Identifying active, highly interactive, and likely asymptomatic/presymptomatic individuals who move across multiple disparate 'high-risk' settings can help single out and focus mitigation efforts on potential super spreaders.

When risk conditions interact. Super spreaders operating in 'hidden' settings is the likely set-up for a black swan scenario. A commercial sex worker meeting multiple clients, some of whom are engaged in gangs/drug using networks, can lead to unforeseen and extensive spread.

Vigilance in known spheres. Continued social distancing vigilance in settings already known with widespread public consciousness to be 'high-risk' is important. These settings and their accompanying activities, such as schools, retail or recreation, tend to be extensive, ubiquitous, and so much a part of day-to-day life that it can be easy for a single festering cluster to slip through the surveillance net.

The Identification of potential risk areas is not just the brainstorming of specific locations but involves understanding individual risk factors in transmission, foreseeing how these can come together in at risk settings, and how such settings can further interact and augment risk. Efforts at identifying potential risk areas should also be ongoing as 'definitions' of higher risk settings/individuals can be elusive and can change with societal/environmental developments.

The identification of risk areas supports targeting of physical distancing efforts. Identification of risk areas can also support targeting of detection/contact tracing efforts (there is emerging evidence and consensus that targeted mass testing and biosurveillance of high risk groups can improve the containment of epidemic spread and conserve resources. [384] [385] [386]

Other Relevant Observations

By COVID-19 related symptoms and age. A US study (Canning et al) using data from a web-based survey found that while the older population and people with symptoms of shortness of breath have lesser close contacts and higher compliance to social distancing measures, people with fever and dry cough have not engaged in greater distancing.

By day type. A study (Ricon-Becker et al) noted peaking of COVID-19 new cases on Thursday-Friday and peaking of death tolls on Wednesday-Thursday in 7 out of the 12 countries studied, likely due to increased social mixing on weekends followed by a median time lag between infection, manifestation of clinical symptoms, and hospitalisation. Further research is required to ascertain this link, and if proven to exist, public health policies can be targeted at respective days of the week.

Table 6: Studies on physical distancing measures/contact patterns in relation to COVID-19/COVID-19 lockdowns

Author/Source	Description/Findings
Jarvis et al [387]	A UK study which surveyed 1,356 participants who recorded 3,849 contacts found a 73% reduction in the average daily number of contacts observed per participant after implementation of the lockdown. Pointing out significant delays between infection, onset of symptoms, and hospitalisation, the study recommended tracking such behavioural change data for rapid assessment of impact of distancing measures.
Freeman and Mahmud [388]	A Berkeley Interpersonal Contact Study (BICS) of 1,425 respondents noted that 85 % reported having contact with less than 4 people and 50% reported of no contact outside of their household. This was a decrease of 70% in daily average number of contacts per person when compared to a similar survey study in 2015.
Backer et al [389]	A recent repeat of a cross-sectional 2016/2017 survey in the Netherlands pointed out that the physical distancing measures implemented which contributed to halting of the COVID-19 epidemic reduced the average number of contacts made in the community per participant from 12.5 to 3.7 (71% reduction). Similar to findings on contacts in school settings mentioned above, the reduction varied according to household sizes, occupation and age groups, and was highest for children and adolescents (between 5 and 20 years) and lowest for elderly above 80 years old.
Zhang et al [390]	A modelling study on China's COVID-19 experience found that 30 days of substantial social distancing reduced Rt from 2.2 to 1.58 and in Wuhan and Hubei and from 2.56 to 1.65 in other provinces. (See also Table 9 for more details on the study.)
Voko ad Pitter [391]	The study assessed the changepoint in the COVID-19 epidemic and its association with level of social distancing in 28 European countries. Changepoints were associated with a significant decline in epidemic spread in 23 out of 28 countries (incidence of COVID-19 cases increased by 24% per day before the changepoint but reduced to 0.9% with increasing social distancing index after the changepoint. A clear dose-response association was observed between decrease of cases and increasing social distancing index.

Author/Source	Description/Findings
Vopham et al [392]	The study assessed the association between state policies, social distancing, and COVID-19 incidence and mortality in the US. 45 states issued stay-home orders and were associated with a 35% increase in social distancing. Each unit increase in social distancing was associated with a 29% reduction in COVID-19 incidence and 35% reduction in mortality.
Bielecki et al [285]	The study "SARS-CoV-2 infections in young, healthy soldiers in two spatially separated groups". It noted that stringent social distancing and hygiene measures (when implemented prior to detection of first case) results in reduced COVID-19 infection rate. These measures are also effective in the case of asymptomatic infection. [285]
Badr et al [393]	The study on the effect of mobility pattern changes across the US noted that mobility patterns are strongly correlated with decreased COVID-19 case growth rates for the most affected counties (Pearson correlation coefficients > 0.7 for 20 of the 25 counties evaluated).
Klepac et al [353]	A UK study of 378,559 reported contacts by 36,155 participants pointed out some observed patterns in the volume of contacts made in various settings and by different age groups, which can be used to inform decisions on social distancing measures. The following observations were made: • On average, participants reported over three times more conversational than physical contacts • On average and across settings, strong age-assortative mixing noted, with concurrent high volume of interactions between children and parents • Dominant eigenvectors that will drive transmission during the exponential phase of an epidemic is highest for the 30-34 age group • Inter-generational mixing at home is especially pronounced in physical contacts • Contacts at work showed less age-assortativity than contacts at home and are predominantly non-physical • Contacts in other settings (not home, work or school) are age-assortative for younger groups but less age-assortative for older groups, with notable contact intensity between older participants and other adults • Both physical and non-physical contacts are higher at home and at other (not school or home) locations during weekends • Participants who spent most time in areas with density between 1,000 and 10,000 people per km reported average of 15 contacts per day while whereas participants in areas with fewer than 10 people per km recorded average of fewer than 10 contacts

Author/Source	Description/Findings
	• Positive association between contacts within the home and household size with saturation at about 4 contacts • Within school-aged groups, more contacts were reported on average at school than in other settings.
Bryant and Elofsson [394]	A study models the impact of changes in mobility patterns in 11 European countries and their effect on the R0. Mobility patterns were measured in 6 different sectors, with grocery and pharmacy being the clearest indicator for Rt change, with a narrow confidence interval, and accounting for over 90% of the change in Rt.
Kim and Jiang [376]	A study of contact tracing data from 3,127 confirmed cases in South Korea observed that female-to-female transmissions occurred more than male-to-male transmissions. Women also shed more virus over time than men, likely because men were more likely to die or be critically ill with less opportunity to spread the virus. It was also observed that children and adolescents infected their parents, and older adults infected other older adults. The 3 major types of clusters were nursing homes, religious gatherings and gym facilities. Path length (a measurement of how far the transmission chain of successive cases can go) was found to be longest for religious gatherings and gym facilities, likely due to their consisting of young/ middle aged adults with active behaviour.
Zhang et al [395]	Another study based on survey data on Wuhan and Shanghai found that the largest number of contacts were recorded in school settings, and school closures eliminated contacts between school-aged individuals.
Post et al [396]	Another similar study compared measures implemented and the effective contact rate (ECR) across 7 European countries. It was observed that immediate effect with significant change points in ECR occurred with the first set of measures taken by government of banning events and closing schools (eg from 9.14 to 1.60 in Italy and from 3.14 to 1.18 in Spain). The effect of additionally closing bars and restaurants with a lockdown seemed limited (further to 0.91 in Italy and to 0.48 in Spain, and minimal effect in Sweden), and the ECR after a full lockdown (as implemented in Italy, Spain, UK and Belgium) was not necessarily lower than the ECR after only a gathering ban (as in Germany and the Netherlands).
Prakash [375]	A study that reviewed and analysed transmission rates across detailed COVID-19 related case-studies found that in general, high quality person to person interactions have a higher than 60% risk of transmission: • Workplace meetings that last about an hour long – 72.7% • Open office setting with no physical separation between people – 78.7% • Practicing singing in a group for around 2 hours involving

Author/Source	Description/Findings
	high mixing interactions – 86.9% • Travelling in a car with family members – 100% • Family dinners – 100% In contrast, travelling on metro trains with masks and possibly no verbal communication involves much lower transmission rates (~0%). The study also noted that Infections can be passed on by seemingly healthy individuals with 44-68% of infections spread in the pre-symptomatic phase.
Leclerc et al [371]	The review identified possible places that are linked to clusters of COVID-19 cases. Large cluster sizes (with maximum cluster > 100 cases) mostly involved hospitals, elderly care, worker dormitories, food processing plants, prisons, schools, shopping and ship settings, and religious venues. Clusters with maximum cluster sizes between 50 and 100 mostly involve sport (65 cases out of 201), bar (80 cases), wedding (98 cases), work (97 cases), and conference (89 cases). 9 clusters were linked to food processing plants and these led to large clusters. The setting with the greatest number of clusters was households with all clusters < 10 cases. Indoor/indoor related settings (21 out of 22) make up the bulk of the clusters.
Sypsa et al [397]	The study on Greece examined the impact of various social distancing measures during the country's lockdown. Rt decrease attributed to school closures, a decline in work contacts and reduced leisure activities was 18.5%, 10.3% and 24.1% respectively. Only implementing multiple interventions at the same time could reduce Rt to below 1.
Brauner et al [398]	The modelling study with 41 countries evaluated the effectiveness of different NPIs on curbing spread of COVID-19 and their perceived burden placed on the population. Six NPIs were found to have a high (>97.5%) posterior probability of being effective: closing schools (mean reduction in R: 58%), limiting gatherings to 10 people or less (24%), closing non-essential businesses (23%), suspending high-risk businesses (19%), testing symptomatic patients (18%), and stay-at-home orders (17%). This data was combined with that from an online best-worst scaling survey on how burdensome the public perceived the NPIs to derive effectiveness-to-burden ratios. NPIs like school closure, symptomatic testing, suspension of businesses involving high transmission risks, and limiting the sizes of gatherings recorded good effectiveness-to-burden trade-offs; while closing most non-essential businesses and issuing stay-at-home orders imposed a strong burden with minimal additional impact.

Author/Source	Description/Findings
Li et al [399]	The study using a meta-analysis of more than 190 COVID-19 research papers and fitting of an epidemiological model to >167 geographical areas found that mass gathering restrictions and school closings resulted in the largest incremental infection rate reductions (29.9% and 17.3% respectively). Stay-at-home policies, in combination with others, effectively reduced Rt to below 1.
Korevaar et al [356]	The study quantifies the impact of NPIs on COVID-19 transmission in the US. The mean Rt was 3.4 without NPIs (level 0) and 1.3 at the highest level of NPIs (level 3). The largest gains occur when moving from no NPIs (level 0) to low level NPIs (level 1), which encompasses imposing limits on mass (500-100 people) gatherings and partial school closures. This suggests that prohibition of mass gatherings, or "superspreader events", corresponds to the greatest decline in transmission relative to other measures. Notwithstanding, Rt values below 1 were never obtained.
Guo et al [400]	A modelling study on interventions in the US noted that states which enacted the mitigations quickly have a lower prevalence of COVID-19 cases, stressing the importance of swift implementation of measures. The study noted that only three out of the nine mitigation interventions (non-essential business ban, large gathering ban of more than 10 people, and restaurant/ bar limit to dining out only) were found to have statistical significance in reducing COVID-19 cases. Notwithstanding, observing effect from other mitigation strategies may require more time. School closures, for example, may take a longer time to take effect as young people are less affected by COVID-19 and likely asymptomatic.
Delen et al [401]	The study examined the effectiveness of social distancing policies across 26 countries over 5 weeks, from mobility patterns and disease transmission rate with data from Google LCC and Apple Inc. and COVID-19 disease statistics. Changes in mobility were accountable for 47% of the variation in the disease transmission rate, with mobility change in public places contributing to the bulk of the transmission rate reduction. The relative significance of different mobility factor is illustrated in Figure 2.
Deforche et al [402]	The study showed that Rt in 33 of 35 Western countries fell to <1 during lockdown. One third of the effect actually happened 6 days (on average) before the lockdown. Decreased mobility in retail and recreation was also a predictor of lower Rt during the lockdown.
Leeuwen et al [403]	This study combined social contact matrices with time-use data in a dynamic-transmission model to explore the impact of reduction in contacts on the epidemic curve of COVID-19 in the UK. Results showed that closing schools had the greatest reduction in contacts in young age groups (0-24 years), closing workplaces had the greatest

Author/Source	Description/Findings
	impact on adults (aged 16-64) and reduction in social visits impacted the elderly age group the most. Reduction of these activities had the greatest impact on reducing the epidemic curve and peak in terms of physical contacts, with schools having the largest impact, followed by social visits, and then workplaces. The model suggests that a large proportion of close-contact transmission occurs in schools, workplaces, and social visits and less so with visits to parks, bars, restaurants, and non-essential shopping.
Pullano et al [404]	A study evaluating the impact of lockdown on mobility patterns in France found that mobility reduction was stronger for long range leisure trips (>100km), rush-hour movements and weekend daytime movements, suggesting the effectiveness of measures reducing recreational activities and work and school closures. “Mobility reduction % in all trips was homogeneously distributed across age classes” but long trips reduction was higher for seniors. Mobility reductions were strong associated with regions with an active population (24-59 years old), workers employed in sectors highly affected by the lockdown, and high hospitalization rates, and fairly correlated to regions’ standard of living.
Canning et al [405]	A modelling study using collected data from an open-access, web-based survey in the US found that: • The older population have significantly lesser close contacts, as compared to the younger generation. • People with symptoms of shortness of breath have higher compliance to social distancing measures. • People with fever and dry cough, two of the common COVID-19 symptoms, have not shown to be engaging in greater social distancing. The study suggested policy makers increase emphasis and clear guidance on relevant symptoms of COVID-19.
Lau et al [377]	The study noted infected children and younger adults (< 60 years old) may be 2.38 times more likely to effect transmission than infected elderly, and may be main drivers of super-spreading.
Ricon-Becker et al [406]	A study noting peaking of COVID-19 new cases on Thursday-Friday and peaking of death tolls on Wednesday-Thursday in 7 out of the 12 countries studied linked this to increased social mixing on weekends followed by a median time lag between infection, manifestation of clinical symptoms, and hospitalisation. Further research is required to ascertain this link, and if proven to exist, public health policies can be targeted at respective days of the week.
Ebrahim et al [407]	Mass gatherings have been observed to exacerbate the scope of pandemics, especially that of respiratory diseases. Anecdotal reports from the 1957 influenza pandemic, for example, suggested that the

Author/Source	Description/Findings
	influenza first emerged in Indochina and Malaysian pilgrims travelled with it to Mecca and transmitted to fellow pilgrims from the rest of the world. Similarly, the recent COVID-19 outbreak in Iran began in Qom, a city that attracts 20 million annual pilgrims from neighboring countries.
Oxford COVID-19 Evidence Service [166]	The review pointed out that the effect of restricting and cancelling mass gatherings and sporting events on respiratory disease rates during pandemics in general is poorly established and requires further assessment. The best available evidence appears to suggest multiple day events with crowded communal accommodations are most associated with increased risk of transmission of respiratory infections.
Brooks-Pollock et al [408]	A recent study conducted in the UK based on data collected in 2009-2010 on social contacts found that policies restricting large-scale gatherings have a comparatively smaller impact on an epidemic (result in a lower reduction rate to R0) than policies restricting smaller group gatherings. This is mainly due to the relative rarity of large-scale gatherings as compared to smaller group gatherings occurring more frequently. Percentage change in Rt in the absence of participation in a gathering is 0.8% for groups > 100 individuals, 2.2% for groups > 50 individuals, 6.4% for groups > 20 individuals and 11.4% for groups > 10 individuals. This suggests the consideration of policies preventing gatherings of smaller groups (eg between 10-20 people) which are more commonly occurring.

Figure 2: Relative importance of mobility factors in determining COVID-19 transmission rate

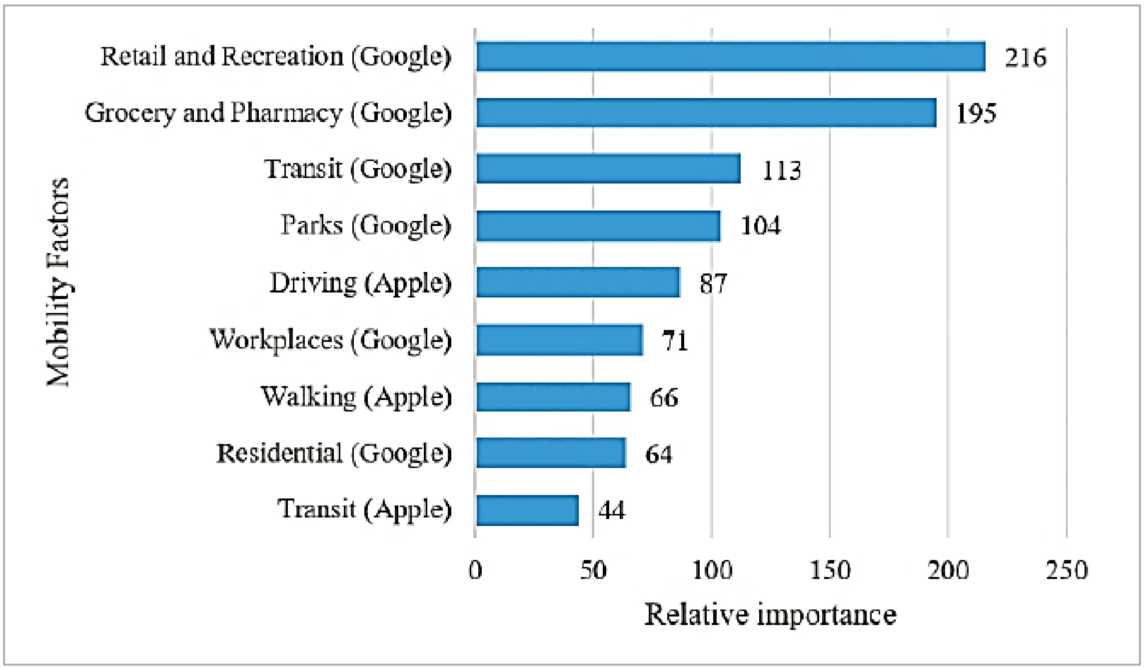


Table 7: Potential 'High-risk' settings/individuals in the community

Settings/Situations/ Individuals	**Risk Considerations**											
	Close / multiple contacts	Ventilation / Enclosed spaces/	Sanitation	Loud/ exertive communications / High quality interactions	Duration of proximity	People with comorbidities	Poor health-seeking behaviour	'Hidden'	Cold, dry conditions	Young/ active people	Air-con conditions /airflow	Other remarks
Populations contained in high density accommodation (Egs: Prisons, army barracks, navy and other shipping vessels, nursing homes, mental health institutes, correctional facilities)	√	√	√	√	√	√	√	√				
Unlicensed brothels/rented rooms	√	√	√	√	√	√	√	√				Cluster from sex workers detected in Japan [409]
Drug using networks	√	√	√	√	√	√	√	√				
Gangs/triads	√	√	√	√	√	√	√	√				
Dating apps like tinder and grindr	√				√			√				
Non-residential disability/eldercare day centres	√	√		√	√	√	√	√				
Food processing/meat packing facilities (including grocery packing in cold rooms)	√	√		√	√				√			Outbreaks in the US [371] [372]
Distribution centres/warehouses	√	√		√	√							
Ice-skating rinks	√	√		√	√				√	√		
Swingers club	√	√		√	√		√			√		
Massage parlours	√	√			√							
Abattoirs	√		√	√	√							Mixing with animals
Poorly ventilated and confined shopping areas	√	√		√						√		
Gyms	√	√		√	√					√	√	Zumba class/gym

Settings/Situations/ Individuals	Risk Considerations											
	Close / multiple contacts	Ventilation / Enclosed spaces/	Sanitation	Loud/ exertive communications / High quality interactions	Duration of proximity	People with comorbidities	Poor health-seeking behaviour	'Hidden'	Cold, dry conditions	Young/ active people	Air-con conditions /airflow	Other remarks
												clusters in South Korea [372]
Choir practices	√			√	√							Clusters in the US [372]
International schools	√			√	√					√		Less centralised control, and risk of imported cases
Call centres	√	√		√	√						√	Outbreak in South Korea [410]
Offices with open concept sitting and frequent/more than hour long meetings	√	√		√	√						√	
Delivery workers	√									√		Movement across multiple locations/ communities
Cleaners	√											
Taxi drivers	√	√			√							
Tuition/violin/piano teachers visiting homes	√				√							
Home nurses/caregivers	√				√	√						
Work out instructors	√			√	√					√		

Other Policy and Implementation Considerations

Timing of implementation. A summary of the evidence for social distancing at Oxford COVID-19 Evidence Service has suggested that timing and duration of such measures are crucial (see also page 99). [166]

Guidances. Public Health England has also published guidance on social distancing for everyone in the UK, and on protecting older people and vulnerable adults. [411]

Monitoring mass gatherings. A recent review article suggested that institutions involved in outbreak monitoring should keep an inventory of mass gatherings and provide advance warnings about outbreaks and recommendations on event cancellation, crowd size limits, and alternatives to the organisers. [407] WHO has recently updated its recommendations for managing the public health aspects of MGs in relation to COVID-19. [412] These include a risk assessment tool that enables organisers to methodically review key considerations and risk management steps for hosting an event with a weighted-system approach that also incorporates risk reduction through mitigation measures. [413]

Considering economic/societal impact/trade-offs. Literature, however, has pointed out that social separation, particularly for long durations, can cause loneliness and emotional detachment, disrupt social and economic life, and infringe individual rights. [7]

<u>Impact on mental wellness.</u> In the recent COVID-19 outbreak, for example, a survey by the Chinese Psychology Society has found that 42.6% of 18,000 Chinese citizens tested positive for anxiety and 16.6% of 14,000 evaluated may be dealing with moderate to severe depression while on lockdown in their homes. China's National Health Commission has deployed a variety of mental health services (such as telephone- and online-based counselling services) to support this phenomenon. [414] [415] A cross-sectional study conducted among the general population in mainland China after the re-opening of Wuhan also noted a higher overall mean Impact of Event Scale (IES) score among the participants (21.5 ± 7.0). [416] Notwithstanding, a study examining the effect of stay-at-home orders on mental health symptoms in the US (based on internet search queries) suggested that mental health search queries, which increased rapidly prior to issuance of the orders, dissipated after their implementation despite decreased social contact. Another recent study noted a negative association between adherence to social isolation measures and coronavirus anxiety, possibly linked to less core belief violation and greater meaning made. More research is needed to examine sustained effects of social separation. [417] [418]

<u>Lifestyle changes.</u> Social separation/staying at home can also effect lifestyle changes that eventually impact population health. A study assessed the impact of the COVID-19 pandemic on eating habits and lifestyle changes of 3,533 Italians and showed that 48.6% believed they gained weight, with 40.3% having a slight weight gain and 8.3% having a huge weight gain. 17.7% perceived less appetite while 34.4% perceived more appetite. Perception of weight gain and increased appetite were associated with individuals who have stopped work or commenced smart working. No significance difference was noted on the proportion of individuals engaging in physical activity before and during the lockdown but individuals previously engage in physical activity increased frequency of training during the lockdown. Smoking habits have been reduced and sleep hours increased during the lockdown. [419] Another study examining the impact of COVID-19 isolation measures on lifestyle in Australia found that 24-hour total energy intake in 2020 was 9.5% higher than 2018/2019, and study participants walked less but maintained their vigorous activity levels. Such diet and physical activity patterns actually sustained even after easing of physical isolation restriction, and can have undesirable consequences for both mental and physical wellbeing. [420]

A recent study on Canadian children and youth noted a significant decline in their physical activity with the COVID-19 pandemic, while a significant increase in leisure screen time and family time spent on sedentary behaviours was observed. Girls in both age groups reported less physical activity, more social media use, and more time sleeping compared with boys. Having a younger parent, parental marital status (cohabited rather than living singly or apart), living in detached homes, and having a dog were associated with positive physically active behaviours, such as outdoor play, while the greatest associations were parental encouragement and co-participation with such physical activities. The study highlights the need for both disease prevention and health promotion efforts to preserve child health during the COVID-19 outbreak and future pandemics. [421]

Quite interestingly, social distancing during the COVID-19 outbreak in South Korea resulted in the doubling of the Public Bicycle Sharing System (PBSS) usage (compared against 2019 usage). Use of PBSS as a public transport alternative and leisure activity may account for the surge in usage. PBSS can be promoted as an alternative to public transport in outbreak situations as it facilitates social distancing measures, reduces the risk of COVID-19 infection to a greater extent as compared to public transport, and promotes physical activity. Relevant authorities can promote the maintenance of good hand hygiene and provide necessary surface disinfectant near PBSS stops to prevent the spread of COVID-19 through common surfaces. [422]

Individual rights and equity issues. Community restrictions also raise profound questions about the government's right to interfere in such areas as faith (religious gatherings), family (funeral attendance), and protection of the vulnerable.

Quantifying cost/benefit. A recent study measured the relative transmission reduction benefit and social cost of closing different industry categories in the US in relation to the COVID-19 pandemic. Risk-reward trade-offs were weighed according dimensions of importance (consumer importance, employment, pay-roll, and receipts) and dimensions of transmission risk (visits, unique visitors, person hours at moderate/high density, average median distance travelled etc). Locations such as banks, general merchandise stores (e.g., Walmart), dentists, grocery stores, and colleges and universities have high importance but low transmission risks while gyms, sporting goods stores, liquor and tobacco stores, bookstores, and cafes have low importance but high transmission risks. [423]

Practising/effecting social distancing. Governments should dedicate themselves to non-discrimination and transparency when planning social distancing measures. It is important that such policies are implemented fairly and with as broad involvement in the planning process as possible. [7]

For countries/regions advocating social distancing practices without a mass 'blanket' stay-at-home order, encouraging change in population behaviour related to greeting habits and proximity to one another can be challenging. Some countries/organisations have employed visible markers to help consciously remind people to stand further apart from each other in queues or meeting settings (see Figure 3). Others have initiated innovative messages motivating such behavioural change. Examples of such messages include:

'Do not change your behaviour to avoid being infected. Assume you are infected, and change your behaviour to avoid transmitting.' (hashtag from Alexandra College)

'Imagine a "zone" around you. People beyond are non-threatening. Choose who you let in, and if you have to, move on quickly.' (Jason CH Yap, personal communication, 19 March 2020)

Figure 3: Distancing solution in a Danish supermarket [424]

Workplace and School Closures

Evidence on Effectiveness

School closures. There is some limited evidence that school closures do reduce seasonal influenza transmission. Recent reviews of the epidemiological evidence have concluded that school closures may have some benefits. [425] (see Table 8).

Table 8: Epidemiological studies on school closures during influenza outbreaks

Author/Source	Description/Findings
Earn et al 2012 [426]	Epidemiological studies have estimated that school closures have reduced the total number of cases of pandemic influenza by 28%, 35% and 52% in Calgary, Edmonton, and the province of Alberta, Canada
Cauchemez et al 2008 [427]	Routine school holidays in France have been estimated to prevent 16–18% of seasonal influenza cases
Heymann et al 2004 [428]	A retrospective cohort study found that school closure was associated with significant decrease (42%) in the diagnoses of

Author/Source	Description/Findings
	respiratory infections during an influenza outbreak (H3N2 influenza local outbreak in Dec 1999)
Wu et al 2004 [429]	By fitting a model of reporting and transmission to case data, transmission of H1N1 in Hong Kong was estimated to be reduced by 25% due to closure of kindergartens, primary and secondary schools based on model studies.

A systematic review of predictive modelling studies suggests that the intervention could lead to reductions of 20 to 60% in the peak incidence of an epidemic and smaller reductions in epidemic size. These reductions are expected to be greater if the intervention causes large reductions in contact, if transmissibility of the virus is relatively low (R0<2), and if infection rates are higher in children than in adults. Findings on timing and duration of closure are less definitive but long closures are generally predicted to lead to greater impact on reductions although closure beyond 8 weeks generally yield minimal additional benefit. Several studies propose early closure to be the most effective but some concluded that intermediately timed closures to work best.

WHO guidelines state that school closures have the greatest benefit for seasonal influenza when applied early in the course of the outbreak. Notwithstanding, the benefit has to be weighed against cost of disruption. [8]

Notwithstanding, a recent systematic review pointed out that the earlier modelling studies based on influenza outbreaks offered limited informative value for COVID-19. While modelling studies on COVID-19 support the use of school closures as part of a larger package of measures, the study pointed out that with a likely R0>2, impact from school closures is unlikely to be great according to earlier influenza outbreak modelling studies (see above). Earlier UK analyses on the 1957 Asian influenza pandemic suggest that school closures would reduce epidemic size by less than 10% when Rt is 2.5-3.5 (similar to that of COVID-19). However, more recent studies on school closures in the COVID-19 pandemic suggests that school closures significantly reduce overall transmission and disease burden, despite lower susceptibility to infection among school-aged individuals, due to the largest number of contacts occurring in school settings (see Page 59). [395]

Time to effectiveness. A recent study of school closure impact in some European countries noted that a reduction in the growth rate of daily confirmed cases took place approximately 9 days after the closure of schools. [430]

Partial closures. A study pointed out that Sweden's partial school closures for students aged 16 and above only led to a reduction in the growth rate of daily confirmed cases around 17 days later, and 8 days after the banning of mass gatherings, suggesting that targeted school closures affecting older students without more widespread social interventions are unlikely to be effective. [430]

Considerations and Complementing Policies

Productivity. School closures would mean children/adolescents missing support structure of the school system and affecting productivity as parents may need to stay home to care for young children. The implications of extending this over months or longer (as pandemics can endure for such periods) can be considerable. [22] [431]

HCW productivity. A recent study evaluated the impact of school closure for COVID-19 on the US healthcare workforce and the net mortality effect. It found that about 15% of healthcare provider households will be in need of childcare during a school closure, assuming non-working adults and 13-year olds in the households can provide childcare. School closures need to reduce cases by over 25% to unambiguously provide a net reduction in COVID-19 mortality, assuming 2% baseline mortality rate. [432]

Another simulation study of school closures across the US estimated effectiveness to range from 172 to 218 fewer hospital beds used per 100,000 and HCW absenteeism rate to range from 7.5% to 8.6%. Substantial variations in these units were noted at the county-level (range of 2.0% to 18.6% for absenteeism and 88 to 280 for hospital beds). Childcare subsidies for HCWs is identified as a potential solution to help maintain healthcare systems during a pandemic – these could be used to incentivise work attendance with extra wages, alleviate financial burden on the entire household, and enable other family or household members to participate in child care (in the likely scenario that many child care avenues would likely be closed). The study estimated that 98.8% of counties would find it less expensive to provide child care to all healthcare workers with children than to bear the costs of healthcare worker absenteeism during school closures. [433]

Children's physical/mental health. A recent review article pointed out that prolonged school closure and home confinement may have negative effects on children's physical and mental health, due to reasons such as longer screen time, being physically less active, irregular sleep patterns, and reduced social interactions. Governments could consider sourcing for and leveraging on existing online education courses that encourage healthy home-based lifestyle (physical activities, balanced diet etc) and making them accessible to the children and families. [434]

Other secondary adverse effects. Another review article mentioned that school closures need to be balanced against secondary adverse effects, including increased dropouts, child labour, violence against children, teen pregnancies (during the Ebola epidemic), and widened inequality due to lack of access to distance learning technologies amongst disadvantaged children. Children's health can also be affected due to lack of subsidised meal programmes, vaccinations and school nurses. Other adverse effects are parents forgoing employment or increasing reliance on vulnerable older relatives. [435]

Other Considerations, Reviews and a modelling study also note that benefits of school closures may be marginal/less than modelled, as contacts between children and adults/elderly continue as part of informal childcare. Heightened risk to older people was also pointed out.

Considering the high costs of prolonged closures, as well as other secondary effects and considerations, schools remaining open only for children of healthcare/essential workers can be an alternative strategy. Policy makers/researcher can also look to school social distancing interventions in countries that have reopened schools as alternatives. [436]

Workplace closures present particularly difficult ethical issues. Apart from the uncertainty of their effectiveness, workplaces are vital to the livelihoods of both employers and employees, and closing them can cause severe financial hardships. [7]

Ideally, public health authorities should work cooperatively with businesses, schools, and communities prior to an emergency in an effort to establish mutually agreeable closure procedures.

Where workplace closures should be deemed absolutely necessary and legally enforced, it would be preferable to subsidise lost profits and incomes as necessary to create incentives for complying with closure requests. This approach was used extensively in countries affected by SARS for people placed in quarantine. [437]

The amount of resources needed to compensate for lost income or profits for the closure duration can be enormous. In 1918 each of the waves of the pandemic lasted for several months, and most locations were hit by multiple waves. [438] Countries could consider tactical closures, such as closing only those entities that most facilitate transmission. For example, schools have been identified as a primary driver of seasonal influenza and could be targeted for closure. Countries might also consider closures as an interim measure to slow down initial spread of disease through the community and buy time for other preparations, and then relaxed when the level of disease in a community exceeds a predetermined level. [439]

Some countries have attempted other less severe forms of school or workplace distancing. In Singapore, for example, doctors have been advised to issue five days of sick leave to patients with respiratory symptoms in an effort to prevent further community spread of COVID-19. Noting that many confirmed cases had continued to go to work and mix with people even after falling ill, the scheme was implemented to signal to all and encourage those with respiratory symptoms to seek medical treatment early and stay home throughout their illness. [122] The move will also help to sieve out non-COVID-19 cases, the symptoms of which will resolve after five days. Some patients, however, especially those from low-income families and paid by the hour, face strong pressure to request for a shorter sick leave period. Some parents have also been reluctant for their children to miss too many days of school. [123]

Another less severe form of school/workplace distancing is the issuance of 14-day leave of absence by Singapore to target population groups with higher risk of being infectious (students and staff) who have recently travelled to/returned from specified countries. The 14-day leave of absence was revised to a stricter stay-home-notice on 18 February, where those issued such notices will need to remain in their place of residence at all times.

Provision of Necessities

Considerations and Policies

If people are instructed to avoid public places, such as markets, stores, and pharmacies, or if those places are required to close, there will be a need for people to procure food, medicine, and other necessities in some other way. Shutting down mass transit also raises distributive-justice concerns as people with the least resources will be most impacted in ability to procure additional resources before the closures occur.

Ideally, governments could facilitate the setup of networks for the distribution of necessary provisions to citizens' homes, with a particular focus on those most in need. Governments could also provide a means by which people who have recovered from influenza (and are therefore presumably immune to the virus) could volunteer to assist with such provision of necessities. Governments should also provide access to medical care to the greatest extent possible, possibly reassigning public safety officers to this purpose.

A lack of resources and amenities is best addressed in the most fair and equitable possible way. Governments as well as national and international organisations should also stockpile medical supplies and food. [7]

Sometimes, necessities or medical supplies could be depleted as a result of unnecessary panic buying by people, as seen in the rush to purchase groceries and face masks in Singapore and Hong Kong in the evolving COVID-19 situation. To ameliorate the situation, Singapore's government distributed a fixed number of masks to each household, discouraged panic buying of groceries in public communications, and imposed purchase limits per person by one of its most extensive local retail chains. [440] [441] [442]

Vulnerable Groups/High Risk Settings

Elderly and people with comorbidities. Some countries, like the UK, target social distancing measures at risk groups such as the elderly. Data from China, South Korea, Italy, and Iran suggest that the case fatality ratio increases sharply with age and is higher in people with underlying comorbidities. [443] A more recent study estimated that 1.7 billion people, or 22% of the global population, have at least one underlying medical condition that heightens their risk of developing severe COVID-19 if infected (ranging from <5% of those younger than 20 years to >66% of those aged 70 and above), with the proportion of the population at increased risk highest in countries with an older age profile. Nevertheless, the study estimated that in comparison, only 349 million people (or 4% of the global population) are at high risk of severe COVID-19. Targeted social distancing, screening and other protective measures for this group could help reduce morbidity and mortality. [444]

Notwithstanding this, social isolation among older adults can also be a serious public health concern because of their heightened risk of other health problems (cardiovascular, autoimmune, neurocognitive etc). A summary of evidence on interventions (such as home-based exercise programmes and technology assisted interventions) that can help maximise mobility in elderly when socially isolated due to COVID-19 measures is available at Oxford COVID-19 Evidence Service. Literature has also pointed out the need for such distancing strategies to be effectively timed as adherence is likely to decrease over time (see also page 111 on how such measures can be incorporated as part of multi-intervention strategies). [166] [445]

People experiencing homelessness. A recent review article pointed to the need to take into account people experiencing homelessness amidst the COVID-19 pandemic. This vulnerable group live in environments that are conducive to disease epidemic (congregate settings with more limited access to basic hygiene supplies), tend to have chronic mental and physical conditions, and have limited access to healthcare. They are also more geographically mobile which makes contact tracing and isolation measures difficult. The article highlighted the likely impending challenges of COVID-19 containment in cities with a sizable population of people experiencing homelessness (such as the many cities in North America). [446]

Populations Contained in High Density Accommodation (PCHDA). Prisons, custodial settings, immigration detention centres and military accommodation settings can be potential epicentres for infectious diseases. (See also section on ‘Physical Distancing’.)

Key concerns

- PCHDA are epicentres for infectious diseases because of the higher background prevalence of infection, the higher levels of risk factors for infection, the unavoidable close contact in often overcrowded, poorly ventilated, and unsanitary facilities, and the poor access to health-care services relative to that available in a community setting. [365]
- Explosive outbreaks in these settings have the potential to overwhelm healthcare services. [366] The COVID-19 outbreak on the Diamond Princess cruise-ship provides a warning about what could happen in these settings.
- Infections can be transmitted between detainees/residents, staff and visitors, between detainees/residents through transfers and staff cross-deployment, and to and from the community. [366]
- The chronic disease risk factors can be higher in some contained adult populations

(mental health institutes, prisons). For example, high smoking rates and poor nutrition can place these populations at higher risk of poor outcomes from infectious diseases. [368]

Given the above factors, research on the topic finds that viruses should be delayed from entering settings as much as possible. If it is already in circulation, it should be controlled. Precautionary measures preventing outbreaks in such settings are listed below.

Precautionary measures prior to outbreaks

- Similar preventive measures applicable to community settings such as health education, compliance on frequent handwashing and respiratory hygiene/cough etiquette, cleaning/infection of venues, and masking.
- Arranging sleeping cots foot to foot instead of head to head
- Organizing training/scheduled activities and sleeping arrangements into discrete clusters.
- More well ventilated sleeping quarters (with wide open windows) where weather conditions permit. [369] [447] [448]

Other useful observations

- Specific to military settings, studies have shown that soldiers in basic training are more likely to experience URI/ILI than soldiers who have already completed basic training (seasoned soldiers) in the same camps. This is more notable in the US military than in the Thai military, likely due to conditions within military barracks in the tropics being less favorable for transmission - higher humidity and temperature, and more well-ventilated areas.
- Some evidence of spatial dependence in military settings where individuals who had a respiratory illness within a week of each other were more likely to have a bed within 3 m of each other. [369] [370] [283]
- Specific to nursing homes or other disability settings (where relevant), a study on California Nursing Homes noted Registered Nurses (RN) and nursing hours per resident day (staffing levels) was negatively associated with incidence of infection control deficiency, health deficiencies, number of beds, and for-profit ownership. Similarly, lower nursing home quality rating, lower RN numbers and hours, higher number of health deficiencies and a greater number of beds were associated with the risk of having a COVID-19 resident in the nursing home. Evidence points out that low staffing contributes to poor quality and health professionals/policymakers can make use of publicly available information about nursing homes to identify those at risk for infections. [449]

Considering the higher risk factors for outbreaks, PCHDA should prepare to deal with a high burden of disease. Social distancing, isolation and quarantine are effective, but they have the greatest impact when implemented early. [366]

There have been early release of prisoners prior to greater community transmission of COVID-19 to reduce the overall burden on healthcare that can result from explosive outbreaks in these settings. [450] The view taken in some settings (prisons and mental health care facilities) is that each person needlessly infected in a correctional setting who develops severe illness will be one too many. [451]

The following points emerge as considerations when there are outbreaks in PCHDA.

Joint strategic planning

- Including all stakeholders in the overall public health response, rather than permitting them to plan and operate in isolation, is more effective in successful quarantines. [366] This could also include representation from PCHDA, to identify and mitigate issues before they escalate.
- PCHDA outbreak response benefits from a public health professional leading / inputting on a day-to-day basis. As evidence by the negative experience of the Diamond Princess cruise ship.

Length of quarantine

- Any quarantine period for PCHDA should be short and the duration should not be changed unless in extreme circumstances. [47]

Communication

- Evidence compellingly finds that information is key; people who are quarantined need to understand the situation. Effective and rapid communication is essential. Most of the adverse effects come from the imposition of a restriction of liberty; voluntary quarantine is associated with less distress and fewer long-term complications. Officials should emphasise the altruistic choice of self-isolating. [47]
- Research finds that social media in the migrant worker community can spread inaccurate information and panic, particularly so if language barriers are present. [452]
- Riots and escapes from lockdown of prisons have been reported in Thailand, Columbia, Brazil, Venezuela, Italy, France and US. [453] [454] [455] [450] Some of these riots led to situations of guards being held hostage, as well as deaths. Poor communication (rumours) played a role in the riots, and similarly good communication, provision of resources and mental health support brought situations under control.

Resources

- To prevent negative reaction, supplies (both general and medical) need to be provided, particularly phones, free Wi-Fi and access to social media for communication and support. [47] Financial compensation is likely also important in worker lockdowns to manage the overall reaction from the population.

Prevention and control

- It is essential to carefully design and implement adequate systems for limiting importation and exportation of cases from or to the community, and transmission and spread within facilities. [366] This will include, developing protocols for entry screening, personal protection measures, social distancing, environmental cleaning and disinfection, and restriction of movement, including limitation of transfers and access for non-essential staff and visitors. [366]
- Well-tested public health principles of isolation, quarantine and exclusion can have good effect. [368] [456]
- Miscommunication can lead to migrant workers delaying seeking medical attention due to stigmatisation of those who are infected and implications of infection. [452] This may suggest that proactive screening would be required to ensure cases are identified rapidly.
- There is little comment on detainment staff being put in separate accommodation to prevent spread to the community, although there are reports that health workers are

being housed in hotels to prevent community spread. [457] Consideration of this would likely depend on the level of outbreak in detainment facilities.

Treatment

- Consideration is needed to explicitly and transparently align to health planning systems, including transfer protocols for patients requiring specialised care. [367]
- The practice of not examining symptomatic detainees within the health centre, but rather sending health staff to visit detainees, has been found to minimise the potential for spread throughout a facility. [368]

Mental health

- Special consideration of the potentially serious mental health effects of isolation in these settings is essential. Psychological distress is a well reported outcome of quarantine. Longer durations of quarantine are associated with poorer mental health, including post-traumatic stress symptoms, avoidance behaviours and anger. [47]
- People in prisons and other places of detention are already deprived of their liberty and may react differently to further restrictive measures imposed upon them [367].
- The psychological and behavioural reactions of prisoners or those detained in other settings are likely to differ from those of people who observe physical distancing in the community; consideration should therefore be given to the increased need for emotional and psychological support, for transparent awareness-raising and information-sharing on the disease, and for assurances that continued contact with family and relatives will be upheld. [249]
- Adequate measures should be in place to prevent stigmatisation or marginalisation of individuals or groups who are considered to be potential carriers of viruses. [367]
- A recent article called for a Singapore Task Force for COVID-19, to advise the government on coordinated mental health policies and psychological intervention. [458] Migrant workers were not explicitly referenced, but would represent an at-risk group.

Working while detained

- In the context of prisons, some detainees are being paid to working on COVID related projects, such as US prisoners digging graves and Taiwan prisoners making masks. [459] [460]

International relations

- UNICEF has stated that the COVID-19 pandemic could devastate refugee, migrant and internally displaced populations without urgent international action. [461]
- Amnesty and global media have reported on the conditions of migrant workers – concerns of overcrowding, poor sanitation and lack of healthcare are cited, as well as financial hardship. [462] [463] [464]
- The UN Basic Principles for the Treatment of Prisoners states that prisoners “shall have access to the health services available in the country without discrimination on the grounds of their legal situation. [465] This would likely be pertinent to all contained populations.

Useful guidance and links:

- WHO (2020) Preparedness, prevention and control of COVID-19 in prisons and other places of detention: Interim Guidance Mar 15, 2020.

- UK Government (2020) COVID-19: prisons and other prescribed places of detention guidance Mar 26, 2020
- A collection of guidance from around the globe is available at the worldwide prison health research and engagement network WEPHREN
- World Prison Brief database has a regularly updated page of information on COVID19 in prisons worldwide and contains news articles, organised by region and country, along with guidance, reports and other initiatives.
- Prison Insider is collating reports on COVID-19 in prisons

Effectiveness studies. A study investigated mitigation measures (depopulation efforts, increased placing of persons in single cells and asymptomatic testing) adopted in a US jail during an outbreak. After depopulation began, transmission rate decreased from 1.89 to 0.83 (56%), then reduced to 0.41 (further 51% decrease) after distribution of more persons to single cells, and then to 0.11 after asymptomatic testing (further 73% decrease). In addition to standard public health measures, depopulation, promoting access to single-occupancy cells and asymptomatic testing can be effective in mitigating COVID-19 transmission, especially in correctional settings. (See also page 9 for study on measures taken for outbreak on Diamond Princess Cruise Ship.) [466]

A case study on the enhanced and infection prevention and control (IPC) procedures undertaken by a psychiatric facility in Wyoming after admitting two COVID-19 patients resulted in a subsequent point prevalence survey that showed no further SARS-CoV-2 transmission. [467]

Business Continuity Planning (BCP)

Predictions vary in terms of how long a pandemic will last and what the rate of sickness at workplace will be. Some estimates suggest pandemics last from 8 to 15 weeks and that at any one time, there could be 25% sickness and up to 50% absence due to people needing to stay at home to look after children, school closures, and the overall reluctance to go out to work. [468] Considering the duration of pandemics and their impact to business operations, BCP is important to ensure continued operability of businesses and preservation of livelihoods.

BCP involve contingency plans and change in work processes during the pandemic period, such as setting up of alternate employee teams deployed at different work schedules and/or physically segregated from one another, cross-training and covering arrangements, and continuity plans with key suppliers/contractors. It also includes workplace culture setting, communications, and screening/hygiene measures such as effective cleaning of shared surfaces and employee hand hygiene. Workplace impact from pandemics can come in waves and the HR response should be flexible and viewed as a long-term effort with a bundle of approaches (rather than a single strategy) that may change over time, depending on the changing circumstances of the business, employees, and wider context.

Although some organisations may be relatively prepared, many (especially the small businesses) do not have pandemic plans. Anecdotally, many small businesses lack an understanding of how to initiate BCP plans in the context of a viral outbreak and are especially susceptible to the negative economic effects of a pandemic. US estimates suggest that 25-40% of small businesses never reopen following a major disaster. [469] [470] [471] [472]

A recent survey of business continuity managers around the world with representation largely from large organisations[9] found that just under 40% of responding organisations had already been impacted by COVID-19. Around 80% had taken specific actions due to COVID-19, such as forming committees to oversee responses, closure of China offices, leave of absences for employees returning from China, IT review to support additional home-working, and other BCP measures. [473]

Guidelines, General Practices and Recommendations

It has been pointed out that most large companies with financial capacity and governmental responsibilities around the world have a major part to play in terms of preparedness and emergency response during an ID outbreak. They should be integrated into the health contingency plans of their governments and other authoritative/international organisations. [474]

Locally contextual guidelines have been made available, such as the Ministry of Manpower's general advisory for workplace measures in response to DORSCON Orange situation [475], which linked to guidance from Enterprise Singapore on Business Continuity Plans especially for small and medium-sized enterprises in Singapore. [476] Other relevant guidances from international organisations include the Center for Infectious Disease Research and Policy's toolkit for organisations on doing business during an influenza pandemic. [477] Harvard Business Review has also recently made available for free an e-book providing insights, advice and practical case studies to help companies tide through and reshape their businesses in the face of the COVID-19 situation. Content include conceptual frameworks to apply when planning a response, protection of employees, legal obligations, and how remote teams can be managed and virtual meetings well conducted. [478] Fisher Philips has also created an FAQ document to address the main employment-related issues/implications facing employers in the wake of the COVID-19 coronavirus, such as workplace safety, personal privacy and extended leave issues. [479]

There is very little research literature evaluating the effectiveness of BCP recommendations, considering also that effectiveness would be highly variable depending on business and context. However, a scan of available literature on learnings from previous epidemics, guidelines and advisories, comment from experts, and relevant research yielded some key recommendations and consensus viewpoints. [480] [481] [482] [469] [483] [484] [485]

Strategic approach

Key Points

- Put in place a capable representative crisis management team that includes on-call staff to manage the evolving situation.
- Set the culture and expectation that unwell employees stay home.
- Review functions, skills and location of work (outlined below)
- Be guided by the advice of government.
- Review IT working from home capacity. Expand supporting network capacity or identify priority users and shut off less critical parts of systems.
- Identify critical business inputs (eg raw materials, suppliers, subcontractor services/products etc). Discuss with suppliers/subcontractors on their BCP plans.

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[9] Of the 168 responses received in total, 75% were from large organisations (more than 1000 employees), 15.5% from medium sized organisations (250 to 999 employees), and 9.5% from small and micro organisations.

HR response should be flexible and viewed as a marathon (rather than a sprint) since impact from pandemics can come in waves over an extended period of time. Most frameworks recommend that there is a capable representative crisis management team that includes on-call staff to manage the evolving situation.

It is critical to set and model the expectation that sick employees must stay home. Companies should allow sick employees to stay home without fear of losing their jobs and allow employees to stay home to care for sick family members. Requirements for doctors' notes could be temporarily waived. Medical guidance and isolation requirements should be followed for symptomatic employees.

Categorising functions, skills, location

Key Points

- Consider categorisation by function, skills and location.
- Tailor working arrangements based on categorisation.
- Develop escalation plans for critical functions and skills.

The following categorisation could be considered based on whether the functions are mission critical, (b) whether the skills required to undertake the task are specialist or transferable to other staff, and (c) whether the function could be undertaken at home or needed to be in the workplace. Across all categories, employees who may be more vulnerable to infection should be sensitively identified and supported to work at home, eg employees who are pregnant, those with compromised immune systems or chronic health conditions like heart disease or diabetes.

Based on the above assessment, working from home should be the default for those functions and roles that can be carried out at home. Working from home could reduce the spread of infection and mitigate some financial consequences of absenteeism. For example, it may be appropriate for employees who may be sick but have mild symptoms and feel able to work, or for those who need to stay home to care for healthy children whose school has been shut. Employees undertaking mission critical functions that can work from home should be set up for working at home. These may not be based on hierarchy in the organisation (eg payroll).

For mission critical functions, organisations should consider approaches to reduce potential transmission, such as operating staggered working, rotating in teams, social distancing in the workplace (further examples are outlined in the workplace interaction section).

For mission critical functions that require specialist skills, employees should train backfills who should be identified through assessment of skills and experience of the workforce. These staff should be protected as far as possible from transmission in the workplace through further measures. These include staggering working times, allocating them their own offices where possible, or seating them far from other people and ensuring that they are allocated their own desk.

Escalation plans should be developed to draw down resources for mission critical functions if the responsible staff become unwell and require backfill. Consider preparing an additional pool of workers to undertake key tasks and provide training where appropriate (eg contractors, cross train employees, retirees).

<u>3 Step Process for Split-Team Deployment in Larger Organisations:</u> The following 3 step process could be considered for split-team deployments within larger organisations with multiple premises:

1. Identify all staff in work functions that can (or that can be enabled to) be done from home. These should be prepared to work from home when split-mode is activated.
2. Identify premises within the organisation that can be used to physically segregate groups of staff in mission critical work that must be done at the workplace. When split-mode is activated, staff from separate premises should avoid coming into contact. They may inadvertently meet en route to or from work but that contact is no different from contact within the general community, and does not pose significantly increased risks.
3. Within these separate premises, divide staff into two or more teams, with each team sufficient to support its team's function. Staff not deployed to the office may work from home. These smaller teams are segregated by defined timings and shifts so that they do not mix. If possible, shifts can be weeklong on weekdays with weekends for natural or deliberate decontamination If such a team becomes too small to be effectively functioning, deployment of staff from step 1 to fill out the team can be considered.

Workplace interactions

Key Points

- Stagger shifts to allow fewer workers in the workplace at the same time. Employees can be allowed to go to work early or late to avoid rush-hour crowding on public transportation.
- Avoid face-to-face meetings. Use the telephone, videoconferencing, and the internet to conduct business as much as possible, even when participants are in the same building.
- If a face-to-face meeting is unavoidable, minimise the meeting time, choose a large meeting room, and sit apart from each other if possible; avoid person-to person contact such as shaking hands.
- Avoid any unnecessary travel and cancel/postpone non-essential meetings, gatherings, workshops, and training sessions.
- Do not congregate in workrooms, pantries, copier rooms or other areas where people socialise.
- Bring lunch and eat at desks or away from others (avoid lunchrooms and crowded restaurants).
- Encourage customers to request information and orders via phone and email in order to minimise person-to-person contact. Have the orders, materials and information ready for fast pickup or delivery.

Communication

Key Points

- Establish an emergency communications plan and revise this periodically. The plan should identify key contacts (with back-ups), chain of communications (including suppliers, customers and employees) and processes for tracking and communicating business and employee status.
- Promote trustworthy sources of information and news to employees.
- Provide clear and accessible information on the changing situation and clear

contacts for employees to discuss issues with.

- To prevent spread of misinformation, HR should work to ensure that employees are not sharing false information or being indiscrete about others.
- Social isolation will likely be an issue and support/communication that brings people together positively (eg sharing good news, stories, etc) should be considered.

Workplace hygiene

Key Points

- Maintain consistent hand hygiene.
- Ensure effective cleaning, particularly of high-use shared surfaces.
- Have a plan for facility decontamination if needed.

How the virus is transmitted and the use and efficacy of personal protective equipment should be well understood in relation to the specific workplace and functions. There are some specific considerations regarding surface transmission to consider for workplaces. Office environments that include shared equipment, such as hot-desks, printers/copy machines, break rooms, restrooms and conference rooms, facilitate the spread of virus infections. [486]

Healthy workplace hygiene of cleaning surfaces and good hand hygiene reduces viral exposure from hands and surfaces significantly, but a level of risk remains. Studies on virus spread in office settings have indicated that surface disinfectant can reduce the risk of infection from viruses by 14-33%. When surface cleaning is combined with personal hand hygiene, the risk of virus infection reduces by 60 – 88% [487] [488] [489]

HR policies

Key Point

- Consider temporarily flexing HR policies.

The following are some examples used during the US H1N1 pandemic:

- Allowing employees to exhaust paid time-off hours and go into negative balances.
- Advancing time up to a year of accrual (if, for example, the employee normally accrues 5 days of sick time per year and has used all 5 days, then consider advancing another 5 days).
- Providing special time-off allotment.
- Allowing employees to donate leave to others.
- Blending sick, vacation and holiday allowances into a single bank.
- Allow staff to borrow from future accrual with written authorisation to deduct from their final check if they do not stay with the company long enough to earn it.
- If no sick or vacation time is available in a small operation, consider developing a contingency bank of time off for extreme situations. Allow people to work extra shifts to offset lost time.

3 Key Considerations on Behavioural Response to BCP Measures. In developing BCP processes, behavioural responses to the measures and how the organisation will monitor

and police compliance should be thought through to help ensure their workability (doable by staff without causing unnecessary inconvenience) and enforceability. Measures implemented can be considered in terms of:

1) Whether they are based on education and voluntary compliance;
2) Or based on forced compliance;
3) And what consequences staff will face in the event of non-compliance.

This will prevent the setting up of processes that are tedious, likely to result in non-compliance, and unenforceable. (For eg mandating daily submission of temperature readings even when staff are working from home, or requiring staff from segregated teams to wear colour-coded identification tags when staff disregarding split-team deployment arrangements will not put on the tags anyway.)

Use of NPIs and Multi-Intervention Strategies

Success of NPIs varies widely and depends heavily on implementation, the natural history of the pathogen concerned, and its transmissibility. They are familiar solutions that may seem to offer immediate relief to nations in the face of a pandemic threat, but some are very resource intensive, involve substantial social and economic costs, and take a toll on governments and their people over a longer period. [48]. It should be also borne in mind that measures like reducing outpatient and inpatient care to potential exposure to the virus necessarily risks depriving current patients of intended and timely care, with the potential for increased morbid and mortal outcomes.

Assessment and adjustment. As such, international organisations and expert consensus recommend that regular severity assessments should be conducted at local, national, and global levels, to inform decisions on these public health measures during an influenza pandemic. Key elements to take into consideration are the disease's transmissibility, level of severity (in terms of complications and for which population groups), and impact on health facilities (whether they are overwhelmed), and necessary adjustments to measures made. [8]

Singapore's response to the MERS outbreak is a case in point on severity assessment and adjustment of public health measures, where it initially put in place containment strategies but stepped down to mitigation approaches that result in minimal disruption when it became apparent later that the disease was less severe than initially feared. [490] Similarly, during the H1N1 pandemic in 2009, a stringent spate of measures that were initially deployed stretched limited resources and funding over the longer term, and the Mexican government concluded eventually that they should be lifted in view of their limited effectiveness in preventing disease spread and the disease's relatively limited toll. [491]

Some countries have also developed national response systems that coordinate across NPIs at varying forms and combinations of enforcement according to severity levels of a disease outbreak situation. For example, Singapore's SARS experience prompted the government to develop a disease outbreak plan with response levels correlated with the WHO Pandemic Alert Response system. Termed Disease Outbreak Response System Condition (DORSCON), it incorporated progressive levels of border controls, community-based measures, infection control in hospitals, and other NPIs, with its four colour-coded alert levels. Similarly, the epidemiological situation was used to define locations within mainland China into four categories in the COVID-19 crisis – 1) areas without cases, 2) areas with sporadic cases, 3) areas with community clusters, and 4) areas with community transmission, each with varying combinations and extent of containment measures. These categories now guide the phased lifting of current containment restrictions as assessed risk in different localities reduces/drops. [29] (See COVID-19 Science Report: Social Distancing & Lockdowns for details of measures implemented.)

A study introduced a prototype model of a graded, individual-level pandemic notification system which can support such regular severity monitoring/assessment and coordination across NPIs at a national level. The prototype consists of 5 threat levels of increasing severity, with each level providing information on the pathogen, level of threat, and actions to be taken. Alerts for low threat levels would be delivered through text messages while alerts for high threat levels would be delivered as a push notification to mobile phones, automating aspects of NPI implementation. [492]

Use of NPIs in combination. The broad range of NPIs are also not applied separately but typically used in combination, where the efficacy of any one NPI or NPIs at a certain level of containment depends in part on the concurrent and degree of application of others. As seen in the earlier section on quarantine (see page 12), selective quarantine can be applied synergistically alongside more scalable social distancing measures to achieve similar reductions in ROs with less extensive resources. The recent lockdowns of cities/countries amidst the COVID-19 pandemic are also multi-intervention approaches involving a combination of various containment measures, and implemented in varying degrees of severity across different countries (see COVID-19 Science Report: Lockdowns for details on measures taken by various countries in lockdowns).

A review article on COVID-19 summarised the key guiding principles in use of NPIs at a national level. Firstly, recognising and understanding the transmission dynamics of superspreading events are crucial in guiding the implementation of measures for mitigation. These include pathogen-specific factors such as virulence and infectious dose; host factors symptomatology and infection duration; environmental factors such as population density and IC in healthcare facilities; behavioural factors including cough hygiene, compliance etc; and implementation factors. Secondly, operational plans/capacities should be made available in the containment phase. Thirdly, detection/contact tracing/isolation and IC measures should be implemented early within healthcare facilities. Lastly, risk communication and community hygiene measures are important and help limit transmission within the community. [345]

China and Lockdowns

Several COVID-19 studies (mostly modelling) evaluated the impact of the combination of measures taken by China (traffic blockage to/from Wuhan, urging the public to stay at home, extending the Chinese New Year holiday, postponing the resumption of schools, workplace distancing, suspending all domestic/international group tours and other preventive measures in other provinces) on national spread and on spread within other provinces in mainland China. (See COVID-19 Science Report: Social Distancing & Lockdowns for details and timeline of implementation of these measures.) All studies found the combination of interventions effective, quantified with a decrease of Rt from 3+ to <1 and reduction of size of infected cases by over 90%. (See Table 9) One study (see Zhang et al in Table 9) found that 30 days of substantial social distancing reduced Rt from 2.2 to 1.58 in Wuhan and Hubei and from 2.56 to 1.65 in other provinces. Another study (Zhang et al in Table 9) which evaluated data in locations outside of Hubei estimated Rt in regions with sufficient data to be reduced to <1 (from as high as 1.71 in some regions).

Comparative effectiveness of individual measures. Some were able to quantify the isolated impact of individual interventions but also pointed out that combined application yielded the strongest impact and most rapidly. One study (Li et al) found mass quarantine to be more effective than traffic blockage in/out of Wuhan (reducing peak of infections by nearly 90% instead of only 20%+ assuming 100% success rate). Another study (Lai et al) found that early detection and isolation of cases was estimated to prevent more infections (reduce cases by 5-fold) than social distancing (reduce cases by 2.6-fold), but integrated NPIs achieve the strongest and most rapid effect. (Epidemics would increase exponentially over the longer term if detection and isolation is not accompanied with social distancing.)

Varying degrees of severity of measures and earlier lifting of measures. Some studies simulated varying degrees of severity of the combination of isolation/quarantine and social distancing measures. One study (Zhu et al) projected epidemic end time in Wuhan (end time being when increment of confirmed infected equals zero) at 136 days from 28 Jan (with total of 62,577 infected) with moderately strict measures versus epidemic end time at 299 days (with total infected as large as 8,923,823) with no rigorous control measures.

The study found that earlier resumption of work on 9 Feb was projected to result in a short rebound with peak of outbreak postponed by 10 days and its magnitude increased by 50% versus scenario of continued implementation of combined control measures. Another (Wan et al) found that relieving personal protection too early may lead to spread of disease for a longer time, more people infected, and possible outbreak again. Contact rate needed to be at least 30% or less of normal levels until April to ensure the rapid ending of the epidemic.

Most of the studies recommended continued implementation of these measures in China until the epidemic is under control (March or April). One study (Maler and Brockmann) recommends that such measures would have to stay in effect for a longer time than the maximum incubation period after the saturation in confirmed cases sets in.

Earlier implementation. Some studies pointed out that earlier implementation of NPIs will result in greater reduction in epidemic size and peak. One study (Lai et al) estimated that if NPIs were conducted one week, two weeks, or three weeks earlier in China, cases could have been reduced further by 66%, 86%, and 95% respectively.

Another study (Zhang et al) found that earlier activation of social distancing at low strength level (about 0.25 of the severity of social distancing actually implemented in China) could yield slightly better results than actual results but the epidemic size may eventually, maybe after 1 Apr, enlarge. Earlier activation of social distancing at a moderate level (about 0.5 to 0.75) would be effective, but earlier activating of substantial social distancing at high level (the actual severity implemented in China) would lead to the best results.

Deciding on the ideal multi-intervention approach. Zhang et al also found that earlier and a three-phased implementation of substantial social distancing measures (first in Wuhan, then in all provinces outside in another two stages), with a much later lockdown of Wuhan or without the lockdown, would be cost-effective and resulted in the smallest nationwide epidemic size and number of deaths. This was, somewhat unexpectedly but also supported by other studies, likely due to the lockdown increasing the Rt and death rate within Wuhan as a result of pressure on local healthcare systems and acute shortage of medical manpower and resources, which neutralised some of the impact from implementation of social distancing. Notwithstanding, the study did point out that an early lockdown confines the epidemic distribution and mitigates nationwide socioeconomic impact. Multi-intervention approaches therefore need to be tailored according to balanced consideration of infection and death numbers, confining epidemic regions, and maintaining socioeconomic activity. [390] [493] [494]

On Herd Immunity (see page 110). A study estimating epidemic parameters across seven European countries projected that 6.4% of the total population would be immune following the first wave of infections. The maximum percentage of the effective population immune was estimated at 19.6% of the total population for the UK, 16.7% for Ireland, 11.4% for Italy, 12.8% for Spain, 18.8% for France, 4.7% for Germany and 12.9% for Switzerland. All 7 countries are nearing or past the peak of daily case rates, and with the majority of each country's total population still susceptible to the infection, future epidemic outbreaks are expected to occur. [495]

Timing from implementation to start of decline. Two studies on the epidemiological curve in China observed that the number of new reported cases peaked about 8-10 days after suppression measures started (see Zou et al and Wang et al in Table 9). A case study of the epidemic development in Shenzhen (with population of about 20 million and ranked among the top affected cities outside Wuhan with 416 confirmed cases by 20 Feb) found that newly diagnosed COVID-19 cases peaked around 7 days after peak date of imported cases and around 10 days after implementation of a serial early preventive measures (see Figure 5 and Figure 6, and Yang et al in Table 9 and Figure 4 for description of measures taken). Another study found that following implementation of multiple Chinese measures, the growth speed of cases reached a peak and began to decline within 14 days in almost all areas of mainland China (except Wuhan and Hubei, which peaked and began to decline in 14-15 days). [496]

What's next. Some studies (see Zou et al and Leung et al) note that China has applied the Suppression approach (see page 110) successfully over the past two months and in view of subsequent susceptibility to the virus being re-introduced, suggests that it moves to a Containment strategy based on strict surveillance and detection, and isolation and quarantine (applied by some regions such as Hongkong, Taiwan and Singapore but may not be feasible in areas already with widespread local transmission).

Table 9: Studies estimating effectiveness of NPIs in China during COVID-19 outbreak

Study	Description
Li et al [497]	The study measures the traffic blockage (restriction of traffic into/out of Wuhan) and mass quarantine measures in Wuhan (public staying at home, self-protective measures, and self-protection at home) on epidemic spread in China. It found that mass quarantine was more effective (reduce infections by nearly 90% assuming 100% compliance) than traffic blockage (alleviate only 21-22% of the peak number of infections assuming 100% traffic blockage).
Zhu et al [498]	Use of mobile phone data and SIR model to simulate three scenarios: 1. No major intervention. Peak will occur near 2 Mar. 2. Combined measures (closing the transportation to/from Wuhan on January 23, extending Spring Festival holiday, postponing school-back day, and suspending all group tours). Decreasing transmissibility to very low levels and full control by 2 March. 3. Resumption of work on 9 Feb. A short rebound after 9 Feb with transmission rate increasing back to 5 Feb levels by 15 Feb. Peak will be postponed by 10 days with magnitude increase of 50% versus Scenario 2. Percentage of cities that will successfully control the disease by 2 March are 67%, 100% and 91% respectively under the three scenarios. Study recommends continuous postponing of work/school resuming under Scenario 2.

Study	Description
Zhao and Chen [499]	Modelling and projection analysis of data in Wuhan, Hubei (excluding Wuhan), China (excluding Hubei) and four first-tier cities of China found that Rt (> 1 before 30 Jan except Beijing) decreased to < 1 for all regions after 30 Jan, indicating effectiveness of quarantine and control measures. Model simulated epidemic trends based three levels quarantine and control measures (termed stage 1 to 3 representing progressive levels of severity). In Wuhan, stage 2 measures result in epidemic end time (end time being when increment of confirmed infected equals zero) at 136 days from 28 Jan (with total of 62,577 infected) while stage 1 measures result in epidemic end time at 299 days (with total infected as large as 8,923,823). Total infected is estimated at 49,510 with stage 3 measures. Study predicts end times of epidemic at around late-March for Wuhan and Hubei (with stage 3 measures), mid-March for China (excluding Hubei) around mid-March, and before March for the four tier-one cities (with stage 2 measures for the latter two settings). The study suggests that these measures should be kept before March in the first-tier cities, and before late-March in Hubei.
Kraemer et al [500]	Analysis of real-time mobility data from Wuhan and detailed case data found that while early increase in reported cases in cites was correlated to human mobility from Wuhan, correlation decreases after 1 Feb, indicating other more impactful factors, such as the public health response.
Lai et al [501]	Estimated that number of cases would see a 67-fold increase across mainland China without NPIs (51-fold increase in Wuhan, a 92-fold increase in other cities in Hubei, and 125-fold increase in other provinces, by 29 February). If NPIs were conducted one week, two weeks, or three weeks earlier in China, cases could have been reduced further by 66%, 86%, and 95% respectively. The early detection and isolation of cases was estimated to prevent more infections (reduce cases by 5-fold) than social distancing (reduce cases by 2.6-fold), but integrated NPIs achieve the strongest and most rapid effect. (Epidemics would increase exponentially over the longer term if detection and isolation is not accompanied with social distancing.)
Wang et al [502]	The impact of NPIs on the epidemic in Wuhan was estimated to decrease Rt from 3.86 to 0.32 and prevent 94.5% of infections until 18 Feb.
Wan et al [503]	Used transmission dynamic model to evaluate effectiveness of integrated restriction and self-protection interventions (including travel restriction, quarantine of entry, contact tracing followed by quarantine and isolation, and contact reducing measures like wearing of masks etc), estimate the risk of partial lifting of control measures, and predict the epidemic trend of the virus in mainland China excluding Hubei province based on the published data. It was found that Rt of 3.36 dropped below 1 since 31 Jan and relieving personal protection too early may lead to spread of disease for a longer time, more people infected, and possible outbreak again. Contact rate

Study	Description
	needs to be at least 30% or less of normal levels until April to ensure the rapid ending of the epidemic. The study recommends maintaining of the integrated interventions until April and outbreak is expected to be ended by April in mainland China apart from Hubei province.
Zhang et al [390]	A modelling study on China's COVID-19 experience found that 30 days of substantial social distancing reduced Rt from 2.2 to 1.58 and in Wuhan and Hubei and from 2.56 to 1.65 in other provinces. Earlier implementation could also significantly limit the epidemic in mainland China, reducing infection numbers up to 98.9% and deaths up to 99.3% by Feb. Earlier activation of social distancing at low strength level could yield slightly better results but epidemic size may eventually, maybe after 1 Apr, enlarge. Earlier activation of social distancing at a moderate level would be effective, but earlier activating of substantial social distancing at high high-level (which is the actual social distancing strength implemented in China) would lead to the best results. Earlier phased implementation of substantial social distancing measures (first in Wuhan, then in all provinces outside in another two stages), with a much later lockdown of Wuhan or without the lockdown, would be cost-effective and resulted in the smallest nationwide epidemic size and number of deaths.
Prem et al [504]	Measures reducing social mixing modelled to reduce number of infections in Wuhan in mid-2020 by 92%, and the sustaining of these measures until April reduces the height of the peak, overall epidemic size in mid-2020, and probability of a second peak. Effects of social distancing measures vary across age categories, with reduction in incidence highest among school children and older individuals and lowest among working-aged adults. Earlier relaxing of interventions in March is still effective if the infectious period is short (3 days) while measures will need to be relaxed a month later (in April) for longer infectiousness (eg 7 days) in order to observe a larger effect.
Wang et al [505]	R0 reduced from 3.38 to 0.5 under the current 40 public health intervention policies of China. Actual growth curve of new cases, virus infection curve, and daily transmission replication curve were flattened significantly under the interventions. With start of policy implementation on 21 Jan, peak of daily new infection occurred on 29 Jan with control outbreak ever since then. Shortening infection duration through early treatment or rapid detection/isolation can further reduce R0.
Zou et al [506]	Increase in number of new reported cases peaked approximately 10 days after Suppression measures started on 23-25 Jan. Peak in reported sick cases occurred 18 days after start of measures on average. Complete suppression took up to 2 months (range from 23-57 days) during which severe measures were in place.

Study	Description
	In view of continued susceptibility of another potential outbreak with lack of herd immunity and outbreaks in other countries, the study suggests shift to a Containment strategy based on strict surveillance, testing of all individuals with symptoms, and followed by isolation of infected individuals and their recent contacts.
Yang et al [507]	Shenzhen has a population of about 20 million and ranked among the top affected cities outside Wuhan with 416 confirmed cases by 20 Feb. The outbreak came under control in a relatively short time with limited cases after a series of early preventive strategies since January 19. Measures included (see Figure 4 for details): - (since 15 Jan) preparation of epidemiological investigation (set up of 24-hour fever clinics in all 49 hospitals PCR detection of coronavirus, chest CT and blood lymphocyte counting, isolation of suspect cases etc), hospital disinfection and IC, medical material reserve, outpatient adjustment, medical waste management etc - (since 23 Jan) cancellation of all Chinese new year's entertainments and temporary closure of many public places including market, cinema, museum, library, gymnasium. Other necessarily kept open public places (including airport, station, port, freeway entrance, urban traffic) were disinfected regularly with employees given regular health examinations and visiting public required to wear masks and have temperatures screened. - (since 2 Feb) strengthening of case management measures - isolation of new arrivals from epidemic area for 14 days, informing living communities of confirmed cases in the communities, use of big data and information technology to track travel histories of contacts and confirmed cases. Newly diagnosed COVID-19 cases peaked around 31 Jan, 7 days after the peak date of imported cases and around 10 days after implementation of the serial early preventive measures. (See Figure 5 and Figure 6)
Shao [493]	Modelling study showed that implementation of lock down of cities led to higher mortality rates in these cities. However, higher degree of implementation measures to lock down residential units in these cities led to lower infection rates with almost 85% of individuals not infected at steady state. Adding hospital beds resulted in better recoveries to deaths ratio (85% to 15% when more hospital beds were added versus 55% to 45% when fewer beds were added). Higher degree implementation of lockdown of residential units led to lesser hospital bed requirements. For example, hospital bed shortage occurred at time frames of 20-24 under complete lockdown of residential units but occurred at 20-140 under non-stringent residential unit lockdown. The combination of adding a large number of hospital beds with stringent city lockdown improved cure rates and reduced mortality rates in lockdown cities.

Study	Description
Zu J et al [508]	The model showed that effective reproductive number of COVID-19 decreased from 2.62 on January 23 to below 1.0 on February 5 in mainland China, suggesting a decline in new infections thereafter. Preventive measures implemented by the government since January 23 were projected to reduce the cumulative number of confirmed cases, confirmed cases at peak time, and deaths by 99.85%, 99.84%, and 99.84% respectively.
Hossain et al [509]	Modelling study using Beijing as a case showed how Rt influenced the impact of border control and quarantine measures on COVID-19's spread between two cities in terms of delay period to the time of outbreak emergence (defined as when threshold cases indicating a >50% probability that community spread will occur has been reached). For border control measures (with effectiveness of reducing 90% of passenger numbers), Rt values of 1.4, 1.68 and 2.92 effected 32.5, 20 and 10 days delay to arrival time respectively. For quarantine (if the individual is quarantined immediately), the three Rt values effected 44, 24.1 and 10 days delay to arrival time respectively.
Kochanczyk et al [510]	Projected the impact of extensive quarantine on reduction of epidemic growth rate in China. The measures imposed in China from 23 Jan resulted in about 50-fold reduction in the growth rate while the softer quarantine imposed in northern Italian provinces from 21 Feb resulted in about 3-fold reduction of in the growth rate. A further 5-fold reduction is necessary to terminate exponential growth. It was suggested that even higher reductions in growth rates should take place in France, Germany and Spain based on epidemic growth numbers there as at 10 March.
Lau et al [511]	Study observing the spread of COVID-19 in relation to the two measures of flight restrictions to/from China by other countries and lockdown of the population of Wuhan as well as the entire Hubei province. While further COVID-19 spread could not be contained (international cases have outnumbered reported cases in China), a significantly decreased growth rate and increased doubling time of cases was noted in mainland China, and as a likely result of lockdown measures in Hubei.
Fang et al [512]	Projected that the lockdown of Wuhan reduced inflow into Wuhan by 76.64%, outflows from Wuhan by 56.35%, and within-Wuhan movements by 54.15%. COVID-19 cases would be 64.81% higher in the 347 Chinese cities outside Hubei province, and 52.64% higher in 16 non-Wuhan cities inside Hubei if Wuhan was not locked down from 23 Jan. Imposing enhanced social distancing policies in the 63 Chinese cities outside Hubei province is also found to be effective in reducing impact of population inflows from epicenter cities in Hubei.
Zhang et al [513]	The study provides an overview of the changing epidemiology and transmission dynamics of COVID-19 in mainland China outside Hubei province, and Rt in locations for which there was sufficient were estimated to be <1 after 30 Jan from peaks between 1.08 in Shenzhen to 1.71 in Shandong.

Study	Description
Brouwer et al [514]	Measures implemented in China on 23 Jan (suspension of all public transportation) brought Rt down from 4.94 to 1.90 and the more stringent measures from 13 Feb (including closing of all non-essential companies/manufacturing plants in Hubei) brought it further down to 0.055. Compared to Italy, nationwide lockdown from 10 Mar had a more gradual effectiveness on Rt from 3.31 to 2.53, and then later to 0.69. It was pointed out that data from the Lombardy region suggests that a substantial proportion of the population were still commuting around notwithstanding quarantine measures and factory closures were only partial until 23 Mar, but this likely reduced further over time. Similar situation in Belgium, where Rt after implementation of containment measures changed from 3.38 to 2.0. Similar for Spain – measures enforced from 11 Mar in Madrid followed by nationwide measures from 15 Mar resulted in observed decrease in Rt but not drastic enough to reverse trend of epidemic.
Leung et al [515]	Rt in mainland China outside of Hubei was shown to have decreased substantially since control measures were implemented on 23 January, and have since remained below 1. The confirmed case-fatality risk (cCFR) outside of Hubei was 0.98%, which was almost five times lower than that in Hubei, which was 5.91%, stemming from variation in healthcare availability, quality and surge capacity. The study recommends gradual relaxation of interventions, with close monitoring of real-time transmissibility and cCFR, ensuring early detection of a second wave and keeping disease prevalence below the surge capacity of the healthcare system.
Maler and Brockmann [516]	Modelling results suggests that the public response to the epidemic and the containment measures put in place were effective despite the increase in confirmed cases. That the behavioural change was observed in all provinces also indicates that containment strategies were universally effective. The study recommends that such strategies would have to stay in effect for a longer time than the maximum incubation period after the saturation in confirmed cases sets in. It also shows that mitigation strategies induce behavioral changes at can be very effective, especially in situations when asymptomatic or mildly symptomatic infectious periods are long or their duration unknown. Standard containment strategies such as contact tracing may become infeasible during large-scale outbreaks of such diseases.
Pan et al [517]	The Rt in Wuhan fluctuated above 3.0 before January 26, decreased to below 1.0 after February 6, and decreased further to less than 0.3 after March 1.
Zhang et al [395]	The study evaluated the impact of social distancing measures on contact patterns in Wuhan and Shanghai before and during the outbreak. Average daily number of contacts per participant reduced from 14.6 to 2.0 in

Study	Description
	Wuhan and 20.6 to 2.3 in Shanghai. Impact of social distancing measures was modelled to drastically reduce Rt. The study also suggests that school closures can significantly reduce overall transmission (see page 74).
Zhang et al [518]	The study observed that confirmed new cases of COVID-19 decreased from 27 to 0 in 53 days (form day first case was confirmed) in Shanghai, suggesting the effectiveness of public health strategies deployed.

Figure 4: Main preventive policies and strategies of COVID-19 in Shenzhen

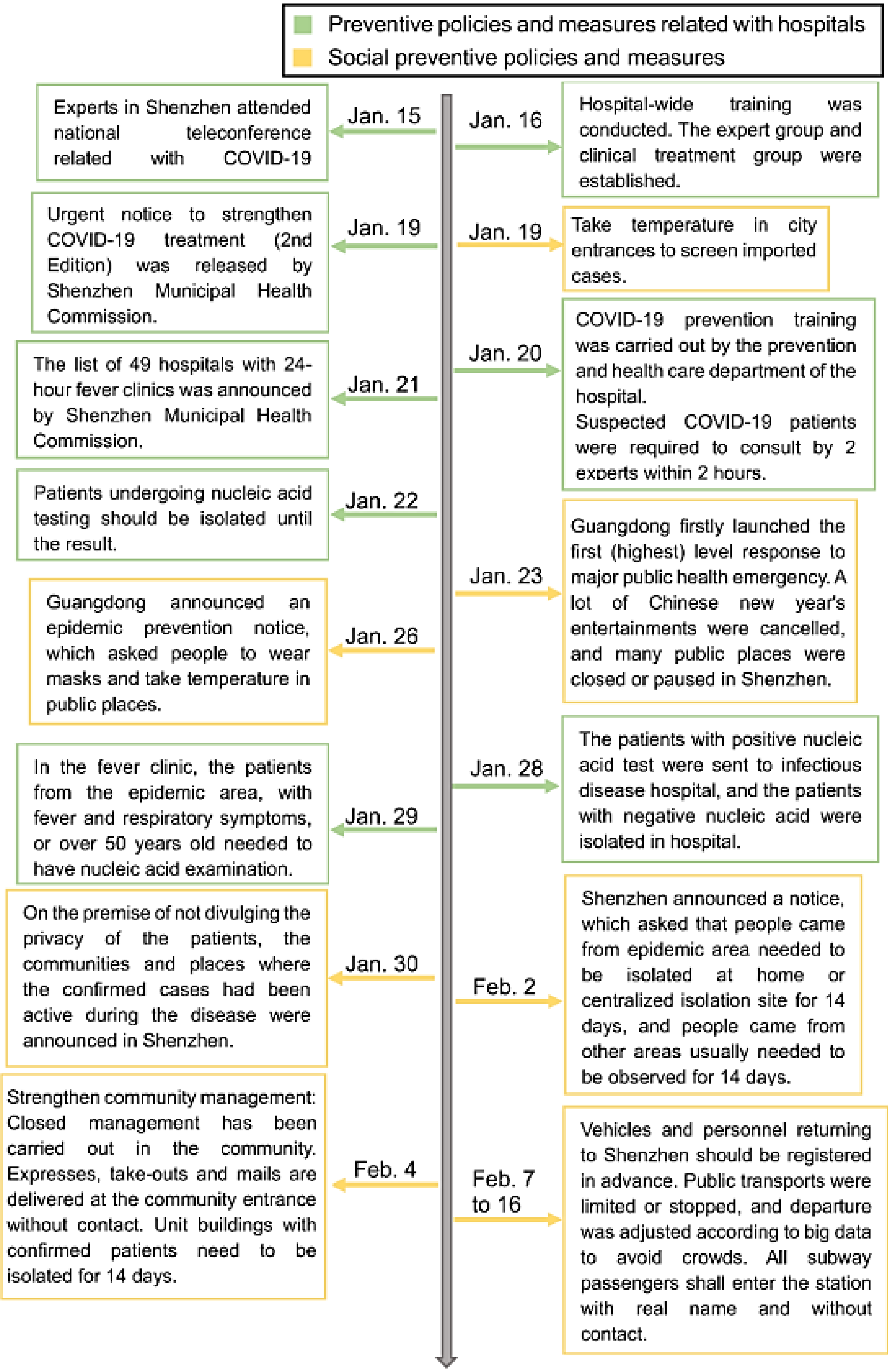


Figure 5: (A) Cumulative number of patients for different indexes & (C) The trend of newly patients came to Shenzhen and newly diagnosed patients

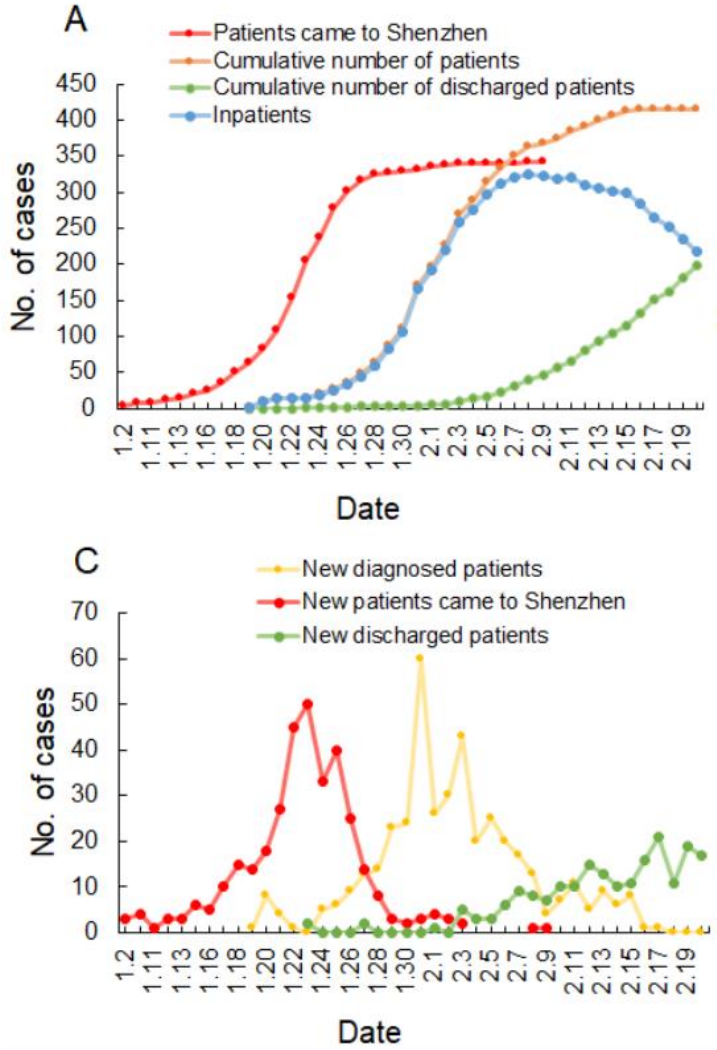
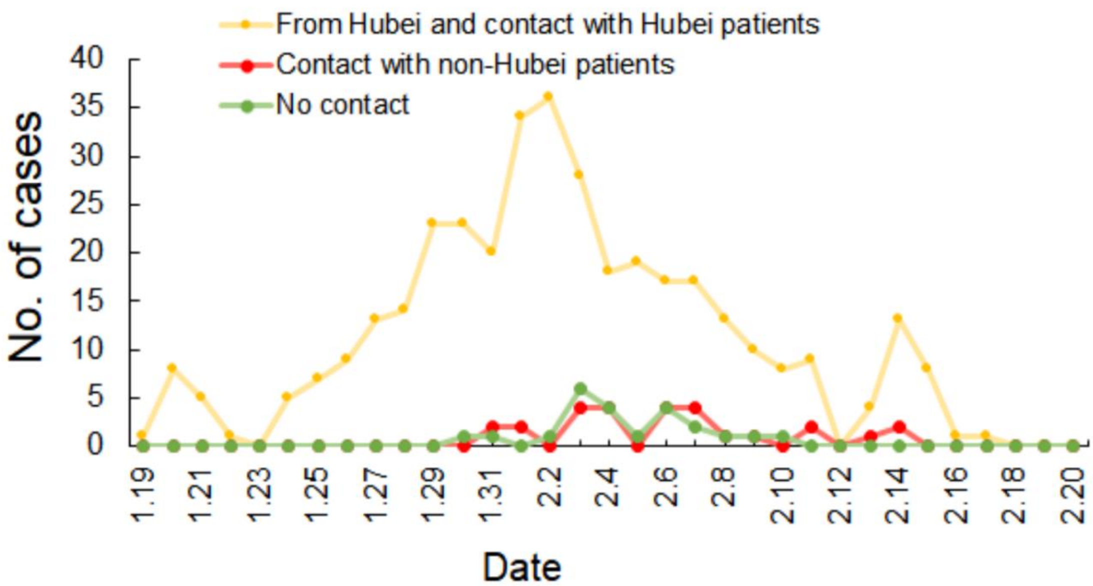


Figure 6: Epidemic curve of COVID-19 patients with different infectious pattern in Shenzhen by February 20, 2020.



Italy. One study which evaluated the reduction in epidemic speed in Italy observed a reduction in the growth factor at the final phase (after implementation of mild restrictive measures taken by the government) versus the initial phase (prior to implementation of measures). The reduction in growth factor was from 0.34 to 0.22. This is described as encouraging but far from being sufficient to stop or substantially slow down the epidemic dynamics (compared to a reduction of 0.33 to 0.003 in China and 0.56 to 0.11 in South Korea. [519] Another modelling study analysing the effect of containment measures across 107 provinces in Italy estimated that restrictions on mobility and human to human interaction had reduced transmission by 45% and further reduced it by an additional 34 % when lockdown was in place. [520]

A study modelling measures taken in core lockdown cities in China (see Shao in Table 9) pointed to how adding a large number of hospital beds along with lockdown of residential units improved cure rates and reduced mortality rates, and how the Italian government should recommend that their citizens undergo stringent home quarantine and increase medical resources in affected regions as soon as possible. [493]

South Korea. A recent analysis pointed out that while South Korea's experience provides evidence that epidemics can be suppressed with less extreme measures than those taken by China, and the necessity of prompt identification and isolation of cases, observation of metro traffic as a proxy for degree of social distancing showed a 80% decrease in traffic volume which suggests that strength of social distancing in Daegu may be comparable to that in Wuhan, China.

It was also pointed out that the recent decrease in the number of reported cases in South Korea is driven by the sharp decrease in Daegu and the epidemic may still persist in other regions, including Seoul and Gyeonggi-do (which reports around 10 new cases almost every day between 11-24 Mar). Small outbreaks may continue to occur in South Korea. [521]

A modelling study comparing the impact from NPI measures across certain countries noted that post mitigation strategies, viral transmission dropped to 9% of its initial value in South Korea but only to 60% in Brazil and to 23% in Italy. [522]

Hong Kong. A survey study suggests that the combination of NPIs implemented in Hong Kong (less drastic than the unprecedented and extensive mobility restrictions implemented in mainland China) have succeeded at containing spread of COVID-19. Hong Kong is located close to neighboring Guangdong province, which recorded the most cases of 1,356 as of 11 March amongst provinces outside of Wuhan. Public health measures included border restrictions, intense surveillance and testing of incoming travellers/local community (about 500 outpatients and 800 inpatients tested each day) with quarantine orders to close contacts of confirmed cases/travellers from affected countries, flexible working arrangements, and school closures (with resumption of teaching via the internet from 13 Feb). The estimated Rt for COVID-19 remained < 1 with little evidence indicating sustained local spread beyond sporadic cases and known clusters seven weeks from since the first known case in Hong Kong, and the Rt for influenza (as a proxy indicating changes in transmission of infection alongside NPIs implemented) registered a 44% decrease during the holiday/closure weeks versus before the start of school holidays/closure (from 1.28 to 0.72). This 44% reduction is greater than the 10-16% reduction in influenza transmission conferred by school closures during the 2009 pandemic and 2017/18 winter in Hong Kong, suggesting that other social distancing measures contributed to the incremental reduction effect.

It was also noted that the COVID-19 situation generated stronger compliance in the public to community measures – 90% and 98% of respondents avoided going to crowded places and wore face masks when leaving home respectively, compared with only 79% and 10% using face masks during the SARS and H1N1 pandemic situations respectively.

The study noted that the measures, being effective and less drastic than those used in Wuhan, are feasible options in other locations. [12]

Nordic countries. An analysis of doubling time (DT – the time it takes before COVID-19 cases doubles) showed positive trending 5-6 days after the governments-imposed shutdowns (working from home, closed schools, travel bans and social distancing). The increase in DT values is evident in all Nordic countries, especially Denmark, whose DT changed from 2 to 10 days over a few weeks. [523]

NPI Combinations, Timing, and Deployment Strategies

After China went into lockdown, and as more countries followed in varying degrees and forms, several studies (mostly modelling ones) emerged projecting the effectiveness of lockdown measures, their respective reductive impact, optimal implementation timing, and other influencing factors.

Large scale NPIs and lockdowns. Non-specific to China, several modelling studies projected the impact of large-scale combination of NPIs and lockdowns. A recent modelling study projecting the impact of 936 local, regional, and national anti-contagion policies recently deployed across localities in China, South Korea, Iran, Italy, France, and the US found that early COVID-19 infections would exhibit exponential growth rates of about 45% per day in the absence of any policy actions. As at the time of the study, the policies packages deployed have already prevented/delayed infections in the order of eighty million (there would have been roughly 74 million more cumulative cases in China, 5 million more in South Korea, 1.2 million more in Italy, 2.6 million more in Iran, 650K more in France and 20K more in US). Policy action in the US was too recent at the time of the study to register substantial impact. [524] Another study estimated that the NPIs in 11 European countries up to 31 Mar averted 59,000 deaths and reduced Rt from 3.87 to 1.43 (averaged across countries). [525]

Another study, which aims to provide evidence on the efficacy of lockdown measures all over the world by means of quantitative analysis through a panel data approach, further affirmed that lockdown measures did reduce COVID-19 cases. [526]

Other modelling studies simulating the impact of various containment measures have shown the effectiveness of combined use of some measures. Two UK studies (Kucharski et al and Davies et al, see Table 10) showed that combination of measures such as isolation of symptomatic cases, contact tracing and physical distancing reduces Rt to <1, while the measures on their own reduces R but not sufficiently. [527] [528] [528] [391] [529] Another modelling study on Thailand projected that the combination of consistent mask wearing, frequent hand washing and good hygiene practices, and social distancing (maintained distance of >1 meter with ≤15 minutes of close contact) in a population would reduce confirmed cases by 84%. [327]

Implementation timing, duration, and severity of measures. Recent modelling studies on the spread of COVID-19 globally or in various countries showed that public health interventions should be executed as soon as possible and that seemingly small delays in policy deployment can produce dramatically different health outcomes. Severity and duration of interventions also make a difference.

<u>Time to effectiveness.</u> A study on the efficacy of lockdown measures all over the world indicated that average time to effectiveness for the policy is about 10 days, with increased

benefits and reduction in infections as the lockdown duration increases. [526] A US study using geographic data from mobile devices observed a 14-day lag effect from the social distancing decision (causing people to stay at home, not work full-time, and travel less distance from home). [530] Another study observed from European data that social distancing interventions reduced the COVID-19 case doubling time (initially at three days), and the impact is typically seen only nine days after their implementation. [531]

Two other modeling studies exploring the effect of mobility and distancing behavioural changes on COVID-19 spread (one on Mexico and the other, non-country specific) projected that time to effectiveness will be 2 days under a perfect intervention scenario, with further delay extended under an imperfect intervention, and even longer if severity of infection increases. [532] [360] A study of the effect of mobility pattern changes across the US noted that the drop of 35-63% relative to normal conditions did not translate to noticeable impact for 9-12 days, and potentially up to 3 weeks (in line with the virus's incubation period and additional reporting time lag). [393]

A few studies (two on the US and India, and the other, Spain) have noted that the reductive effect on epidemic spread set in prior to implementation of lockdown measures. An early decrease in Rt was observed prior to national lockdown in 14 Spanish regions, possibly due to enforcement of personal hygiene and social distancing measures. [533] [393] [534] More notably, mobility fell as case counts rose in the US, often before stay-at-home orders were issued. Mobility also reduced by 15% in India a week prior to the series of lockdowns. These were possibly due to population adherence to social distancing guidelines and some state level school closures. [534] Another study using data from British Columbia, Canada, showed that a control measure change at population takes 3 weeks or more before a substantial difference in cases compared to baseline trajectory can be noted/measured. The timeframe is usually longer for distancing changes. [535]

<u>Delayed implementation.</u> A number of studies quantified the impact of delayed implementation. A study on Mexico pointed out that transmission rate reduction needs to be achieved within 7 days, and delaying action by 1-2 weeks will result in outbreak growing significantly. [532] Another modelling study (Wei et al) pointed out that a 7-day delay in measures implemented in Wuhan would have increased the necessary severity of transmission control by 65%. A study on the US concluded that postponing measures by one week would result in 2.2 times the current number of confirmed cases, [534] while similar US studies pointed to earlier implementation of policies (ranging from 5 to 17 days earlier) resulting in reductions of infections (ranging from 61.6% to 84%). [536] [537] [538] A global study noted a positive correlation between a slower response time and the maximum deaths number and growth rate of daily deaths. Additional deaths on peak day was 9 and average daily growth rate in deaths was 0.083 percentage points higher for each additional day of delay (days since the first case in reaching a determined level of stringency in implemented measures). [539] A US study estimated that earlier implementation of measures by 35 days (from day 85 to day 50) would result in reduction of minimum feasible peak from 612,493 to 16,543. [540] Another study on France projected that both hospital occupancy and deaths would have decreased by 30% and 85% in average if lockdown was implemented 20 and 30 days earlier respectively. [541] Two US studies also noted association between implementation timing of lockdown and timing to the peak. One study pointed out that regions where stay-at-home mandates were implemented late (the latest 10%) registered an extra 35.3 days to the peak number of cases and 38.3 days to the peak number of deaths. The studies also suggested the possibility of a "threshold" duration within which an implemented mandate would be effective, with one study estimating the window for optimal

application of lockdown measures to be within the first 10 days of epidemic or when initial cases reach 250 or 2.4 cases/km^2. [542] [543]

A study of mortality trends in 27 European countries suggested that earlier adoption of effective national lockdown was associated with lower mortality. Countries which implemented lockdown after a week from outbreak onset (UK, Spain, France and Italy) experienced the highest mortality (up to 26,384 deaths), countries with lockdown measures implemented in less than a week from outbreak have intermediate mortality (up to 6,917 deaths), while countries which implemented lockdown before the onset of outbreak (Slovakia, Latvia, Bulgaria) experienced the lowest mortality (up to 536 deaths). Statistically, cumulative deaths were highly correlated with the timing of lockdown implementation (r^2= 0.876). [544] Similarly, modelling studies across multiple countries noted that countries with earlier implementation and more stringent implementation of measures were associated with lower Rt values and time taken to control pandemic. One of the studies defined early implementation to be 2 weeks before the 100th case for lockdown type physical distancing measures and about a week before the detection of the first case for travel bans. [545] [546] [547]

Interestingly, two studies suggested that the timing of national measures may be more important than their stringency. A regression analysis (Papadopoulos et al) examining the association between various national responses and COVID-19 mortality rates and case numbers in 150 countries found that "early introduction of first measure, early international travel restrictions, and early public information" were associated with lower case numbers and that 'early introduction of first measure, early international travel restrictions, early public information, early generalised workplace closure and early generalised school closure" were associated with reduced mortality. The analysis noted no significant association between maximum stringency of lockdown policies and mortality and case numbers. [548] Another modelling study on data from OECD countries observed that the timing of initiation of social distancing was most important and explains 62% of the death numbers while lockdown strictness/duration are less informative in explaining mortality rates. A delay of 7.49 days in implementation doubles the number of deaths. [549]

Duration and severity of measures. Several studies also simulated scenarios of strong versus more relaxed measures. Generally, there are increased benefits and reduction in infections as the lockdown duration and severity increases. Notwithstanding, Papadopoulos et al (see study in above section) suggested that timing of national policies may be more important than their severity. One study simulated comprehensive interventions (including strict travel restriction, cancel conferences, mandatory quarantine, restriction of public transportation, school closing and shut down all non-essential companies) across 102 countries. A scenario of active intervention versus one of limited intervention one month later resulted in the maximum number of cumulative cases increasing from 211,000 to 3,929,641 (18.6 times) and the number of deaths increasing from 174 to 133,608 (using 3.4% as average case fatality rate). Duration time of epidemic was increased from 157 days to 215 days. [550] [524] [526] [83]

Wei et al projected that prolonging outbreak duration in Wuhan by applying an intermediate, rather than strict, transmission control would not prevent hospital overload regardless of bed capacity, and would likely result in a high ratio (21% ~ 84%) of the population being infected but not treated. [551]

Another UK study using simple stochastic simulations showed that the less strict the implementation of social distancing, the more time it will take for life to return to normal with more lives at risk. With a perfectly implemented lockdown in the UK, the epidemic will be resolved in roughly 1.5 months with only 22,000 dead. A semi-lockdown situation will result in 4.5 months of semi-lockdown situation with approximately 80,000 dead, and if the lockdown is even more relaxed, the lockdown may need to take over 6 months and result in more than 300,000 fatalities. [552]

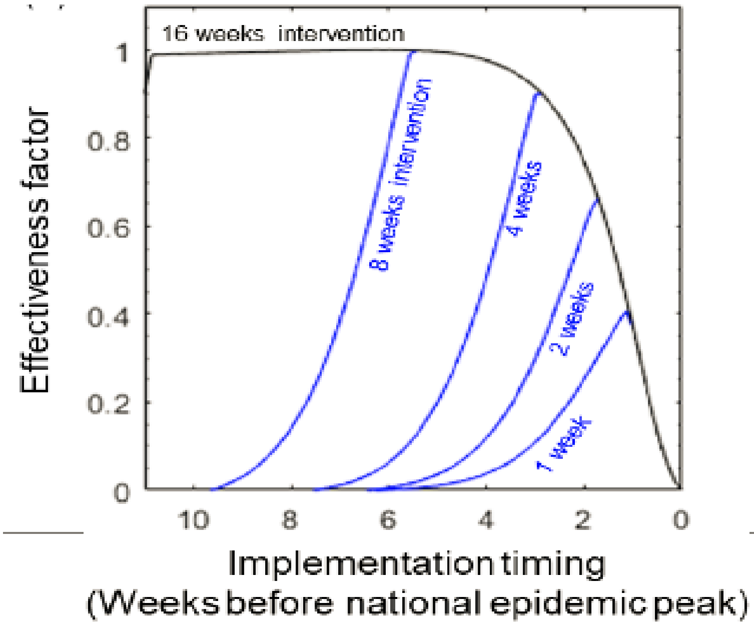
A modelling study on US (Liu et al) projected that earlier aggressive traffic controls (two weeks before) would have delayed and reduced epidemic peak by up to 30% but its influence dwindles to a negligible level up to March 16. Other interventions such as contact tracing and quarantine, business and school closure, and restricting public gatherings, effect a more constant impact. The study, as well as other similar ones, quantified the severity of measures and their corresponding reductive impact on spread:

- Liu et al estimated that A 25% reduction in transmissibility (Rt reduced to 2.01) across all US states delayed national epidemic peak by about 35 days and reduced its magnitude by 39%, and a 50% reduction in transmissibility (Rt reduced to 1.34) postponed the national epidemic peak to winter 2020 and reduced its magnitude to 1%. [15]
- A simulation (Milne et al) of the application of four social distancing interventions (school closure, workplace non-attendance, case isolation and community contact reduction) in Newcastle, Australia, projected that continued use of four interventions with 90% workplace non-attendance and a 70% reduction in community-wide contact reduced infection rate from 66% to < 1%, and at lower intensity (workplace non-attendance of 50% and reduction in community-wide contact by 30%), reduced infection rate to < 10% (even with activation delays in the order of weeks). [553]
- Another study noted that contact rate has to be reduced by 80% over days (downside of workforce dropping to 20%) to immediate stop exponential growth of infections and lower Rt to <1. [554]
- A modelling study on counties across the US quantified that a reduction of non-essential businesses to a national average of 70% resulted in the proportion of counties with Rt < 1.0 increasing to 49% and 96% at temperatures of 35 °F and 55 °F respectively. (Baseline scenario assuming social distancing of 35%, with 1% and 20% of counties with Rt < 1.0 at 35 °F and 55 °F respectively. [354]

A study (Chang et al, in Table 10) on intra-city travel in Taiwan found that a 60% intra-city travel reduction for 2 months had similar outcomes as a 70% reduction for 1 month. [555]

Considering the negative socio-economic impact of prolonged school and business closures, Liu et al pointed out that when and for how long should these interventions be put into effect to maximise net benefit is important. The study plots the empirical relationship informing the optimal timing and practically affordable duration to enforce these community level interventions shown in Figure 7. [15]

Figure 7: Effectiveness (quantified by normalized % of reduction in epidemic peak magnitude) as a function of the implementation timing (quantified with no. of weeks ahead of national epidemic peak).



A more recent study estimating the effectiveness of Stay-at-Home Orders in the US found that these had a significant impact on the growth rate of infections (estimated to be 18.2% at day 22 of intervention). Should the order have been implemented 13 March 2020 (17 days earlier than what was done), new infections would be reduced by 62.3% (hundreds of thousands), and preventing thousands of deaths.

A study assessing changes in Rt in 16 Spanish regions noted small occasional increases in Rt in 9 regions after the enforcement of a lockdown, possibly due to the migration of students and families after closure of schools and workplaces. Interestingly, the study noted that strengthening of lockdown measures had minimal reduction on Rt while 5 regions showed increases in Rt. This may be attributed to the exhaustion of lockdown by the public, resulting in relaxation in compliance. [533]

Comparing across NPIs. A number of studies analysed the comparative effectiveness of the NPIs on outbreaks. (See Table 10) Generally, detection/contact tracing with subsequent quarantine/isolation yield effective results with less detrimental economic impact. Social distancing measures (including workplace/school closures and stay home orders) are also effective and can reduce infection rate up to 60 to over 70 percent, and reduce R_t to <1 and by 81%. (Studies on the UK and the Netherlands quantified contacts reduced to be about 70% to slightly less than 4 per person, slightly less than >85% reduction to about 2 per person noted in China (see pages 58).) [389] [395] [397] Evidence on community hygiene measures are less definitive. Border control measures can delay and reduce the impact of local epidemics and are important at the earlier phase of an outbreak but have limited impact over the rest of the outbreak duration.

See also section on ‘Physical Distancing’ (page 58) for studies on the comparative effectiveness of social distancing measures in different settings/age groups.

<u>Policies vs voluntary measures.</u> A number of studies also pointed to a difference between government-imposed measures (stay-home-orders, quarantine etc) and measures taken by individuals as a result of awareness and self-motivation (handwashing, mask-wearing, social distancing, restaurant/bars patronage limit etc). While the former can be effectively implemented more swiftly, the latter can have a larger and more sustainable impact. A study

(Chernozhukov et al in Table 10) pointed out that both policies and people's voluntary change in behaviour as a result of awareness on transmission risks are crucial determinants of social distancing practice.

A modelling study (Teslya et al) evaluated the impact of self-imposed prevention measures due to COVID-19 awareness and of government-imposed social distancing on the peak number of cases, attack rate and time to the peak. Disease awareness, coupled with self-imposed prevention measures has a much larger impact on the epidemic even if efficacy levels of the measures are moderate or low. For example, at a modest handwashing efficacy of 30%, impact on the epidemic is predicted at a 65% reduction in the peak, a 29% decrease in the attack rate, and a delay in peak timing of 2.7 months. In comparison, government imposed social distancing reduces contact rate regardless of disease awareness and halts the epidemic for the duration of the intervention but epidemic resurgence is expected as soon as measures are lifted. When awareness spreads fast, self-imposed measures are more effective as they can reduce epidemic impact even at moderately high efficacy levels (about 50%).

Studies on economic/societal impact. There is a general lack in economic studies on NPIs, possibly because the impact of such measures is difficult to evaluate scientifically, and researchers' attention tended to focus on medical interventions. A 2017 systematic review (Pasquini-Descomps) evaluated the cost-effectiveness of interventions administered during the H1N1 pandemic and indicated the relatively higher cost-effectiveness of quarantine and contact tracing/tracking measures, while school closure and social distancing as measures by themselves were not seen as cost-effective. Brauner et al also compared extent of Rt reduction attributable to the different NPIs with public perception data to derive effectiveness-to-burden ratios. NPIs such as school closure, symptomatic testing, suspension of businesses involving high transmission risks, and limiting the sizes of gatherings recorded good effectiveness-to-burden trade-offs; while closing most non-essential businesses and issuing stay-at-home orders imposed a strong burden with minimal additional impact.

Table 10: Studies analysing comparative effectiveness of individual NPIs in combined use

Study	Description
Cheatley et al [556]	A rapid review was done to analyse the effectiveness of the NPIs on outbreaks. Social distancing and household quarantine measures were deemed the most effective among the NPIs. Estimates of the respective NPIs' effectiveness from various earlier studies were listed as: • Social distancing measures were generally effective in containing outbreaks by reducing Influenza attack rate by 23-73 %. • Household quarantine is potentially the most effective measure if compliance was high. It could reduce attack rate by 10 % and up to 70 % when the measure is taken together with school and work closure and border controls. • Environmental and personal hygiene, and masks and hand hygiene could reduce Influenza infection risks by 2.14 % and 27 % respectively. • Travel restrictions can only reduce attack rate by 0.02 %. However, these measures also come with economical and psychological costs. Social distancing and household quarantine

Study	Description
	measures were deemed the most effective among the NPIs. Policy packages, as opposed to individual policies, were deemed as most effective approaches.
Abouk et al [557]	AUS study that measured the impact of 6 social distancing common policies on people's presence at home and mobility in different types of public places in the US. The study used Google released daily human mobility indicators to analyse the difference in policies on stay home order, more limited stay home orders, non-essential business closure, large gathering ban, mandatory school closure and restaurants and bars limit. It was found that: • Stay home order effectively kept people at home • Non-essential business closure and restaurants and bars limit moderately kept people at home Other policies did not appear to keep people at home.
Koo et al [558]	A modelling study on Singapore estimated the cumulative number of SARS-CoV-2 infections at 80 days after detection of 100 cases of community transmission, under three infectivity scenarios of Rt at 1.5, 2.0 and 2.5, and assuming 7·5% of infections are asymptomatic. The estimated median number of cases for each of the scenarios and with government led interventions of quarantine, school closure, and workplace distancing are listed in Table 11. Asymptomatic fraction of infections impacts the results of these interventions, with fractions up to 50·0% resulting in 277 000 estimated infections at day 80 with combined intervention at Rt of 1·5. The study recommends combined intervention, with other measures such as rapid diagnosis and appropriate case management, and public cooperation in community measures such exercising good hygiene and infection prevention in shared spaces, if local containment fails. The significance of school closure and workplace distancing was pointed out in light of Singapore's previous experience of school closures to limit spread of hand, foot and mouth disease (decreased up to 53% in secondary cases) and having one of the highest employment rates among older individuals amongst OECD nations.
Milne et al [553]	A modelling study simulated the application of four social distancing interventions (school closure, workplace non-attendance, case isolation and community contact reduction) in Newcastle, Australia. It found that continued use of four interventions at varying levels of severity can lower the infection rate significantly, even with activation delay of 6 to 10 weeks. The model suggests that school closure is the least effective (on the assumption that children still have contact in the wider community when schools are closed) while case isolation (assuming 100% children and 90% adult compliance, and that only cases are isolated, not the

Study	Description
	whole family) and 70% reduction in community-wide contact are highly effective.
Teslya et al [559]	A modelling study evaluated the impact of self-imposed prevention measures (handwashing, mask-wearing, and social distancing) due to COVID-19 awareness and of short-term government-imposed social distancing on the peak number of cases, attack rate and time to the peak. Self-imposed measures, coupled with disease awareness, has a large impact even at moderately low efficacy levels (handwashing efficacy of 30% results in 65% reduction in the peak, 29% decrease attack rate, and 2.7 months delay to peak timing). Government imposed social distancing works regardless of disease awareness at stringent contact rate reductions. (100% efficacy mass quarantine postpones the peak by almost 7 months.)
Ellerson et al [560]	A modelling study found that lockdowns are most effectively implemented when workplace and public sphere contacts (the more important spheres in disease spread) are significantly reduced. The study also explored viable strategies for mitigation that do not require a total lockdown. For example, when reopening society, workplace restrictions can be lifted (to alleviate economic impact) while keeping social gatherings at a minimum. Widespread testing, contact tracing, and short periods of quarantine for individuals, is a cost-effective alternative, and shown to reduce the average 100 days of quarantine per person (in lockdown measures) to around 20 days per person.
Kucharski et al [527]	A modelling based on BBC Pandemic data from 40,162 UK participants found that a combination of isolation of symptomatic cases and tracing of their contacts reduced Rt more than mass testing or self-isolation alone. A combination of these two measures with physical distancing reduces Rt to R0<1.
Chang et al [555]	A modelling study on Taiwan simulated local travel restrictions to evaluate its effects on the spread of SARS-CoV-2. It was observed that intra-city travel reduction had a greater impact on reducing the number of infections than intercity travel reduction. It was also found that higher levels of reduction and longer periods of reduction for intra-city travel can yield similar results (eg a 60% intracity travel reduction for 2 months had similar outcomes as a 70% reduction for 1 month). Notwithstanding, intercity travel reduction influences infection numbers across cities and can reduce the number of cities that have infections during the initial stage of the outbreak.
Pasquini-Descomps 2017 [561]	A 2017 systematic review evaluating the cost-effectiveness of interventions administered during the H1N1 pandemic indicated the relatively higher cost-effectiveness of quarantine and contact tracing/tracking measures, even for medium to low severity crisis. School closure and social distancing as measures by themselves were not seen as cost-effective. The review qualified however that use of

Study	Description
	these measures as part of multi-intervention strategies may yield different results.
Brauner et al [398]	The modelling study with 41 countries evaluated the effectiveness of different NPIs on curbing spread of COVID-19 and their perceived burden placed on the population. Six NPIs were found to have a high (>97.5%) posterior probability of being effective: closing schools (mean reduction in R: 58%), limiting gatherings to 10 people or less (24%), closing non-essential businesses (23%), suspending businesses involving high transmission risks (19%), testing symptomatic patients (18%), and stay-at-home orders (17%). This data was combined with that from an online best-worst scaling survey on how burdensome the public perceived the NPIs to derive effectiveness-to-burden ratios. NPIs like school closure, symptomatic testing, suspension of businesses involving high transmission risks, and limiting the sizes of gatherings recorded good effectiveness-to-burden trade-offs; while closing most non-essential businesses and issuing stay-at-home orders imposed a strong burden with minimal additional impact.
Chernovzhukov et al [562]	The study assesses the impact of various policies adopted by the US states (both direct impact and indirect impact through change in social distancing behaviour) and the impact of voluntary behavioural change by people in response to information on COVID-19 cases. It estimated that the combination of all policies reduced the growth rate of cases by 63%, of which 21% is attributable to their direct effect while 42% is attributable to their indirect effect on social distancing behaviour. Mandating the use of face masks on 1 April 2020 across all states was predicted to have brought down the case growth rate by 10-25% in late May. Keeping non-essential businesses open was estimated to have increased the cases by -10% to 40%. The study also pointed out that individuals were observed to have voluntarily limited their activities and interactions outside upon learning of a rise in infected cases. This can somewhat offset the likely increase in infection rates following the removal of policies.
Davies et al [528]	The study examined the potential impact of different control measures in alleviating the burden of COVID-19 in the UK. School closures, physical distancing, shielding of people aged 70 and above, and self-isolation of symptomatic cases were all found to reduce R individually, but neither of them was sufficient to produce a sustained decline such that ICU demand dropped below the available health service capacity. Although combining all four strategies was more effective in decreasing Rt, only implementing lockdown periods simultaneously were enough to bring R_t, near or below 1. The study pointed out the importance of considering the trade-offs between having fewer, longer lockdown periods and having more frequent, shorter lockdown periods.

Study	Description
Koh et al [545]	The study on data from 142 countries evaluated the effectiveness of three different types of measures: (i) international travel controls, (ii) restrictions on mass gatherings, (iii) and lockdown-type measures. With early implementation, lockdown-type measures have the largest effect on reducing Rt, followed by complete travel bans. The study also noted a wide range of lockdown-type measures ranging from less stringent forms such as working from home up to complete movement restrictions, and the differing types often effect similar results (less stringent working from home or staying home policies reduces Rt effectively by 0.24 and 0.45 respectively).
Wilasang et al [547]	The study examined the effectiveness of control measures in the reduction of Rt in 10 countries: China and South Korea, who implemented extensive detection/contact tracing/quarantine of contacts with social distancing measures registered sharp Rt reductions (to below 1) within 3-4 weeks while the other 8 countries (Belgium, France, Germany, Iran, Thailand, Spain, the US and the UK) who relied more solely on social distancing measures.

Table 11: Estimated median or cumulative number of SARS-CoV-2 infections on day 80 by location, intervention, and level of infectivity

	Baseline	Quarantine	School closure	Workplace distancing	Combined intervention
R_0=1·5					
Total number of infections	279 000 (245 000–320 000)	15 000 (800–30 000)	10 000 (200–28 000)	4000 (200–23 000)	1800 (200–23 000)
Home community	138 000 (116 000–152 000)	2200 (300–7800)	2000 (117–7200)	700 (98–5500)	300 (13–5700)
School	1400 (1100–1500)	14 (5–80)	16 (2–70)	7 (4–51)	1 (0–54)
Workplace	139 000 (128 000–164 000)	12 000 (500–21 900)	8000 (124–21 000)	3500 (102–17 800)	1500 (42–18 000)
R_0=2·0					
Total number of infections	727 000 (670 000–776 000)	130 000 (38 000–244 000)	97 000 (14 000–219 000)	67 000 (11 000–145 000)	50 000 (2000–143 000)
Home community	372 000 (339 000–411 000)	66 000 (23 000–129 000)	46 000 (11 000–113 000)	28 000 (8000–79 000)	21 000 (1200–68 000)
School	4300 (3700–4300)	600 (100–1200)	500 (27–1000)	300 (33–800)	200 (11–800)
Workplace	351 000 (327 000–361 000)	63 000 (15 000–127 000)	51 000 (3000–105 000)	38 000 (2800–65 000)	28 000 (800–67 000)
R_0=2·5					
Total number of infections	1 207 000 (1 164 000–1 249 000)	520 000 (268 000–754 000)	466 000 (175 000–728 000)	320 000 (116 000–558 000)	258 000 (65 000–508 000)
Home community	640 000 (623 000–675 000)	264 000 (144 000–410 000)	235 000 (92 000–366 000)	163 000 (66 000–281 000)	132 000 (34 000–265 000)
School	7100 (7200–7900)	3000 (1400–4000)	2400 (1300–3600)	1500 (800–3400)	1300 (300–2800)
Workplace	560 000 (550 000–584 000)	253 000 (140 000–390 000)	228 000 (82 000–358 000)	156 000 (49 000–274 000)	124 000 (31 000–241 000)

Data are median (IQR). All numbers up to 10 000 have been rounded to the nearest hundred, and numbers higher than 10 000 have been rounded to the nearest thousand, therefore, some discrepancies will exist in the summations. Due to the stochasticity within each simulation, numbers less than 20 indicate nearly complete suppression and should not be compared to assess effectiveness. SARS-CoV-2=severe acute respiratory syndrome coronavirus 2. R_0=basic reproduction number.

Political factors on timing. An event history analysis of dataset on five social distancing policies across fifty states in the US reveals that the most important predictors of implementation and timing of the policies are political. All else being equal, Republican governors and governors from states with more Trump supporters were slower to adopt social distancing policies (Republican governors were 42.2% less likely to mandate social distancing than their Democratic counterparts). Poorer states were less likely to adopt social distancing policies (sates at 25th percentile of GDP per capita were 26.6% less likely to implement social distancing than states at the 75th percentile). Neighbouring state actions also increased the likelihood of social distancing policies (a state with no neighbours adopting a given policy was 32% less likely to adopt it). Confirmed state-level caseload had only a small effect on social distancing timing. [563]

Targeted lockdown approach. A study predicted and measured the effect of the current 21-day lockdown on the reduction of cases and deaths in three states (Maharashtra, Delhi, Tamil Nadu) and overall, India. Based on varying scenarios of lockdown effectiveness, it was estimated that the lockdown would only bring about a 0.1% case reduction and 0.3%-0.5% death reduction in Maharashtra, and a 0.2%-0.6% case reduction and 0.2%-0.5% death reduction in overall India. On the contrary, the lockdown would bring about a 30%-33% case reduction and 39%-52% death reduction in Delhi, and a 21%-29% case reduction and 32%-48% death reduction in Tamil Nadu, indicating effectiveness of the lockdown, and possible further case and death reductions with its extension. [564] Another later study revealed that epidemiological transition of COVID-19 in India is such that slower growth or peaking is observed in high HDI (Human Development Index) states while disease is growing in mid and lower HDI states. Similarly, a study noted that lower population density and temperate weather change were associated with decreased COVID-19 incidence in counties across the US. The 21 counties in the top decile for population density had the highest incident case and fatality rate per 100,000 people, nearly 10 times the estimates in the lowest quartile, and relative Rt increased across the coldest temperatures. [354] Public health efforts focused on specific states (eg urban low HDI states in India, colder and high population density states/counties in the US) can help target resources and reduce impact from a larger universal lockdown. [565] [566]

Influencing factors on lockdowns. The implementation of lockdowns was especially effective when curfews and fines are implemented concurrently. Considering that the timing of NPI implementations is important and directly affects NPIs' effectiveness, it was found that factors such as higher population density, higher income level, and later first case detection, were linked to delayed NPI implementation. [355]

A study (see Pullano et al in Table 6) evaluating lockdown and mobility patterns in France noted that mobility reductions were strongly associated with regions with an active population (24-59 years old), with workers employed in sectors highly affected by the lockdown, and with high hospitalization rates. There was also some correlation to regions' standard of living. [404]

Community level lockdowns? A study seeks to determine if social distancing of 2 meters is achievable in two informal settlements in Cape Town. Dwellings were outlined via a Geographic Information System vector data set for the study.

Results show that the Masiphumelele settlement is denser than the Klipfontein Glebe settlement and will have a harder time social distancing. Nonetheless, both settlements are unable to achieve the 2m social distance, with large portions of homes that are unable to effectively self-isolate due to their proximity, and are instead merged into large clusters.

The study recommends that when implementing lockdowns in informal settlements, the Cape Town authorities and other authorities in the developing world may need to consider implementing shutdowns at the community level, rather than at the household level. [567]

Available resources. Several online models have been made available for use by academic medical centers and policy makers to simulate and estimate impact of COVID-19 spread and mitigating public health measures:

An online model, real-time, and interactive simulation model to facilitate local policy making and regional coordination in the US by providing estimates of hospital bed demand and impact of public health measures on COVID-19 spread has been made available in a preprint article from the Schools of Engineering and Medicine at Stanford University. The model is already actively being used by several academic medical centers and policy makers. [568] Link to model: https://surf.stanford.edu/covid-19-tools/covid-19/

Another online tool sharing organised social contact data and incorporating physical distancing measures and COVID-19 age-specific susceptibility and infectiousness is available at http://www.socialcontactdata.org/tools/ [569]

COVOID is a stochastic individual contact model which allows rapid modelling of many potential intervention scenarios and can be tailored to various settings while requiring only standing computing infrastructure. The software and codes are available at:

https://www.epimodel.org

https://www.r-project.org

https://gist.github.com/timchurches/ce8858ae1e572153a54271bd52deb9c3

https://gist.github.com/timchurches/95204f0565b0311ec32408a7e27c0f7f [570]

An online dashboard that integrates new knowledge of population risks and allows policymakers and health officials to monitor/evaluate potential health care demand at a granular level as infection rate and hospital capacity changes: https://covid19.demographicscience.ox.ac.uk/demrisk [571]

Beyond Lockdowns

As most countries went into lockdown with the COVID-19 pandemic, epidemiological modelling studies emerged projecting strategies could take moving forward. One of the first in line was a study by the Imperial College COVID-19 Response Team.

The study summarised combined NPI implementation into two possible overarching strategies for the UK and US – (a) Mitigation and (b) Suppression. Mitigation focuses on slowing but not necessarily stopping epidemic spread (reducing Rt but not to below 1) such that peak healthcare demand is reduced while protecting those most at risk of severe disease as the population acquires sufficient herd immunity, while Suppression aims to reverse epidemic case numbers to low levels (reducing Rt to <1) and maintaining that situation indefinitely until a vaccine becomes available (potential 18 months or more).

Under Mitigation, optimal policies are the combination of home isolation of suspect cases, home quarantine of those living in the same household as suspect cases, and social distancing of vulnerable groups. Notwithstanding, this is projected to reduce peak healthcare demand by 2/3 and deaths by half, which will still exceed general ward and ICU bed capacity by at least 8-fold with 250,000 deaths in the UK and 1.1-1.2 million deaths in the US. Under Suppression, a minimal combination of social distancing of the entire population and home isolation of cases and household quarantine of their family members will need to be maintained until a vaccine becomes available. The interventions may be relaxed temporarily in relative short time windows but will need to be reintroduced when case numbers rebound. Otherwise, a large epidemic wave will likely take place later due to insufficient build-up of herd immunity. Suppression has been the strategy taken by China so far, with several studies estimating that its interventions reduced Rt to <1 (see page 87). Close monitoring of the situation in China in the following weeks will help inform strategies in other countries.

In view of the high number of deaths under the Mitigation scenario, the study concludes that Suppression is the only viable strategy at the current time and the social/economic effects of measures needed with this strategy will be profound. [572]

Following the study, several studies modelled variants of the Mitigation and Suppression strategies, as well as other possible alternatives. These include:

- Adaptive triggering where social distancing measures are switched on and off intermittently over a prolonged epidemic duration (triggered when ICU capacity or other surveillance thresholds are crossed and then relaxed when the situation alleviates).
- Relaxation of measures for lower-risk groups while higher-risk groups remain under quarantine.
- Frequent mass testing of population and isolation of infected individuals, combined with less severe or minimal social distancing/lockdown measures.
- Strong surveillance of population, combined with other accompany measures and strategies.

In depth exploration of these various exit strategies and more alternatives is covered in COVID-19 Science Report: Exit Strategies & Scenarios.

Other Influencing Factors

Risk communication in use of containment measures is particularly important in a rapidly evolving situation where little is known about an epidemic or virus. Without effective communication, the many unknowns can result in development of rumours and unnecessary panic. [8] [490] (See section on 'Risk Communication' on page 56).

Whole-of-society approach. As a pandemic requires a whole-of-society approach, individuals and communities should also be engaged, listened to, and have their concerns addressed in the evolving situation. [573] [574] Success of implementation of NPIs depends heavily on the community's acceptance and cooperation. In China (during the COVID-19 crisis), the community largely accepted what have been described as 'the most ambitious, agile and aggressive disease containment effort in history' and fully participated in the management of self-isolation and enhancement of public compliance. In fact, civil society organisations have been mobilised to support prevention and response activities, and community volunteers were organised to help solve practical difficulties for isolated residents. These contributed to the NPIs' speed of implementation and efficacy in reversing the escalating cases in Hubei and importation provinces. [29]

<u>All communities.</u> The community's acceptance and cooperation depend on a conscious and deliberate effort by the government to test a measure's acceptability against as many communities as possible, even if the constituencies are small and not the foremost priorities. A one size fits all approach can lead to small points of challenge or difficulty in certain population groups that can result in dissatisfaction/resistance to the measures and)their eventual compliance/efficacy. For example, strong enforcement of isolation/quarantine at designated facilities can pose difficulties for the expatriate or migrant community (eg. Permanent Residents) who do not have family support structures in the community. Individuals from these communities may be reluctant to come forth when symptomatic for fear of lack of childcare arrangements should they be isolated/quarantined.

Failure to address such issues also leads to longer term economic impact with an exodus of foreign companies post outbreak and their influx into other countries in the region, or deglobalisation in broad. These have important implications for countries highly dependent on global trade and pivoted to solidify/expand relationships regionally/internationally.

A recent rapid review on community engagement approaches used in past epidemics noted that community engagement activities focused on the community at large, with no specific equity considerations and the make-up of strategies lacking diversity and representation. The study highlighted that with social responses being crucial in the fight against COVID-19, it is especially important to involve ethnic and minority populations in the making of decisions. [575]

A study proposed the following pragmatic principles that can improve sustained social efficacy of public health measures (improved social cohesion, mutual solidarity and sense of collective efficacy):

- Anticipate behavioural/social stability change and the need for strong risk communications
- Accurate and clear dissemination of practical instructions
- Making constructive behavior visible – perceived social norms are important in shaping social behavior
- Use of role models – guidelines of behavioural changes/sacrifices being relayed by public figures
- Highlight past or present experiences of the country overcoming ordeals via collective capacity and social cooperation
- Avoid excessive media coverage of behaviours stemming from panic or anxiety as they may induce uncertainty/reinforce such behavior.
- Encourage spontaneous sharing of experiences/contributions by individuals
- Mitigate impact of social inequality and ensure equal distribution of risks/burdens. [576]

Public awareness. Public awareness about an outbreak contributes to more timely and better levels of community acceptation and participation in NPIs. A study noted how timing and degrees of public awareness varied markedly across the cities in mainland China during the COVID-19 outbreak. Through the use of the Baidu search engine data and history of SARS cases in the cities, it was found that cities with more migration with the epicentre Wuhan (migration flows is a proxy for long-distance information flows as workers born/raised in a city but now work in another are likely to relate information back to friends and family in their home city[10]) and that were struck by SARS (and therefore, with a stronger memory of similar previous events) showed earlier, stronger and more durable public awareness of the outbreak. The study suggests that it is important to consider migration ties/online social networks in relation to speed of information flows, and memory of prior catastrophic events, as influencers of public response to public health threats. [577]

A study based on an online survey on 1,000 Italians found that less engaged people show higher levels of perceived susceptibility to the virus and severity of the disease. Less engaged people also have less trust for scientific and healthcare authorities, feel less self-effective in managing their own health, and are less likely to cooperate with healthcare

[10] This is particularly relevant in the Chinese context, where migrant workers account for more than one-third of the working population.

professionals. These people also search for more information and are more likely to change their purchasing behaviours. [578]

Another cross-sectional online survey study in the US showed that with increase in public knowledge on COVID-19, purchasing of goods, attending large gatherings, and medical masks use are negatively correlated with odd ratios of less than 1 at 0.88, 0.87 and 0.56 respectively. The odds of Democrats attending large gatherings and medical mask use were 30% and 48% lower compared to the Republicans. [579]

A survey study on the Hong Kong population found that a large proportion (80 and 90 over percent) was continuous concerned/interested in pandemic related developments. 67.5% believed that efforts done at the individual level were just as important as government policies. However, only 47.8% reported to have sufficient knowledge on protecting their health and safety during the pandemic. Risk perception is high with 96% of respondents believing that infectivity was high or very high and 80% believing that the virus had severe or very severe impact on health. A significant association was found between belief in a measure's effectiveness and its practice regarding community hygiene and social distancing measures, with a lower compliance in social distancing observed as compared to personal and household hygiene. [580]

Use of technology. The evolving COVID-19 outbreak has seen the rapid adaptation and adoption of technology to support various containment measures, such as social or workplace/school distancing and contact tracing. These include the massive adoption of online education and work tools by Chinese schools and workplaces. Medtech developments are also deployed to support triaging/detection of at-risk individuals seeking consultation advice or in the community, and to aggregate and estimate regional case estimates and risk at near real time. In Europe, anonymous location data from telecommunication providers were used to map and monitor concentrations of movement. [130] These solutions help relieve the administrative burden of public health services, increased accessibility to health services, and free up capacity in the healthcare systems. [581] [29] [582]

A study projects that telehealth will transform healthcare delivery in three different phases of the COVID-19 pandemic in the US:

- 1st Phase: Stay home phase where telehealth services will maintain continued access of medical care to reduce spread of the virus. Inpatient visits will drop drastically and be reserved for urgent cases and those who cannot access telehealth technology.
- 2nd Phase: COVID-19 related surge phase where telehealth services can be put in place to engage additional help from clinicians who cannot be physically present in the hospital.
- 3rd Phase: Post pandemic recovery phase where care capacity may be diminished due to the downstream consequences of deferring care for serious conditions. Use of telehealth is needed to ensure efficient use of hospital space and staff. Re-evaluation of regulation, policies and reimbursement needs to be carried out at this phase, including deciding which components of care are physical interactions absolutely necessary. [583]

Review articles have stressed the importance of tele-consultations and access to patient information from electronic medical records to manage patient follow-up visits remotely in the COVID-19 pandemic situation. [584]

Tracking behavioural change/other indicative data. Several studies and some countries have also started using social media, mobile network operators, online payment platforms, location-based data, and other data on mobility patterns and social interactions to monitor regional outbreak risks and implementation of NPIs. The COVID-19 Science Report: Exit Strategies & Scenarios covers these efforts in greater detail under the section on surveillance.

Concluding Points

The above containment measures are not applied separately but typically used in combination as part of larger multi-intervention strategies. The efficacy of any one containment measure depends in part on the extent and manner of implementation of other measures. Use of the measures should also be flexible and agile to adjust to an evolving pandemic situation. For example, entry restrictions should adapt not only to the travel pathways from different sources but also to the demographics of the potential travellers.

Where the first level of containment fails or leaks, measures supporting the next level can be strengthened to contain the situation. Maximising the effectiveness of a single measure may also accompany costs that are too high to bear such that a combination of less stringent measures actually serves the purpose more cost-effectively. In the case of the evolving COVID-19 epidemic, for example, governments of various countries adjusted travel restrictions when the source epidemic had extended to secondary infections outside of the Wuhan province. Similarly, travel restrictions and combination of measures taken at a national level should change if disease spread moves to a stage where numerous secondary sources are based at and travelling from multiple countries outside of China.

The selection of the combination of measures to deploy depends not only on the evolution of the spread of the virus (single source, multiple sources, international) but also on the travel volumes along each axis of potential importation, factors for each channel (eg throughput speed, transit time, ease of control and detection of infected persons) and other attributes. Particular measures should not be considered in isolation to the larger panoply of measures taken but a strategic view taken of the whole “area of operations”.

Such agility enables a country to reallocate resources more effectively to areas of need and away from areas where an initial threat has diminished, and factor in cost-effectiveness in its multi-intervention efforts and strategy.

Search Method

This descriptive review was based on searches of research databases (PubMed and Google Scholar), relevant journals, science reports, preprint servers, expert comment, news sites, relevant government websites and Google. The search strings included a combination of the terms ‘containment’ / ’control measures’, ‘pandemic’ / ‘epidemic’ / ’outbreak’ / ‘spread’, ‘SARS’ / ‘MERS’ / ‘H1N1’ / ‘COVID-19’ / ‘SARS-CoV-2’ / ‘2019-nCoV’ / ‘coronavirus’ / ‘respiratory illnesses’, ‘border control’ / ‘travel restrictions’, ‘border quarantine’, ‘isolation’, ‘quarantine’, ‘detection’, ‘release’, ‘hospital’, ‘healthcare’, ‘protection of healthcare personnel’, ‘protection of healthcare worker’, ‘infection control’, ‘use of mask’, ‘face mask’ / ‘N95 mask’ / ‘surgical mask’, ‘community hygiene’, ‘hand hygiene’, ‘risk communication’, ‘social distancing’, ‘workplace closure’, ‘school closure’, ‘business continuity plan’ / ‘BCP’, ‘working arrangements’ / ‘HR working arrangements’, workplace’, ‘effectiveness’ / ‘cost impact’ / ‘implications’.

Works reviewed include mainly policy or regulatory documents on general practices and recommendations, epidemiological/modelling studies, systematic reviews and qualitative/case studies that estimate or evaluate effectiveness or analyse influencing factors, and other relevant news articles and related references.

After the initial review, weekly searches were undertaken on with the same search strings in relation to COVID-19 or SARS-CoV-2 at PubMed, pre-print server medRxiv, relevant news sites, and clinical trial sites.

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References

[1] U.S. Department of Health and Human Service, “HHS Pandemic Influenza Plan,” 2017. [Online]. Available: https://www.cdc.gov/flu/pandemic-resources/pdf/pan-flu-report-2017v2.pdf. [Accessed 2 Mar 2020].

[2] Government of Singapore, “Infectious Diseases Act: Infectious Diseases (Quarantine) Regulations,” 2020. [Online]. Available: https://sso.agc.gov.sg/SL/IDA1976-RG1?DocDate=20190401. [Accessed 2 Mar 2020].

[3] Centers for Disease Control and Prevention, “Quarantie and Isolation: Coronavirus Disease 2019 Guidance for Ships,” 2019. [Online]. Available: https://www.cdc.gov/quarantine/maritime/recommendations-for-ships.html. [Accessed 2 Mar 2020].

[4] WHO, “Proceedings And Reports Relating To International Quarantine,” WHO, Geneva, 1956.

[5] Marine Department, the Government of the HKSAR, “Administrative Measures for Entry and Exit Inspection and Quarantine on Ships of International Sails,” 2002. [Online]. Available: https://www.mardep.gov.hk/en/pub_services/pdf/ship_quarantine.pdf. [Accessed 2 Mar 2020].

[6] Pacific Islands Legal Information Insitute, “Laws of Tuvalu: Quarantine (Maritime And Aerial) Regulations,” 2008. [Online]. Available: www.paclii.org › legis › consol_act_2008 › qaqaar507. [Accessed 2 Mar 2020].

[7] L. O. Gostin and B. E. Berkman, “Preparing for Pandemic Influenza: Legal and Ethical Challenges,” in *Institute of Medicine (US) Forum on Microbial Threats; Ethical and Legal Considerations in Mitigating Pandemic Disease; Workshop Summary*, Washington (DC), 2007.

[8] World Health Organization , “Managing Epidemics: Key facts about major deadly diseases,” 2018. [Online]. Available: https://www.who.int/emergencies/diseases/managing-epidemics-interactive.pdf?ua=1. [Accessed 2 Mar 2020].

[9] S. Ryu et al, “Nonpharmaceutical Measures for Pandemic Influenza in Nonhealthcare Settings—International Travel-Related Measures,” *Emerg Infect Dis,* vol. 26, no. 5, pp. 961-966, 2020.

[10] M. Chinazzi et al, “The effect of travel restrictions on the spread of the 2019 novel coronavirus (2019-nCoV) outbreak,” medRxiv (preprint), 2020. [Online]. Available: https://www.medrxiv.org/content/10.1101/2020.02.09.20021261v1. [Accessed 20 Feb 2020].

[11] A. Anzai et al, “Assessing the impact of reduced travel on exportation dynamics of novel coronavirus infection (COVID-19),” medRxiv (preprint), 2020. [Online]. Available: https://doi.org/10.1101/2020.02.14.20022897. [Accessed 20 Feb 2020].

[12] B. J. Cowling et al, “Impact assessment of non-pharmaceutical interventions against COVID-19 and influenza in Hong Kong: an observational study,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.12.20034660],* 2020.

[13] V. Constantino, D. J. Heslop and C. R. MacIntyre, “The effectiveness of full and partial travel bans against COVID-19 spread in Australia for travellers from China,” *medRxiv (preprint) [Available at:https://doi.org/10.1101/2020.03.09.20032045],* 2020.

[14] C. R. Wells et al, “Impact of international travel and border control measures on the global spread of the novel 2019 coronavirus outbreak,” *PNAS [Available at: https://www.pnas.org/cgi/doi/10.1073/pnas.2002616117],* 2020.

[15] P. Liu , P. Beeler and R. K. Chakrabarty, “COVID-19 Progression Timeline and Effectiveness of Response-to-Spread Interventions across the United States,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.17.20037770],* 2020.

[16] T. D. Hollingsworth, N. M. Ferguson and R. M. Anderson, “Will travel restrictions control the international spread of pandemic influenza?,” *Nature Medicine,* vol. 12, no. 5, pp. 497-99, 2006.

[17] A. Aleta and Y. Moreno, “Evaluation of the incidence of COVID-19 and of the efficacy of contention measures in Spain: a data-driven approach,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.01.20029801],* 2020.

[18] A. Zlojutro, D. Rey and L. Gardner, “A decision-support framework to optimize border control for global outbreak mitigation,” *Sci Rep,* vol. 9, no. 2216, 2019.

[19] E. D. Carter, “When Outbreaks Go Global: Migration and Public Health in a Time of Zika,” *Migration Policy Institute,* 7 Jul 2016.

[20] A. Aleta, Q. Hu, J. Ye, P. Ji and Y. Moreno, “A data-driven assessment of early travel restrictions related to the spreading of the novel COVID-19 within mainland China,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.05.20031740],* 2020.

[21] M. Boyd, M. G. Baker, O. D. Mansoor , G. Kvizhinadze and N. Wilson, “Protecting an island nation from extreme pandemic threats: Proof-of-concept around border closure as an intervention,” *PLoS ONE,* vol. 12, no. 6, 2017.

[22] L. O. Gostin , Public Health Law: Power, Duty, Restraint (Second Edition), New York and Berkeley: Milbank Memorial Fund and University of California Press, 2007.

[23] H. Nishiura, N. Wilson and M. G. Baker, “Quarantine for pandemic influenza control at the borders of small island nations,” *BMC Infect Dis,* vol. 9, no. 27, 2009.

[24] S. Clifford et al, “Interventions targeting air travellers early in the pandemic may delay local outbreaks of SARS-CoV-2,” medRxiv (preprint), 2020. [Online]. Available: https://doi.org/10.1101/2020.02.12.20022426. [Accessed 20 Feb 2020].

[25] H. Tian et al, “An investigation of transmission control measures during the first 50 days of the COVID-19 epidemic in China,” *Science,* vol. 368, no. 6491, pp. 638-642, 2020.

[26] J. Liebig, R. Jurdak, A. E. Shoghri and D. Paini, “The current state of COVID-19 in Australia: importation and spread,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.25.20043877.],* 2020.

[27] L. A. Selvey, C. Antão and R. Hall, “Evaluation of Border Entry Screening for Infectious Diseases in Humans,” *Emerging Infectious Diseases,* vol. 21, no. 2, pp. 197-201, 2015.

[28] P. Bajardi, C. Poletto, J. J. Ramasco, M. Tizzoni and Coliz, “Human Mobility Networks, Travel Restrictions, and the Global Spread of 2009 H1N1 Pandemic,” *PLoS ONE,* vol. 6, no. 1, 2011.

[29] WHO-China Joint Mission, “Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19),” World Health Organisation, 2020.

[30] J. G. Wood , N. Zamani , C. MacIntyre and N. G. Becker, “Effects of Internal Border Control on Spread of Pandemic Influenza,” *Emerg Infect Dis,* vol. 13, no. 7, p. 1038, 2007.

[31] Fergusen et al, “Strategies for containing an emerging influenza pandemic in Southeast Asia,” *Nature,* vol. 437, 2005.

[32] H. e. al, “Forecast and control of epidemics in a globalized world,” *PNAS,* vol. 101, no. 42, pp. 15124-15129, 2004.

[33] A. I. Adekunle, M. Meehan, D. Rojas, J. Trauer and E. McBryde, “Delaying the COVID-19 epidemic in Australia: Evaluating the effectiveness of international travel bans,” *medRxiv (preprint([Available at: https://doi.org/10.1101/2020.03.22.20041244],* 2020.

[34] O. Brynildsrud and V. Eldholm, “High COVID-19 incidence among Norwegian travellers returned from Lombardy: implications for travel restrictions,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.20.20038406],* 2020.

[35] L. A. Selvey, C. Antão and R. Hall, “Evaluation of Border Entry Screening for Infectious Diseases in Humans,” *Emerging Infectious Diseases,* vol. 21, no. 2, pp. 197-201., 2015.

[36] B. J. Quilty et al, “Effectiveness of airport screening at detecting travellers infected with novel coronavirus (2019-nCoV),” *Euro Surveill,* vol. 25, no. 5, 2020.

[37] J. C. Wang, R. H. Brook and C. Y. Ng, “Response to COVID-19 in Taiwan: Big Data Analytics, New Technology, and Proactive Testing,” *JAMA,* 2020 (Published online on 3 Mar).

[38] J. Rocklov, H. Sjodin and A. Wilder-Smith, “COVID-19 outbreak on the Diamond Princess cruise ship: estimating the epidemic potential and effectiveness of public health countermeasures,” *Journal of Travel Medicine (Accepted Manuscript),* no. Available at: https://doi.org/10.1093/jtm/taaa030, 2020.

[39] L. F. Moriatty et al, “Public Health Responses to COVID-19 Outbreaks on Cruise Ships —Worldwide, February–March 2020,” *Morbidity and Mortality Weekly Report,* 2020.

[40] World Health Organisation, “International Health Regulations,” WHO, Geneva, 2005.

[41] K. Pongpirul et al, “Commercial Airline Protocol during Covid-19 Pandemic: An Experience of Thai Airway International,” *From MedRxiv (preprint) [Available at:doi: https://doi.org/10.1101/2020.06.15.20132183],* 2020.

[42] United Nations Economic and Social Council, “Siracusa Principles on the Limitation and Derogation Provisions in the International Covenant on Civil and Political Rights,” 1985. [Online]. Available: https://www.uio.no/studier/emner/jus/humanrights/HUMR5503/h09/undervisningsmateriale/SiracusaPrinciples.pdf. [Accessed 2 Mar 2020].

[43] D. Markovits, “Quarantines and distributive justice,” *Journal of Law, Medicine and Ethics,* vol. 33, no. 2, p. 323–344, 2005.

[44] D. Heyman, “Model operational guidelines for disease exposure control (Pre-publication draft). Center for Strategic and International Studies (CSIS),” 2005. [Online]. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.357.2252&rep=rep1&type=pdf. [Accessed 3 Mar 2020].

[45] P. L. Ooi , S. Lim and S. K. Chew, “Use of quarantine in the control of SARS in Singapore,” *American Journal of Infection Control,* vol. 33, no. 5, pp. 252-7, 2005.

[46] L. Hawryluck, W. L. Gold , S. Robinson , S. Pogorski and S. Gale, “SARS control and psychological effects of quarantine,” *Emerging Infectious Diseases,* vol. 10, no. 7, p. 1206–1212, 2004.

[47] S. K. Brooks et al, “The psychological impact of quarantine and how to reduce it: rapid review of the evidence,” *The Lancet (Online First),* pp. DOI:https://doi.org/10.1016/S0140-6736(20)30460-8, 2020.

[48] M. Greenberger, “Better prepare than react: Reordering public health priorities 100 years after the spanish flu epidemic,” *American Journal of Public Health,* vol. 108, no. 11, pp. 1465-1468, 2018.

[49] G. J. Annas, “Your liberty or your life. Talking Point on public health versus civil liberties,” *EMBO reports,* vol. 8, no. 12, pp. 1093-1098, 2007.

[50] A. Mubayi et al, “A Cost-Based Comparison of Quarantine Strategies for New Emerging Diseases,” *Mathematical Biosciences and Engineering,* vol. 7, no. 3, pp. 687-717, 2010.

[51] H. Hsieh et al, “Impact of quarantine on the 2003 SARS outbreak: A retrospective modeling study,” *Journal of Theroretical Biology,* vol. 244, pp. 729-736, 2007.

[52] T. Day, A. Park, N. Madras, A. Gumel and J. Wu, “When Is Quarantine a Useful Control Strategy for Emerging Infectious Diseases?,” *American Journal of Epidemiology,* vol. 163, no. 5, pp. 479-485, 2006.

[53] C. Fraser, S. Riley, R. M. Anderson and N. M. Ferguson, “Factors that make an infectious disease outbreak controllable,” *Proceedings of the National Academy of Sciences of the United States of America,* vol. 101, no. 16, p. 6146–6151, 2004.

[54] C. M. Peak , L. M. Childs LM, Y. H. Grad and C. O. Buckee, “Pathogen dynamics determine containment strategies,” *Proceedings of the National Academy of Sciences,* vol. 114, no. 15, pp. 4023-4028, 2017.

[55] C.-Y. Chu et al, “Quarantine Methods and Prevention of Secondary Outbreak of Pandemic (H1N1) 2009,” *Emerging Infectious Diseases,* vol. 16, no. 8, pp. 1300-1302.

[56] A. Bendix, “A Person Can Carry And Transmit COVID-19 Without Showing Symptoms, Scientists Con,” *Science Alert,* pp. Available at: https://www.sciencealert.com/researchers-confirmed-patients-can-transmit-the-coronavirus-without-showing-symptoms , 24 Feb 2020.

[57] Chinese Center for Disease Control and Prevention, “The Epidemiological Characteristics of an Outbreak of 2019 Novel Coronavirus Diseases (COVID-19) — China, 2020,” *China CDC Weekly,* vol. 2, no. 8, 2020.

[58] L. Zou et al, “SARS-CoV-2 Viral Load in Upper Respiratory Specimens of Infected Patients Specimens of Infected Patients,” *The New England Journal of Medicine,* vol. DOI: 10.1056/NEJMc2001737, 2020.

[59] NUS Saw Swee Hock School of Public Health, “COVID-19 Science Report: Clinical Characteristics,” NUS. Available at: https://sph.nus.edu.sg/covid-19/, 2020.

[60] W.-J. Guan et al, “Clinical characteristics of 2019 novel coronavirus infection in China,” *medRxiv (pre-print),* 2020.

[61] W.-j. Guan et al, “Clinical characteristics of 2019 novel coronavirus infection in China,” *New England Journal of Medicine,* p. Available at: https://www.nejm.org/doi/10.1056/NEJMoa2002032, 2020.

[62] W. Xia et al, “Transmission of corona virus disease 2019 during the incubation period may lead to a quarantine loophole,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.06.20031955],* 2020.

[63] C. Peak et al, “Modeling the Comparative Impact of Individual Quarantine vs. Active Monitoring of Contacts for the Mitigation of COVID-19,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.05.20031088],* 2020.

[64] R. M. Anderson, H. Heesterbeek, D. Klinkenberg and T. D. Hollingsworth, “How will country-based mitigation measures influence the course of the COVID-19 epidemic?,” *The Lancet (Published Online),* 2020.

[65] R. K. Webster, S. K. Brooks, L. E. Smith, L. Woodland, S. Wessely and G. J. Robin, “How to improve adherence with quarantine: Rapid review of the evidence,” *medRxiv (preprint) [Available at:https://doi.org/10.1101/2020.03.17.20037408],* 2020.

[66] R. J. Blendon et al, “Attitudes Toward The Use Of Quarantine In A Public Health Emergency In Four Countries,” *Health Affairs,* vol. 25, no. 1, 2006.

[67] P. L. Ooi, T. Seetoh and J. Cutter, “The Singapore Field Epidemiology Service: Insights Into Outbreak Management,” *Journal of Preventive Medicine & Public Health,* no. 45, pp. 277-282, 2012.

[68] World Health Organisation, “Ethical considerations in developing a public health response to pandemic influenza,” World Health Organisation, 2007.

[69] J. Lim, “Singapore's Experience - COVID-19,” Saw Swee Hock School of Public Health, NUS, 18 Mar 2020. [Online]. Available: https://sph.nus.edu.sg/2020/03/singapores-experience-tackling-covid-19/. [Accessed 24 Mar 2020].

[70] The Economist, “The virus is coming,” *The Economist,* 27 Feb 2020.

[71] P. J. Heijmans and Bloomberg, “Singapore’s coronavirus response has contained the outbreak—but its strategy is hard to replicate,” *Fortune,* 28 Feb 2020.

[72] Channel News Asia, “Singapore confirms 2 COVID-19 cases linked to new Science Park cluster; 3 more discharged,” *CNA,* 28 Feb 2020.

[73] L. O. Gostin and J. G. Hodge, “US Emergency Legal Responses to Novel Coronavirus Balancing Public Health and Civil Liberties,” *JAMA (New Online),* p. doi:10.1001/jama.2020.2025, 2020.

[74] World Health Organisation, “Considerations for quarantine of individuals in the context of containment for coronavirus disease (COVID-19): Interim Guidance,” 29 Feb 2020. [Online]. Available: https://www.who.int/docs/default-source/coronaviruse/20200229-covid-19-quarantine.pdf. [Accessed 9 Mar 2020].

[75] Ministry of Health, “MOH Circular 54A/2020: Revision Of Suspect Case Definition For Coronavirus Disease 2019 (COVID-19),” MOH, 2020.

[76] Centers for Disease Control and Prevention, “Interim Guidance: Healthcare Professionals 2019-nCoV: Evaluating and Reporting Persons Under Investigation (PUI),” 27 Feb 2020. [Online]. Available: https://www.cdc.gov/coronavirus/2019-nCoV/hcp/clinical-criteria.html. [Accessed 2 Mar 2020].

[77] Business Insider, “South Korea is testing 200,000 members of a doomsday church that is the source of more than 60% of its coronavirus cases,” *Business Insider,* 25 Feb 2020.

[78] BBC, “Scottish surveillance testing system for Covid-19 begins,” *BBC,* 1 Mar 2020.

[79] P. M. De Salazar et al , “Using predicted imports of 2019-nCoV cases to determine locations that may not be identifying all imported cases,” *MedRxiv (preprint),* p. Available at: https://www.medrxiv.org/content/10.1101/2020.02.04.20020495v2.full.pdf, 2020.

[80] M. Pablio and De Salazar et al, “Estimating underdetection of internationally imported COVID-19 cases,” *medRxiv (preprint),* p. Available at: https://www.medrxiv.org/content/10.1101/2020.02.13.20022707v1.

[81] Y. Ng et al, “Evaluation of the Effectiveness of Surveillance and Containment Measures for the First 100 Patients with COVID-19 in Singapore — January 2–February 29, 2020,” *Morbidity and Mortality Weekly Report,* 2020.

[82] C. Kenyon et al, “Intensive COVID-19 testing associated with reduced mortality - an ecological analysis of 108 countries,” *From medRxiv (preprint) [Available at: doi: 10.1101/2020.05.28.20115691.t],* 2020.

[83] C. T. Leffler et al, “Association of country-wide coronavirus mortality with demographics, testing, lockdowns, and public wearing of masks,” *From medRvix (preprint) [Available at: doi: 10.1101/2020.05.22.20109231],* 2020.

[84] Y. Liu et al, “A Modelling Study for Designing a Multi-Layered Surveillance Approach to Detect the Potential Resurgence of SARS-CoV-2,” *From medRxiv (preprint) [Available at: doi: 10.1101/2020.06.27.20141440],* 2020.

[85] J. Eberhardt, N. Breuckmann and C. Eberhardt, “Multi-Stage Group Testing Improves Efficiency of Large-Scale COVID-19 Screening,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.10.20061176],* 2020.

[86] C. Anderson et al, “Pooling nasopharyngeal swab specimens to increase testing capacity 1 for SARS-CoV-2,” *bioRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.05.22.110932],* 2020.

[87] N. Meyerson et al, “A Community-Deployable SARS-CoV-2 Screening Test Using Raw Saliva with 45 minutes Sample-to-Results Turnaround,” *From medRxiv (preprint) [Available at: doi: 10.1101/2020.07.16.20155614],* 2020.

[88] M. S. Pulia et al, “Multi-tiered screening and diagnosis strategy for COVID-19: a model for sustainable testing capacity in response to pandemic.,” *Annals of Medicine,* 2020.

[89] C. Telford et al, “Mass Screening for SARS-CoV-2 Infection among Residents and Staff in Twenty-eight Long-term Care Facilities in Fulton County, Georgia,” *From medRxiv (preprint) [Available at: doi:10.1101/2020.07.01.20144162],* 2020.

[90] F. Sandmann et al, “Optimising benefits of testing key workers for infection with SARS-CoV-2: A mathematical modelling analysis,” *Clinical Infectious Diseases,* 2020.

[91] W. Ahmed et al, “Detection of SARS-CoV-2 RNA in commercial passenger aircraft and cruise ship wastewater: A surveillance tool for assessing the presence of COVID-19 infected travelers,” *Journal of Travel Medicine,* 2020.

[92] D. Marshall et al, “Sentinel Coronavirus Environmental Monitoring Can Contribute to Detecting Asymptomatic SARS-CoV-2 Virus Spreaders and Can Verify Effectiveness of Workplace COVID-19 Controls,” *From MedRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.06.24.20131185],* 2020.

[93] J. Hellewell et al, “Feasibility of controlling COVID-19 outbreaks by isolation of cases and contacts,” *Lancet Glob Health 2020 (Published Online),* pp. Available at https://doi.org/10.1016/S2214-109X(20)30074-7, 2020.

[94] W. Wei, Z. Li, C. Chiew, S. Yong, M. Toh and V. Lee, “Presymptomatic Transmission of SARSCoV-2 - Singapore,” Centers for Disease Control and Prevention, 2020.

[95] G. Qian , N. Yang and A. Ma et al, “A COVID-19 Transmission within a family cluster by presymptomatic infectors in China,” *Clinical Infectious Diseases,* 2020.

[96] L. Huang, X. Zhang and X. Zhang et al, “Rapid asymptomatic transmission of COVID-19 during the incubation period demonstrating strong infectivity in a cluster of youngsters 50 aged 16-23 years outside Wuhan and characteristics of young patients with COVID-19: a prospective contact-tracing study,” *J Infect.,* 2020.

[97] X. He et al, “Temporal dynamics in viral shedding and transmissibility of COVID-19,” *Nature Medicine,* vol. 26, p. 672–675, 2020.

[98] Arons, “Asymptomatic Transmission, the Achilles’ Heel of Current Strategies to Control Covid-19,” *NEJM,* 2020.

[99] L. Ferretti et al, “Quantifying SARS-CoV-2 transmission suggests epidemic control with digital contact tracing,” *Science,* vol. 6491, p. 368.

[100] C.-Q. Zhu et al, “A COVID-19 case report from asymptomatic contact: implication for contact isolation and incubation management,” *Infectious Diseases of Poverty,* vol. 9, no. 70, 2020.

[101] L. Tindale et al, “Evidence for transmission of COVID-19 prior to symptom onset,” *eLife,* vol. 9, 2020.

[102] S. Moghadas et al, “The implications of silent transmission for the control of COVID-19 outbreaks,” *Proceedings of the National Academy of Sciences,* 2020.

[103] M. E. Kretzschmar, G. Rozhnova and M. v. Boven, “Effectiveness of isolation and contact tracing for containment and slowing COVID-19 epidemic: a modelling study,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.10.20033738],* 2020.

[104] A. James et al, “Successful contact tracing systems for COVID-19 rely on effective quarantine 1 and isolation,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.06.10.20125013],* 2020.

[105] H.-Y. Yuan, A. Mao, G. Han, H. Yuan and D. Pfeiffer, “Effectiveness of quarantine measure on transmission dynamics of COVID-19 in Hong Kong,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.09.20059006],* 2020.

[106] V. Fiore et al, “Containment of Future Waves of COVID-19: Simulating the Impact of Different Policies and Testing Capacities for Contact Tracing,” *medRxiv (preprint) [Available at: doi: 10.1101/2020.06.05.20123372],* 2020.

[107] E. Davis et al, “An Imperfect Tool: COVID-19 ‘Test and Trace’ Success Relies on Minimising the Impact of False Negatives and Continuation of Physical Distancing,” *From medRxiv (preprint) [Available at: doi: 10.1101/2020.06.09.20124008],* 2020.

[108] A. Kucharski et al, “Effectiveness of Isolation, Testing, Contact Tracing, Physical Distancing on Reducing Transmission of SARS-CoV-2 in Different Settings: A Mathematical Modelling Study,” *The Lancet Infectious Diseases,* vol. 20, 2020.

[109] G. Cencetti et al, “Using Real-World Contact Networks to Quantify the Effectiveness of Digital Contact Tracing and Isolation Strategies for COVID-19 Pandemic,” *From medRxiv (preprint) [Available at: doi: 10.1101/2020.05.29.20115915],* 2020.

[110] R. Hinch et al, “Effective Configurations of a Digital Contact Tracing App: A report to NHSX,” 16 Apr 2020. [Online]. Available: https://cdn.theconversation.com/static_files/files/1009/Report_-_Effective_App_Configurations.pdf?1587531217. [Accessed 12 Jun 2020].

[111] D. J. Currie et al, “Stemming the flow: how much can the Australian smartphone app help to control COVID-19?,” *public health research & practice,* vol. 30, no. 2, 2020.

[112] P. Bachtiger et al, “Belief of Previous COVID-19 Infection and Unclear Government Policy are Associated with Reduced Willingness to Participate in App-Based Contact Tracing: A UK-Wide Observational Study of 13,000 Patients,” *medRxiv (preprint) [Available at: https://www.medrxiv.org/content/10.1101/2020.06.03.20120337v1],* 2020.

[113] S. Jansen-Kosterink et al, “Predictors to use mobile apps for monitoring COVID-19 symptoms and contact tracing: A survey among Dutch citizens,” *From medRxiv (preprint) [Available at: doi: 10.1101/2020.06.02.20113423],* 2020.

[114] R. Thomas et al, “More than privacy: Australians’ concerns and misconceptions about the COVIDSafe App: a short report,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.06.09.20126110],* 2020.

[115] M. J. Keeling et al, “The Efficacy of Contact Tracing for the Containment of the 2019 Novel Coronavirus (COVID-19),” *medRxiv (preprint),* p. Available at: https://doi.org/10.1101/2020.02.14.20023036.

[116] E. Mahase, “Coronavirus: home testing pilot launched in London to cut hospital visits and ambulance use,” *BMJ,* vol. 368, no. m621, 2020.

[117] L. Donnelly, “'Drive-thru' coronavirus testing to start in Britain on Monday,” *The Telegraph,* 22 Feb 2020.

[118] BBC, “Coronavirus: Drive through testing begins at Edinburgh hospital,” *BBC,* 28 Feb 2020.

[119] K. Toussaint, “What an equitable coronavirus response should look like,” Fast Company & Inc © 2020 Mansueto Ventures, LLC, 4 Mar 2020. [Online]. Available: https://www.fastcompany.com/90470785/what-an-equitable-coronavirus-response-should-look-like. [Accessed 10 Mar 2020].

[120] A. Mcguckin, “Coronavirus: First drive-thru COVID-19 testing centre opens in Winnipeg,” *Global News,* 21 Mar 2020.

[121] K. T. Kwon, J.-H. Ko, H. Shin, M. Sung and J. Y. Kim, “Drive-Through Screening Center for COVID-19: a Safe and Efficient Screening System against Massive Community Outbreak,” *J Korean Med Sci.,* vol. 35, no. 11, 2020.

[122] L. Lai, “Coronavirus: Docs to give 5-day medical leave to patients with respiratory symptoms; subsidised rates for S'poreans at designated clinics,” *The Straits Times,* 14 Feb 2020.

[123] T. Goh, “Coronavirus: More patients with respiratory symptoms at PHPCs, but some afraid 5-day MC will affect income,” *The Straits Times,* 24 Feb 2020.

[124] H.-W. Cho, “Effectiveness for the Response to COVID-19: The MERS Outbreak Containment Procedures,” *Osong Public Health Res Perspect,* vol. 11, no. 1, pp. 1-2, 2020.

[125] Korea Centers for Disease Control & Prevention, “Contact Transmission of COVID-19 in South Korea: Novel Investigation Techniques for Tracing Contacts,” *Osong Public Health Res Perspect,* vol. 11, no. 1, pp. 60-63, 2020.

[126] C.-C. Hsieh et al, “The Outcome and Implications of Public Precautionary Measures in Taiwan–Declining Respiratory Disease Cases in the COVID-19 Pandemic,” *International Journal of Environmental Research and Public Health,* vol. 17, no. 13, p. 4877, 2020.

[127] B. B.-J. Chang and T.-Y. Chiu, “Ready for a long fight against the COVID-19 outbreak: an innovative model of tiered primary health care in Taiwan,” *BJGP Open,* 2020.

[128] S. de Lusignan et al, “Emergence of a Novel Coronavirus (COVID-19): Protocol for Extending Surveillance Used by the Royal College of General Practitioners Research and Surveillance Centre and Public Health England,” *JMIR Public Health Surveill,* vol. 6, no. 2, 2020.

[129] M. Gong et al, “Cloud-Based System for Effective Surveillance and Control of COVID-19: Useful Experiences From Hubei, China,” *J Med Internet Res,* vol. 22, no. 4, 2020.

[130] I. Ekong et al, “COVID-19 Mobile Positioning Data Contact Tracing and Patient Privacy Regulations: Exploratory Search of Global Response Strategies and the Use of Digital Tools in Nigeria,” *JMIR Mhealth Uhealth,* vol. 8, no. 4, 2020.

[131] J. S. Obeid et al, “An AI approach to COVID-19 infection risk assessment in virtual visits: a case report,” Oxford University Press., 2020.

[132] K. Lancaster and T. Rhodes, “Wastewater monitoring of SARS-CoV-2: lessons from illicit drug policy,” *The Lancet,* vol. 5, 2020.

[133] S. Mallapaty, “How sewage could reveal true scale of coronavirus outbreak,” *nature news,* 3 Apr 2020.

[134] CNA, “More wastewater testing under way in Singapore to tackle COVID-19; pilot launched at foreign worker dormitories,” *Channel News Asia,* 19 Jun 2020.

[135] Y. Liu, “Clinical and biochemical indexes from 2019-nCoV infected patients linked to viral loads and lung injury,” *Science China Life Sciences ,* vol. 63, pp. 364-374, 2020.

[136] Public Health England, “Infection control precaution to minimize transmission of acute respiratory tract infections in healthcare settings,” 2016. [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file. [Accessed 12 Feb 2020].

[137] X. Marchand-Senecal et al, “Diagnosis and Management of First Case of COVID-19 in Canada: Lessons applied from SARS,” academic.oup.com, 2020. [Online]. Available: https://academic.oup.com/cid/advance-article-abstract/doi/10.1093/cid/ciaa227/5800047. [Accessed 16 Mar 2020].

[138] C. Huang et al, “Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China,” *The Lancet (Articles, Online First),* pp. Available at: https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(20)30183-5/fulltext, 2020.

[139] “China’s Diagnosis and Treatment Guidelines for COVID-19 (6th Edition)”.

[140] Evening Standard, “Eight of UK's nine coronavirus patients discharged from hospital,” *Evening Standard,* 18 Feb 2020.

[141] Caixin, “Puzzling: Canadian patient tested to be positive after two weeks post-discharge.,” *Caixin,* 16 Feb 2020.

[142] South China Morning Post, “Coronavirus: Wuhan to quarantine all cured patients for 14 days after some test positive again,” *SCMP,* 23 Feb 2020.

[143] South China Morning Post, “Coronavirus suspects in Wuhan ordered to go to quarantine,” *SCMP,* 15 Feb 2020.

[144] L. Lan, D. Xu and G. Ye, “Positive RT-PCR Test Results in Patients Recovered From COVID-19,” *JAMA (New Online) [Available at: 10.1001/jama.2020.2783],* 2020.

[145] Z. Zheng et al, “Patient Follow-up after Discharge after COVID-19 Pneumonia: Considerations for Infectious Control,” *Journal of Medical Virology,* 2020.

[146] Ministry of Health, Singapore, “Revised Discharge Criteria for COVID-19 Patients,” MOH, Singapore, 2020.

[147] NCID, Academy of Medicine Singapore, Chapter of Infectious Disease Physicians, “Position Statement from the National Centre for Infectious Diseases and the Chapter of Infectious Disease Physicians, Academy of Medicine, Singapore,” 23 May 2020. [Online]. Available: https://www.ams.edu.sg/view-pdf.aspx?file=media%5c5558_fi_168.pdf&ofile=Period+of+Infectivity+Position+Statement+. [Accessed 2 Jun 2020].

[148] Korea Centers for Disease Control & Prevention, “Findings from Investigation and Analysis of Re-Positive Cases,” 19 May 2020. [Online]. Available: https://www.cdc.go.kr/board/board.es?mid=a30402000000&bid=0030&act=view&list_no=367267&nPage=1. [Accessed 3 Jun 2020].

[149] R. Wolfel et al, “Virological assessment of hospitalized cases of coronavirus disease 2019,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.05.20030502],* 2020.

[150] R. Kmar et al, “Management of mild COVID-19: Policy implications of initial experience in India.,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.05.20.20107664],* 2020.

[151] D. Chang, H. Xu, A. Rebaza, L. Sharma and C. S. Dela Cruz, “Protecting health-care workers from subclinical coronavirus infection,” *Lancet Respir Med, Correspondence,* pp. Available at: https://doi.org/10.1016/S2213-2600(20)30066-7, 2020.

[152] G. Gopalakrishna, P. Choo, Y. S. Leo, B. K. Tay, Y. T. Lim, A. S. Khan and C. C. Tan, “SARS transmission and hospital containment,” *Emerging infectious diseases,* vol. 10, no. 3, p. 395–400, 2004.

[153] H. Secon, “More than 1,700 Chinese healthcare workers have gotten the coronavirus, and 7 have died. A study found that 29% of infections were in medical staff,” *Business Insider Singapore,* 18 Feb 2020.

[154] D. Wang, H. Chang and H. Bo, “Clinical Characteristics of 138 Hospitalized Patients With 2019 Novel Coronavirus–Infected Pneumonia in Wuhan, China,” *JAMA,* p. doi:10.1001/jama.2020.1585, 2020.

[155] X. Zheng et al, “Analysis of the infection status of the health care workers in Wuhan during the COVID-19 outbreak: A cross-sectional study.,” *Clinical Infectious Diseases,* 2020.

[156] World Health Organisation, “Infection prevention and control during health care when novel coronavirus (nCoV) infection is suspected,” WHO, 2020.

[157] Centers for Disease Control and Prevention, “Interim Infection Prevention and Control Recommendations for Patients with Confirmed Coronavirus Disease 2019 (COVID-19) or Persons Under Investigation for COVID-19 in Healthcare Settings,” CDC, 21 Feb 2020. [Online]. Available: https://www.cdc.gov/coronavirus/2019-ncov/infection-control/control-recommendations.html. [Accessed 2 Mar 2020].

[158] E. Toner and R. Waldhorn, “What US Hospitals Should Do Now to Prepare for a COVID-19 Pandemic,” Johns Hopkins Bloomberg School of Public Health (JHSPH) Center for Health Security, 27 Feb 2020. [Online]. Available: www.centerforhealthsecurity.org/cbn/2020/cbnreport-02272020.html. [Accessed 2 Mar 2020].

[159] Zhejiang University School of Medicine, “Handbook of COVID-19 Prevention,” Jack Ma Foundation, Zhejiang University, The First Hospital of Zhejiang Province, Alibaba Cloud, AliHealth, 2020.

[160] Y. Y. Dan et al, “Cost-effectiveness analysis of hospital infection control response to an epidemic respiratory virus threat,” *Emerging infectious diseases,* vol. 15, no. 12, p. 1909, 2009.

[161] World Health Organization, “Influenza (Avian and other zoonotic),” World Health Organization, 2018. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/influenza-(avian-and-other-zoonotic. [Accessed 20 Feb 2020].

[162] D. Fisher and A. Chow, “Healthcare Epidemiology: An Overview of Principles and Practices,” *ENB Quarterly,* vol. 45, no. 1, pp. 3-7, 2019.

[163] Centers for Disease Control and Prevention, “Fundamental Elements Needed to Prevent Transmission of Infectious Agents in Healthcare Settings: Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings,” CDC, 2019. [Online]. Available: https://www.cdc.gov/infectioncontrol/guidelines/isolation/prevention.html. [Accessed 12 Feb 2020].

[164] National Infection Prevention and Control Committee, “The National Infection Prevention And Control Guidelines For Acute Healthcare Facilities 2017,” MOH, 2017. [Online]. Available: https://www.moh.gov.sg/docs/librariesprovider5/resources-statistics/guidelines/national-infection-prevention-and-control-guidelines-for-acute-healthcare-facilities---2017.pdf. [Accessed 12 Feb 2020].

[165] World Health Organisation, “Coronavirus Disease (Covid-19) Outbreak: Rights, Roles And Responsibilities Of Health Workers, Including Key Considerations For Occupational Safety And Health,” 2020. [Online]. Available: https://www.who.int/docs/default-source/coronaviruse/who-rights-roles-respon-hw-covid-19.pdf?sfvrsn=bcabd401_0. [Accessed 2 Mar 2020].

[166] CEBM, “Oxford COVID-19 Evidence Service,” Nuffield Department of Primary Care Health Sciences, 2020. [Online]. Available: https://www.cebm.net/oxford-covid-19/. [Accessed 23 Mar 2020].

[167] RCOphth, “Coronavirus RCOphth update – need to know points,” 19 Mar 2020. [Online]. Available: https://www.rcophth.ac.uk/wp-content/uploads/2020/03/Coronavirus-RCOphth-update-March-19th.pdf. [Accessed 23 Mar 2020].

[168] AAO, “Alert: Important coronavirus updates for ophthalmologists,” 18 Mar 2020. [Online]. Available: https://www.aao.org/headline/alert-important-coronavirus-context. [Accessed 23 Mar 2020].

[169] T. H. T. Lai et al, “Stepping up infection control measures in ophthalmology during the novel coronavirus outbreak: an experience from Hong Kong,” *Graefe's Archive for Clinical and Experimental Ophthalmology (Accepted 26 Feb),* 2020 .

[170] X. Peng, X. Xu, Y. Li, L. Cheng, X. Zhou and B. Ren, “Transmission routes of 2019-nCoV and controls in dental practice,” *International Journal of Oral Science,* vol. 12, no. 9, 2020.

[171] L. Meng, F. Hua and Z. Bian, “Coronavirus Disease 2019 (COVID-19): Emerging and Future Challenges for Dental and Oral Medicine,” *Journal of Dental Research,* p. 107, 2020.

[172] L. Meng et al, “Coronavirus Disease 2019 (COVID-19): Emerging and Future Challenges for Dental and Oral Medicine,” *Journal of Dental Research,* vol. 99, no. 5, pp. 481-487, 2020.

[173] M. Peditto et al, “Dentistry during the COVID-19 Epidemic: An Italian Workflow for the Management of Dental Practice.,” *Public Health.*

[174] J. Arellano-Cotrina et al, “Effectiveness and recommendations for the use of dental masks in the prevention of COVID-19: A literature review.,” *Disaster Medicine and Public Health Preparedness,* 2020.

[175] F. Dexter, P. Michelle, B. Jeremiah and L. Randy, “An Evidence-Based Approach for Optimization of Infection Control and Operating Room Management,” *Anesthesia & Analgesia (Published ahead of print),* 2020.

[176] H. J. Kim, J. S. Ko and T.-Y. Kim, “Recommendations for anesthesia in patients suspected of COVID-19 Coronavirus infection,” *Korean Journal of Anesthesiology,* vol. 73, no. 2, pp. 89-91, 2020.

[177] X. Zhao et al, “Anesthetic Management of Patients with COVID 19 Infections during Emergency Procedures,” *Journal of Cardiothoracic and Vascular Anesthesia,* vol. 34, pp. 1125-1131, 2020.

[178] P. W. Peng et al, “Outbreak of a new coronavirus: what anaesthetists should know,” *British Journal of Anaesthesia,* vol. 124, no. 5, pp. 497-501, 2020.

[179] H. Mehanna et al, “Recommendations for head and neck surgical oncology practice in a setting of acute severe resource constraint during the COVID-19 pandemic: an international consensus,” *Lancet Oncol,* 2020.

[180] P. E. Chandy, M. U. Nasir, S. Srinivasan, D. Klass, S. Nicolaou and S. B. Babu, “Interventional radiology and COVID-19: evidence-based measures to limit transmission,” *Diagn Interv Radiol [Published online],* 2020.

[181] M. T. Hirschmann et al, “COVID-19 coronavirus: recommended personal protective equipment for the orthopaedic and trauma surgeon,” *Knee Surgery, Sports Traumatology, Arthroscopy,* 2020 (Published: 27 April 2020).

[182] A. Thamboo et al, “Clinical evidence based review and recommendations of aerosol generating medical procedures in otolaryngology – head and neck surgery during the COVID-19 pandemic,” *Journal of Otolaryngology - Head & Neck Surgery,* vol. 49, no. 28, 2020.

[183] J. Porter et al, “Society of Robotic Surgery Review: Recommendations Regarding the Risk of COVID-19 Transmission During Minimally Invasive Surgery,” *BJU International (Accepted Articles),* 2020.

[184] I. Aquila et al, “SARS-CoV-2 pandemic: review of the literature and proposal for safe autopsy practice,” *Archives of Pathology & Laboratory Medicine (early online release),* 2020.

[185] World Health Organisation, “The COVID-19 Risk Communication Package for Healthcare Facilities,” WHO, 2020.

[186] M. Weaver, “Majority of retired NHS staff don't want to return to tackle Covid-19 crisis,” *The Guardian,* 4 Mar 2020.

[187] C. P. Dunne, S. S. Dunne and E. Spain, “Covid-19: Is it reasonable to ask retired doctors to return to “duty”,” *The BMJ,* 5 Mar 2020.

[188] J. G. Adams and R. M. Walls, “Supporting the Health Care Workforce During the COVID-19 Global Epidemic,” *JAMA [Published online 12 March],* 2020.

[189] Y.-H. Jin et al, “Perceived infection transmission routes, infection control practices, psychosocial changes, and management of COVID-19 infected healthcare workers in a tertiary acute care hospital in Wuhan: a crosssectional survey.,” *Military Medical Research,* 2020.

[190] L. A. Morgantini et al, “Factors Contributing to Healthcare Professional Burnout During the COVID-19 Pandemic: A Rapid Turnaround Global Survey,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.05.17.20101915],* 2020.

[191] S. X. Zhang et al, “Succumbing to the COVID-19 Pandemic – Healthcare Workers not Satisfied and Intend to Leave Their Jobs,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.05.22.20110809],* 2020.

[192] E. Nguemeleu et al, “Economic analysis of healthcare-associated infection prevention and control interventions in medical and surgical units: Systematic review using a discounting approach,” *Journal of Hospital Infection,* 2020.

[193] V. Cheng et al, “Escalating infection control response to the rapidly evolving epidemiology of the Coronavirus disease 2019 (COVID-19) due to SARS-CoV-2 in Hong Kong,” *Infection Control & Hospital Epidemiology (Accepted Manuscript) [Available at: 10.1017/ice.2020.58],* 2020.

[194] S. Wiboonchutikul, W. Manosuthi and S. Likanonsakul et al, “Lack of transmission among healthcare workers in contact with a case of Middle East respiratory syndrome coronavirus infection in Thailand,” *Antimicrob Resist Infect Control,* vol. 5, no. 21, 2016.

[195] N. K. Jones et al, “Effective control of SARS-CoV-1 2 transmission between healthcare workers during a period of diminished community prevalence of COVID-19,” *Accepted manuscript. [Available at: https://elifesciences.org/articles/59391],* 2020.

[196] J. Zhou et al, “Investigating SARS-CoV-2 surface and air contamination in an acute healthcare setting during the peak of the COVID-19 pandemic in London,” *Clinical Infectious Diseases.,* 2020.

[197] S. Wu et al, “Environmental contamination by SARS-CoV-2 in a designated hospital for coronavirus disease 2019.,” *American Journal of Infection Control.*

[198] S. Rawlinson, “COVID-19 Pandemic – Let’s not forget surfaces,” *Journal of Hospital Infection,* 2020.

[199] M. J. Parker and R. D. Goldman, “Paediatric emergency department staff perceptions of infection control measures against severe acute respiratory syndrome,” *Emergency medicine journal,* vol. 23, no. 5, pp. 349-353, 2006.

[200] C. Houghton et al, “Barriers and facilitators to healthcare workers’ adherence with infection prevention and control (IPC) guidelines for respiratory infectious diseases: a rapid qualitative evidence synthesis (Review),” *Cochrane Database of Systematic Reviews,* no. 4, 2020.

[201] Tartari et al, “Influenza-like" symptoms and work-related behavior among healthcare workers and other professionals: Results of a global survey.,” *PLoS ONE,* 2020.

[202] Cheng et al, “Clinical management and infection control of SARS: Lessons Learned,” *Antiviral Research,* vol. 100, no. 2, pp. 407-419, 2013.

[203] Chowell et al, “SARS outbreaks in Ontario, Hong Kong and Singapore: the role of diagnosis and isolation as a control mechanism,” *J. Theor. Biol,* vol. 224, pp. 1-8, 2003.

[204] Leung, “Infection control for SARS in a tertiary paediatric centre in Hong Kong,” *J. Hosp. Infect,* vol. 56, pp. 215-222, 2004.

[205] Ho et al, “An outbreak of severe acute respiratory syndrome among hospital workers in a community hospital in Hong Kong,” *Ann. Intern. Med,* vol. 139, pp. 564-567, 2003.

[206] Dwosh et al, “Identification and containment of an outbreak of SARS in a community hospital,” *CMAJ,* vol. 168, pp. 1415-1420, 2003.

[207] Liu et al, “Epidemiologic study and containment of a nosocomial outbreak of severe acute respiratory syndrome in a medical center in Kaohsiung. Taiwan,” *Infect. Control Hosp. Epidemiol.,* vol. 27, pp. 466-472, 2006.

[208] Nishiura et al , “Rapid awareness and transmission of severe acute respiratory syndrome in Hanoi French Hospital Vietnam,” *Am. J. Trop. Med. Hyg.,* vol. 73, pp. 17-25, 2005.

[209] Varia et al , “Investigation of a nosocomial outbreak of severe acute respiratory syndrome (SARS) in Toronto, Canada,” *CMAJ,* vol. 169, pp. 285-292, 2003.

[210] X. Chen, J. Tian, G. Li and G. Li, “Initiation of a new infection control system for the COVID-19 Outbreak,” *Lancet Infect Dis ,* pp. Available at: https://doi.org/10.1016/S1473-3099(20)30110-9, 2020.

[211] C. Chen et al, “COVID-19 infection prevention and control practices in Wuhan radiotherapy,” *Advances in Radiation Oncology,* vol. 20, pp. 30126-3, 2020.

[212] J. C.-H. Cheung, L. T. Ho, J. V. Cheng, E. Y. K. Cham and K. N. Lam, “Staff safety during emergency airway management for COVID-19 in Hong Kong,” *Lancet Respir Med,* pp. Available at: https://doi.org/10.1016/S2213-2600(20)30084-9, 2020.

[213] J. Schwartz, C.-C. King and M.-Y. Yen, “Protecting Health Care Workers during the COVID Outbreak Lessons from Taiwan's SARS response,” *Clinical Infectious Diseases,* 2020.

[214] J. Wong, Z. Tan and Y. C. Tay, “Preparing for a COVID-19 pandemic: a review of operating room outbreak response measures in a large tertiary hospital in Singapore,” *J Can Anesth,* [Published online: 11 March 2020].

[215] S. S. X. Kok et al, “Dealing with COVID-19: initial perspectives of a small radiology department,” *Singapore Medical Journal (online first publication),* 2020.

[216] L. Wee et al, “Respiratory surveillance wards as a strategy to reduce nosocomial transmission of COVID-19 through early detection: the experience of a tertiary hospital in Singapore,” *Infection Control & Hospital Epidemiology,* pp. 1-16, 2020.

[217] H. L. Htun et al, “Responding to the COVID-19 outbreak in Singapore Staff Protection and Staff Temperature and Sickness Surveillance Systems,” Oxford University Press, [Online]. Available: https://academic.oup.com/cid/advance-article-abstract/doi/10.1093/cid/ciaa468/5823245. [Accessed 20 May 2020].

[218] H. J. Ho et al, “Validation of a Real-Time Locating System for Contact Tracing of Healthcare Workers during the COVID-19 Pandemic in Singapore.,” *JMIR Preprints,* 2020.

[219] H. Lee, J. W. Heo, S. W. Kim, J. Lee and J. H. Choi, “A Lesson from Temporary Closing of a Single University-affiliated Hospital owing to In-Hospital Transmission of Coronavirus Disease 2019,” *J Korean Med Sci,* vol. 35, no. 13, 2020.

[220] T. Huang, Y. Guo, Y. Zheng, L. Lei and X. Zeng, “Application and effects of fever screening system in the prevention of nosocomial infection in the only designated hospital of coronavirus disease 2019 (COVID-19) in Shenzhen, China,” *Infection Control & Hospital Epidemiology (accepted as part of Cambridge Coronavirus Collection.,* 2020.

[221] V. Luigi et al, “Prevention And Protection Measures Of Healthcare Workers Exposed In Health Settings To Severe Acute Respiratory Infections From Sars-cov-2 In A University Hospital In Bari, Apulia Region, Southern Italy,” *Journal of Hospital Infection,* vol. 20, pp. 30255-3, 2020.

[222] J. Price et al, “Development and delivery of a real-time hospital-onset COVID-19 surveillance system using network analysis,” *Clinical Infectious Diseases,* 2020.

[223] Chung et al , “Debate on MERS-CoV respiratory precautions: surgical mask or N95 respirators?,” *Singapore Med J 2,* vol. 55, no. 6, pp. 294-297, 2014.

[224] M. Loeb et al, “Surgical mask vs N95 respirator for preventing influenza among health care workers: a randomized trial,” *JAMA,* vol. 302, p. 1865–1871, 2009.

[225] D. Atrie and A. Worster, “Surgical mask versus N95 respirator for preventing influenza among health care workers: a randomized trial,” *Cjem,* vol. 14, no. 1, pp. 50-52, 2012.

[226] Y. Long et al, “Effectiveness of N95 respirators versus surgical masks against,” *J Evid BasedMed.,* pp. 1-9, 2020.

[227] D. K. Chu et al, “Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis,” *The Lancet (published online),* 2020.

[228] C. R. Macintyre et al, “A randomized clinical trial of three options for N95 respirators and medical masks in health workers,” *American journal of respiratory and critical care medicine,* vol. 187, no. 9, pp. 960-066, 2013.

[229] C. R. Macintyre et al, “A cluster randomized clinical trial comparing fit-tested and non-fit-tested N95 respirators to medical masks to prevent respiratory virus infection in health care workers,” *Influenza and other respiratory viruses,* vol. 5, no. 3, pp. 170-179, 2011.

[230] P. Iannone et al, “The need of health policy perspective to protect Healthcare Workers during COVID-19 pandemic. A GRADE rapid review on the N95 respirators effectiveness.,” *PLoS ONE.*

[231] J. Ha, “The Covid-19 Pandemic, Personal Protective Equipment, and Respirator: A Narrative Review,” *(Accept Manuscript) [Available at: doi: 10.1111/IJCP.13578].*

[232] W. H. Seto , D. Tsang and R. W. Yung et al, “Advisors of Expert SARS group of Hospital Authority. Effectiveness of precautions against droplets and contact in prevention of nosocomial transmission of severe acute respiratory syndrome (SARS),” *Lancet,* vol. 361, pp. 1519-20, 2003.

[233] T. Jefferson, C. Del Mar and L. Dooley et al , “Physical interventions to interrupt or reduce the spread of respiratory viruses: systematic review,” *BMJ,* vol. 339:b3675, 2009.

[234] C. Burton et al, “What is the performance and impact of disposable and reusable respirators for healthcare workers in the context of COVID-19?,” Centre for Evidence-Based Medicine, 2020. [Online]. Available: https://www.cebm.net/covid-19/what-is-the-performance-and-impact-of-disposable-and-reusable-respirators-for-healthcare-workers-in-the-context-of-covid-19/. [Accessed 26 May 2020].

[235] P. Wong et al, “COVID-19 and cardiopulmonary resuscitation: the recommended N95 mask may not be adequate,” *British Journal of Anaesthesia (Pre-proof),* 2020.

[236] H. Smart et al, “Preventing Facial Pressure Injury for Health Care Providers Adhering to COVID-19 Personal Protective Equipment Requirements,” *Advances in Skin & Wound Care (published ahead of print),* 2020.

[237] S. Hines et al, “Self-reported Impact of Respirator Use on Healthcare Worker Ability to Perform Patient Care,” *American Journal of Infection Control,* 2020.

[238] A. C. Ralph et al, “In hospital verification of non CE-marked respiratory protective devices to ensure safety of healthcare staff during the COVID-19 outbreak,” *Journal of Hospital Infection,* vol. 20, pp. 30254-1, 2020.

[239] C. Booth et al, “Effectiveness of surgical masks against influenza Bioaerosols,” *Journal of Hospital Infection,* 2013.

[240] A. Balazy et al, “Do N95 respirators provide 95% protection level against airborne viruses, and how adequate are surgical masks?,” *AJIC Major Articles,* 2006.

[241] T. Khoury et al, “Aerosolized Particle Reduction: A Novel Cadaveric Model and a Negative Airway Pressure Respirator (NAPR) System to Protect Health CareWorkers From COVID-19,” *American Academy Of Otolaryngology- Head And Neck Surgery,* 2020.

[242] E. Mahase, “Covid-19: hoarding and misuse of protective gear is jeopardising the response, WHO warns,” *The BMJ,* 4 Mar 2020.

[243] The National Institute for Occupational Safety and Health (NIOSH), “Recommended Guidance for Extended Use and Limited Reuse of N95 Filtering Facepiece Respirators in Healthcare Settings,” CDC, 2018. [Online]. Available: https://www.cdc.gov/niosh/topics/hcwcontrols/recommendedguidanceextuse.html. [Accessed 10 Mar 2020].

[244] A. A. Chughtai, H. Seale, M. S. Islam, M. Owais and R. C. Macintyre, “Policies on the use of Respiratory Protection for Hospital Health Workers to Protect from Coronavirus Disease (COVID-19),” *International Journal of Nursing Studies (Journal Pre-proof),* 2020.

[245] M. Klompas, C. A. Morris, J. Sinclair, M. Pearson and E. S. Shenoy, “Universal Masking in Hospitals in the Covid-19 Era,” *The New England Journal of Medicine,* 2020.

[246] A. F. Widmer and G. Richner, “Proposal for a EN 149 acceptable reprocessing method for FFP2 respirators in times of severe shortage,” *Antimicrobial Resistance and Infection Control,* vol. 9, no. 88, 2020.

[247] G. Ibanez-Cervantes et al, “Disinfection of N95 masks artificially contaminated with SARS-CoV-2 and ESKAPE bacteria using hydrogen peroxide plasma: impact on the reutilization of disposable devices,” *American Journal of Infection Control (journal pre-proof),* 2020.

[248] A. Cramer et al, “Disposable N95 Masks Pass Qualitative Fit-test But Have Decreased Filtration Efficiency After Cobalt-60 Gamma Irradiation,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.28.20043471],* 2020.

[249] Q.-X. Ma et al, “Decontamination of face masks with steam for mask reuse in fighting the pandemic COVID-19: experimental supports,” *Journal of Medical Virology,* 2020.

[250] M. Pascoe et al, “Dry heat and microwave generated steam protocols for the rapid decontamination of respiratory personal protective equipment in response to COVID-19-related shortages,” *Journal of Hospital Infection,* vol. 6701, no. 20, 2020.

[251] L. Anderegg et al, “A Scalable Method of Applying Heat and Humidity for Decontamination of N95 Respirators During the COVID-19 Crisis,” *From MedRxiv preprint [Available at: doi: https://doi.org/10.1101/2020.04.09.20059758],* 2020.

[252] J. M. Carnino et al, “Pretreated household materials carry similar filtration protection against pathogens when compared with surgical masks,” *American Journal of Infection Control,* 2020.

[253] E. Kopp, “CDC suggests nurses use bandanas, scarves during face mask shortage,” *Roll Call,* 18 Mar 2020.

[254] C. Macintre, H. Seale and T. Dung et al, “A cluster randomised trial of cloth masks compared with medical masks in healthcare workers,” *BMJ Open,* 2015.

[255] H.-l. Wu, J. Huang, C. J. P. Zhang, Z. He and W.-K. Ming, “Facemask shortage and the novel coronavirus disease (COVID-19)outbreak: Reflections on public health measures,” *EClinicalMedicine,* 2020.

[256] O. J.-P. Li, D. S. C. Lam, Y. Chen and D. S. W. Ting, “Novel Coronavirus disease 2019 (COVID-19): The importance of recognising possible early ocular manifestation and using protective eyewear,” *Br J Ophthalmol,* vol. 104, no. 3, 2020.

[257] M. Liu et al, “Use of personal protective equipment against coronavirus disease: cross sectional study,” *the BMJ,* vol. 369, 2020.

[258] R. Flumignan et al, “Evidence from Cochrane systematic reviews for controlling the dissemination of COVID-19 infection. A narrative review,,” *Sao Paulo Med Journal,* vol. X, pp. 1-9, 2020.

[259] College of Radiologists, Singapore, “Resource site for Radiology & Imaging,” Academy of Medicine, Singapore, 2020. [Online]. Available: https://www.ams.edu.sg/colleges/radiologists/covid-19-resource-site-for-radiology-imaging. [Accessed 10 Mar 2020].

[260] S. L. Lockhart et al, “Personal protective equipment (PPE) for both anesthesiologists and other airway managers: principles and practice during the COVID-19 pandemic,” *Can J Anesth (published online),* 2020.

[261] K. El-Boghdadly et al, “Risks to healthcare workers following tracheal intubation of patients with COVID-19: a prospective international multicentre cohort study,” *Accepted Manuscript. [Available at: https://doi.org/10.1111/anae.15170],* 2020.

[262] S. W. X. Ong, Y. K. Tan, S. Sutjipto and P. Y. Chia, “Absence of contamination of personal protective equipment (PPE) by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2),” *Infection Control & Hospital Epidemiology,* 2020.

[263] C. T. Matava, J. Yu and S. Denning, “Clear plastic drapes may be effective at limiting aerosolization and droplet spray during extubation: implications for COVID-19,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.26.20044404],* 2020.

[264] Y. Yan et al, “Consensus of Chinese experts on protection of skin and mucous membrane barrier for workers fighting against coronavirus disease 2019,” *Dermatol Ther [Epub ahead of pring],* 2020.

[265] A. Bui et al, “A pilot study of the impact of facial skin protectants on qualitative fit testing of N95 masks,” *Journal of the American Academy of Dermatology,* 2020.

[266] G. Gon, S. Dancer, R. Dreibelbis, W. J. Graham and C. Kilpatrick, “Reducing hand recontamination of health workers during COVID-19,” *Infection Control & Hospital Epidemiology (as part of Cambridget Coronavirus Collection),* 2020.

[267] C. C. Tan, “SARS in Singapore-key lessons from an epidemic,” *Annals-Academy of Medicine Singapore,* vol. 35, no. 5, p. 345, 2006.

[268] D. H. Le et al, “Lack of SARS transmission among public hospital workers,” *Vietnam. Emerg. Infect. Dis.,* vol. 10, pp. 265-268, 2004.

[269] S. Jiang et al, “Ventilation of wards and nosocomial outbreak of severe acute respiratory syndrome,” *Chin. Med. J. (Engl.),* vol. 116, pp. 1293-1297, 2003.

[270] C. Chen and B. Zhao, “Makeshift hospitals for COVID-19 patients: where health-care workers and patients need sufficient ventilation for more protection,” *Journal of Hospital Infection [Journal Pre-proof],* 2020.

[271] E. Mascha et al, “Staffing With Disease-Based Epidemiologic Indices May Reduce Shortage of Intensive Care Unit Staff During the COVID-19 Pandemic,” *Anesthesia & Analgesia,* vol. 131, no. 1, pp. 24-30, 2020.

[272] B. Salzberger, T. Gluck and B. Ehrenstein, “Successful containment of COVID-19: the WHO-Report on the COVID-19 outbreak in China,” *Infection,* 2020.

[273] C. Massonnaud, J. Roux and P. Crepey, “COVID-19: Forecasting short term hospital needs in France,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.16.20036939].*

[274] R. Khera, S. Jain and Z. Lin, “Evaluation of the Anticipated Burden of COVID-19 on Hospital-Based Healthcare Services Across the United States,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.01.20050492],* 2020.

[275] G. Grasselli, A. Pesenti and M. Cecconi, “Critical Care Utilization for the COVID Outbreak in Lombardy, Italy,” *JAMA [published online],* 2020.

[276] L. Rosenbaum, “Facing Covid-19 in Italy — Ethics, Logistics, and Therapeutics on the Epidemic’s Front Line,” *The New England Journal of Medicine,* 2020.

[277] O. Goldhill, “Ethicists agree on who gets treated first when hospitals are overwhelmed by coronavirus,” *Quartz,* 20 Mar 2020.

[278] Centers for Disease Control and Prevention, “Public Health Guidance for Community-Level Preparedness and Response to Severe Acute Respiratory Syndrome (SARS),” U.S. Department of Health & Human Services, 2005. [Online]. Available: https://www.cdc.gov/sars/guidance/index.html. [Accessed 3 Mar 2020].

[279] National Environment Agency, “Interim List of Household Products and Active Ingredients for Disinfection of Novel Coronavirus (COVID-19),” NEA, 8 Feb 2020. [Online]. Available: https://www.nea.gov.sg/our-services/public-cleanliness/environmental-cleaning-guidelines/guidelines/interim-list-of-household-products-and-active-ingredients-for-disinfection-of-novel-coronavirus . [Accessed 13 Feb 2020].

[280] J. Barker, D. Stevens and S. F. Bloomfield, “Spread and prevention of some common viral infections in community facilities and domestic homes,” *Journal of Applied Microbiology,* vol. 9, no. 11, 2001.

[281] G. Kampf, D. Todt, S. Pfaender and E. Steinmann, “Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents,” *The Journal of Hospital Infection,* vol. 104, no. 3, p. 246–251, 2020.

[282] S. W. X. Ong et al, “Air, Surface Environmental, and Personal Protective Equipment Contamination by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) From a Symptomatic Patient (Published online on 4 March),” *JAMA ,* 2020.

[283] J. Biryukov et al, “Increasing Temperature and Relative Humidity Accelerates Inactivation of SARS-CoV-2 on Surfaces,” *mSphere,* vol. 5, no. 4, 2020.

[284] J. Xiao et al, “Nonpharmaceutical Measures for Pandemic Influenza in Nonhealthcare Settings—Personal Protective and Environmental Measures,” *Emerg Infect Dis,* vol. 26, no. 5, pp. 967-975, 2020.

[285] M. Bielecki et al, “Social distancing alters the clinical course of COVID-19 in young adults: A comparative cohort study,” *Clinical Infectious Diseases,* 2020.

[286] Y. Huang et al, “Measures Undertaken in China to Avoid COVID-19 Infection: Internet-Based, Cross-Sectional Survey Study.,” *Journal of Medical Internet Research.,* 2020.

[287] W. Jang, D. Jang and J. Lee, “Social Distancing and Transmission-reducing Practices during the 2019 Coronavirus Disease and 2015 Middle East Respiratory Syndrome Coronavirus Outbreaks in Korea,” *Journal of Korean Medical Science,* vol. 35, no. 23, pp. 1-11, 2020.

[288] N. P. T. Nguyen et al, “Preventive 1 behavior of Vietnamese people in response to the COVID-19 pandemic,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.05.14.20102418],* 2020.

[289] K. Muto et al, “Japanese citizens' behavioral changes and preparedness against COVID-19: An online survey during the early phase of the pandemic,” *Plos One, 15(6),* vol. 15, no. 6, 2020.

[290] R. Gharpure et al, “Knowledge and Practices Regarding Safe Household Cleaning and Disinfection for COVID-19 Prevention — United States,” *Morbidity and Mortality Weekly Report,* 2020.

[291] S. He et al, “Analysis of Risk Perceptions and Related Factors Concerning COVID - 19 Epidemic in Chongqing, China.,” *Journal of Community Health,* 2020.

[292] T. M. Pham et al, “The Potential Impact of Intensified Community Hand Hygiene Interventions on Respiratory tract Infections: A Modelling Study,” *From medRxiv (preprint) [Available at: doi: 10.1101/2020.05.26.20113464],* 2020.

[293] Bin-Reza et al , “The use of masks and respirators to prevent transmission of influenza: a systematic review of the scientific evidence,” *Influenza and Other Respiratory Viruses,* vol. 6, no. 4, pp. 257-267, 2012.

[294] Sim et al, “The use of facemasks to prevent respiratory infection: a literature review in the context of the Health Belief Model,” *Singapore Med J.,* vol. 55, no. 3, p. 160–167, 2014.

[295] N. Brienen et al, “The Effect of Mask Use on the Spread of Influenza During a Pandemic,” *Risk Analysis,* 2010.

[296] M. Liang et al, “Efficacy of face mask in preventing respiratory virus transmission: a systematic review and meta-analysis,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.03.20051649],* 2020.

[297] Saunders-Hastings et al, “Effectiveness of personal protective measures in reducing pandemic influenza transmission: A systematic review and meta-analysis,” *Epidemics,* vol. 20, pp. 1-20, 2017.

[298] T. Suess et al, “Facemasks and intensified hand hygiene in a german household trial during the 2009/2010 influenza a(h1n1) pandemic: Adherence andtolerability in children and adults.,” *Epidemiol Infect,* vol. 139, p. 1895–1901, 2011.

[299] Tracht et al , “Economic Analysis of the Use of Facemasks During Pandemic (H1N1) 2009,” *J Theor Biol.,* vol. 300, p. 161–172, 2012.

[300] W. Wu et al, “Comparison of clinical course of patients with severe acute respiratory syndrome among the multiple generations of nosocomial transmission. Chinese medical jo,” *Chinese medical journal,* vol. 117, no. 1, pp. 14-18, 2004.

[301] C. T. Leffler et al, “Association of country-wide coronavirus mortality with demographics, testing, lockdowns, and public wearing of masks,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.05.22.20109231],* 2020.

[302] T. Mitze et al, “Face Masks Considerably Reduce Covid-19 Cases in Germany,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.06.21.20128181],* 2020.

[303] W. Lyu et al, “Community Use Of Face Masks And COVID-19: Evidence From A Natural Experiment Of State Mandates In The US,” *Health Affairs,* 2020.

[304] D. Miyazawa and G. Kaneko, “Face mask wearing rate predicts country’s COVID-19 death rates,” *From MedRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.06.22.20137745],* 2020.

[305] G. D. Barr, “A simple model to show the relative risk of viral aerosol infection from breathing and the benefit of wearing masks in different settings with implications for COVID-19,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.28.20082990],* 2020.

[306] S. E. Eikenberry et al, “To mask or not to mask: Modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.06.20055624],* 2020.

[307] Y. Chen and M. Dong, “ow Efficient can Non-Professional Masks Suppress COVID-19 Pandemic?,” *From medRxiv (preprint) [Available at: doi: 10.1101/2020.05.31.20117986],* 2020.

[308] A. Burgess and M. Horii, “Risk, ritual and health responsibilisation: Japan’s ‘safety blanket’ of surgical face mask-wearing,” *Sociology of Health & Illness,* vol. 34, no. 8, 2012.

[309] P. Baehr, “City under Siege: Authoritarian Toleration, Mask Culture, and the SARS Crisis in Hong Kong,” in *Networked Disease: Emerging Infections in the Global City*, Blackwell Publishing, 2008, pp. 138-151.

[310] Centers for Disease Control and Prevention, “Interim Guidance Issued for the Use of Facemasks and Respirators in Public Settings During an Influenza Pandemic,” CDC, 2020. [Online]. Available: https://www.cdc.gov/media/pressrel/2007/r070503.htm. [Accessed 12 Feb 2020].

[311] World Health Organisation, “Advice on the use of masks the community, during home care and in health care settings in the context of the novel coronavirus (2019-nCoV) outbreak,” 2020. [Online]. Available: https://www.who.int/docs/default-source/documents/advice-on-the-use-of-masks-20. [Accessed 20 Feb 2020].

[312] WHO, “Advice on the use of masks in the context of COVID,” 6 Apr 2020. [Online]. Available: file:///C:/Users/ephcij/Downloads/WHO-2019-nCov-IPC_Masks-2020.3-eng.pdf. [Accessed 7 May 2020].

[313] W. Lin, “Student deaths stir controversy over face mask rule in PE classes,” *Global Times,* 5 May 2020.

[314] W. Zang, “After Multiple Deaths, Officials Call for No Masks in Gym Class,” *Sixth Tone,* 8 May 2020.

[315] B. Chandrasekaran and S. Fernandes, ““Exercise with facemask; Are we handling a devil's sword?” – A physiological hypothesis,” *Medical Hypotheses,* vol. 144, 2020.

[316] C. C. Leung, T. H. Lam and K. K. Cheng, “Mass masking in the,” *The Lancet (published online) [Available at: https://doi.org/10.1016/S0140-6736(20)30520-1],* 2020.

[317] S. Geng, C. Shen, N. Xia, W. Song, M. Fan and B. J. Cowling, “Rational use of face masks in the COVID-19 pandemic,” *The Lancet (Published Online),* 2020.

[318] J. Achenbach, L. H. Sun and L. McGinley, “CDC considering recommending general public wear face coverings in public,” *The Washington Post,* 31 Mar 2020.

[319] A. Davies et al, “Testing the Efficacy of Homemade Masks: Would They Protect in an Influenza Pandemic?,” *Disaster Medicine and Public Health Preparedness,* 2013.

[320] M. Sande et al, “Professional and Home-Made Face Masks Reduce Exposure to Respiratory Infections among the General Population,” *PLoS One,* 2008.

[321] M. S. Kabindra, A. Noyes, R. Kalin and R. E. Peltier, “Evaluating the efficacy of cloth facemasks in reducing particulate matter exposure,” *Journal of Exposure Science and Environmental Epidemiology,* 2017.

[322] M.-N. Kim, “What Type of Face Mask Is Appropriate for Everyone-Mask-Wearing Policy amidst COVID-19 Pandemic?,” *J Korean Med Sci.,* vol. 35, no. 20, 2020.

[323] A. Chughtai et al, “Effectiveness of Cloth Masks for Protection Against Severe Acute Respiratory Syndrome Coronavirus 2,” *Emerging Infectious Diseases,* vol. 26, no. 10, 2020.

[324] E. de Araujo, “Teach, and Teach and Teach: Does the Average Citizen Use Masks Correctly During Daily Activities? Results from an Observational Study with more than 12,000 Participants,” *From medRxiv (preprint). doi: 10.1101/2020.06.25.20139907,* 2020.

[325] T. L. D. Huynh, ““The more I fear about COVID-19, the more I wear medical masks”: A survey on risk perception and medical masks’ uses,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.26.20044388],* 2020.

[326] G. Madhu et al, “The use of facemasks by the general population to prevent transmission of Covid 19 infection: A systematic review,” *medRxiv (preprint) [[Available at: https://doi.org/10.1101/2020.05.01.20087064],* 2020.

[327] P. Doung-ngern et al, “Associations between Wearing Masks, Washing Hands, and Social Distancing Practices, and Risk of COVID-19 Infection in Public: A Cohort-Based Case-Control Study in Thailand,” *From medRxiv (preprint) [Available at: doi: 10.1101/2020.06.11.20128900],* 2020.

[328] Y. Yan et al, “Do Face Masks Create a False Sense of Security? A COVID-19 Dilemma,” *From medRxiv (preprint) [Available at: doi: 10.1101/2020.05.23.20111302],* 2020.

[329] A. Ronen et al, “Examining the protection efficacy of face shields against cough aerosol droplets using water sensitive papers,” *From medRxiv (preprint) [Available at: doi:10.1101/2020.07.06.20147090],* 2020.

[330] B. Pietsch, “Cash could be spreading the coronavirus, warns the World Health Organisaton,” *The Telegraph,* 5 Mar 2020.

[331] Reuters, “South Korea burns, quarantines bank notes as Covid-19 rages,” *New Straits Times,* 6 Mar 2020.

[332] Bloomberg, “China sanitises, quarantines millions of bank notes in Covid-19 fight,” *New Straits Times,* 16 Feb 2020.

[333] F. Javier García de Abajo et al, “ack to Normal: An Old Physics Route to Reduce SARS-CoV-2 Transmission in Indoor Spaces,” *ACS Nano (Article ASAP),* 2020.

[334] E. Mantlo et al, “Luminore CopperTouch Surface Coating Effectively Inactivates SARS-CoV-2, Ebola, and Marburg Viruses In Vitro,” *From medRxiv (preprint) [Availalble at: doi: 10.1101/2020.07.05.20146043],* 2020.

[335] Y. Tian et al, “Review article: gastrointestinal features in COVID-19 and the possibility of faecal transmission,” *Alimentary Pharmacology & Therapeutics,* vol. 51, no. 9, 2020.

[336] S. Amirian, “Potential fecal transmission of SARS-CoV-2: Current evidence and implications for public health,” *International Journal of Infectious Diseases,* vol. 95, pp. 363-370, 2020.

[337] J. Zhou et al, “Infection of bat and human intestinal organoids by SARS-CoV-2,” *nature medicine,* 2020.

[338] M. Gomley, T. J. Aspray and D. A. Kelly, “COVID-19: mitigating transmission via wastewater plumbing systems,” *The Lancet [Published Online],* 2020.

[339] L. Rosling and M. Rosling, “Pneumonia causes panic in Guangdong province,” *British Medical Journal 2003,* vol. 326, no. 7386, p. 416, 2003.

[340] Channel News Asia, “Health Minister orders POFMA correction directions to States Times Review, Facebook over COVID-19 post,” *CNA,* 14 Feb 2020.

[341] S. Olcer et al, “Lay perspectives on social distancing and other official recommendations and regulations in the time of COVID-19: A qualitative study of social media posts,” *BMC Public Health,* 2020.

[342] B. Oosterhoff and C. Palmer, “Attitudes and Psychological Factors Associated With News Monitoring, Social Distancing, Disinfecting, and Hoarding Behaviors Among US Adolescents During the Coronavirus Disease 2019 Pandemic,” *JAMA Pediatrics,* 2020.

[343] Z. Li et al, “Vicarious traumatization in the general public, members, and non-members of medical teams aiding in COVID-19 control,” *Brain, Behavior, and Immunity (Accepted manuscript) [Available at: https://doi.org/10.1016/j.bbi.2020.03.007],* 2020.

[344] World Health Organisation, “Avian influenza: assessing the pandemic threat,” WHO, 2005.

[345] T. R. Frieden, “Identifying and Interrupting Superspreading Events—Implications for Control of Severe Acute Respiratory Syndrome Coronavirus 2,” *Emerging Infectious Diseases,* vol. 26, no. 6, p. 1059–1066, 2020.

[346] Liu et al, “Aerodynamic Characteristics and RNA Concentration of SARS-CoV-2 Aerosol in Wuhan Hospitals during COVID-19 Outbreak,” *From bioRxiv (preprint) [Available at: doi: 10.1101/2020.03.08.982637].*

[347] L. Bourouiba, “Turbulent Gas Clouds and Respiratory Pathogen Emissions: Potential Implications for Reducing Transmission of COVID-19,” *JAMA,* 2020 [Available at: . doi:10.1001/jama.2020.4756].

[348] S. Amirian, “Potential fecal transmission of SARS-CoV-2: Current evidence and implications for public health,” *International Journal of Infectious Diseases,* vol. 95, pp. 363-370, 2020.

[349] N. van Doremalen et al, “Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1,” *N Engl J Med,* 2020 [Available at: https://www.nejm.org/doi/pdf/10.1056/NEJMc2004973].

[350] M. Guo, “Coronavirus detected on doorknob in S. China’s Guangzhou,” 2020. [Online]. Available: Available at: https://news.cgtn.com/news/2020-02-03/Coronavirus-detected-on-doorknob-in-S-China-s-Guangzhou-NMua1LcOWY/index.html.

[351] A. Chin et al, “Stability of SARS-CoV-2 in different environmental conditions,” *The Lancet Microbe,* 2020 [Available at: https://doi.org/10.1016/S2666-5247(20)30003-3].

[352] NUS Saw Swee Hock School of Public Health, “COVID-19 Science Report: Clinical Characteristics,” 29 May 2020. [Online]. Available: DOI: 10.25540/32s7-wc9p. [Accessed 7 Jun 2020].

[353] P. Klepac et al, "Contacts in context: large-scale setting-specific social mixing matrices from the BBC Pandemic project," *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.02.16.20023754],* 2020.

[354] D. Rubin et al, "The Association of Social Distancing, Population Density, and Temperature with the SARS-CoV-2 Instantaneous Reproduction Number in Counties Across the United States.," *medRxiv (preprint) [Available at https://www.medrxiv.org/content/10.1101/2020.05.08.20094474v1],* 2020.

[355] A. Summan et al, "Timing of non-pharmaceutical interventions to mitigate COVID-19 transmission and their effects on mobility: A cross-country analysis.," *medRxiv (preprint) [Available at https://www.medrxiv.org/content/10.1101/2020.05.09.20096420v1],* 2020.

[356] H. Korevaar et al, "Quantifying the Impact of US State Non-Pharmaceutical Interventions on COVID-19 Transmission," *From medRxiv (preprint) [Available at: doi: 10.1101/2020.06.30.20142877],* 2020.

[357] Centre for Evidence-Based Medicine, "Do weather conditions influence the transmission of the coronavirus (SARS-CoV-2)?," CEBM, 23 Mar 2020. [Online]. Available: https://www.cebm.net/covid-19/do-weather-conditions-influence-the-transmission-of-the-coronavirus-sars-cov-2/. [Accessed 7 Jun 2020].

[358] F. Benedetti et al, "Inverse correlation between average monthly high temperatures and COVID-19-related death rates in different geographical areas," *Journal of Translational Medicine,* vol. 18, no. 251, 2020.

[359] M. Lonergan, "Even one metre seems generous. A reanalysis of data in: Chu et al. (2020) Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19," *From MedRxiv (Preprint) [Available from: doi: https://doi.org/10.1101/2020.06.11.20127415],* 2020.

[360] A. Nande et al, "Dynamics of COVID-19 under social distancing measures are driven by transmission network structure," *From MedRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.06.04.20121673],* 2020.

[361] M. Groenewold et al, "Increases in Health-Related Workplace Absenteeism Among Workers in Essential Critical Infrastructure Occupations During the COVID-19 Pandemic — United States, March–April 2020," *MMWR Morbidity Mortality Weekly Report,* vol. 69, p. 853–858, 2020.

[362] Q. Jing et al, "Household secondary attack rate of COVID-19 and associated determinants in Guangzhou, China: A retrospective cohort study," *The Lancet Infectious Diseases,* 2020.

[363] T. Leng et al, "The Effectiveness of Social Bubbles as part of a COVID-19 Lockdown Exit Strategy: A Modelling Study," *From medRxiv (preprint) [Available at: doi: 10.1101/20],* 2020.

[364] G. Huber et al, "A Minimal Model for Household Effects in Epidemics," *From medRxiv (preprint) [Available at: doi: 10.1101/2020.07.09.20150227],* 2020.

[365] K. Dolan et al, "Global burden of HIV, viral hepatitis, and tuberculosis in prisoners and detainees," *The Lancet,* vol. 388, pp. 1089-1102, 2020.

[366] S. A. Kinner et al, "Prisons and custodial settings are part of a comprehensive response to COVID-19," *The Lancet (published online),* 2020.

[367] WHO, "Preparedness, prevention and control of COVID-19 in prisons and other places of detention: Interim Guidance," 15 Mar 2020. [Online]. Available: http://www.euro.who.int/__data/assets/pdf_file/0019/434026/Preparedness-prevention-and-control-of-COVID-19-in-prisons.pdf?ua=1. [Accessed 2 Apr 2020].

[368] J. Guthrie et al, "Influenza control can be achieved in a custodial setting: pandemic (H1N1) 2009 and 2011 in an Australian prison.," *Public Health,* vol. 126, pp. 1032-1037, 2012.

[369] J. W. Levy et al, "Elevated transmission of upper respiratory illness among new recruits in military barracks in Thailand," *Influenza and Other Respiratory Viruses,* vol. 9, no. 6, p. 08–314, 2015.

[370] A. A. Eick, Z. Wang, H. Hughes, S. M. Ford and S. K. Tobler, "Comparison of the trivalent live attenuated vs. inactivated influenza vaccines among U.S. military service members," *Vaccine,* p. 3568–3575, 2009.

[371] Q. Leclerc et al, "What settings have been linked to SARS-CoV-2 transmission clusters? {Version 2: peer review: 1 approved]," *Wellcome Open Research,* vol. 5, no. 83, 2020.

[372] K. Kupferschmidt, "Why do some COVID-19 patients infect many others, whereas most don't spread the virus at all?," *Science,* 19 May 2020.

[373] The Future of Customer Engagement and Experience, "Warehouses and COVID-19: Safety versus supply," 2020. [Online]. Available: https://www.the-future-of-commerce.com/2020/03/30/warehouses-and-covid-19/. [Accessed 7 Jun 2020].

[374] A. Buhat et al, “Modeling the Transmission of Respiratory Infectious Diseases in Mass Transportation Systems,” *From medRxiv (preprint) [Available at: doi: 10.1101/2020.06.09.20126334],* 2020.

[375] M. Prakash, “Eat, Pray, Work: A meta-analysis of COVID19 Transmission Risk in Common Activities of Work and Leisure,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.05.22.20110726],* 2020.

[376] Y. Kim and X. Jiang, “Evolving Transmission Network Dynamics of COVID-19 Cluster Infections in South Korea: a descriptive study.,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.05.07.20091769],* 2020.

[377] M. D. Lau et al , “Characterizing super-spreading events and age-specific infectivity of COVID-19 transmission in Georgia, USA,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.06.20.20130476],* 2020.

[378] J. Harris, “Data from the COVID-19 Epidemic in Florida Suggest That Younger Cohorts Have Been Transmitting Their Infections to Less Socially Mobile Older Adults,” *From medRxiv (preprint) [Available at: doi: 10.1101/2020.06.30.20143842],* 2020.

[379] K. Bourassa et al, “Social distancing as a health behavior: County-level movement in the United States during the COVID-19 pandemic is associated with conventional health behaviors,” *Annals of Behavioral Medicine,* 2020.

[380] Liu et al, “COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China,” *Emerging Infectious Diseases,* vol. 7, no. 26, 2020.

[381] E. Ring, “Simon Harris urged to clarify coronavirus reporting in disability settings,” *Irish Examiner,* 3 Jun 2020.

[382] A. H. Mahmud, “MSF-funded centres for vulnerable families, persons with disabilities to progressively open from Jun 2,” *Channel News Asia,* 31 May 2020.

[383] E. McGraw, “A few superspreaders transmit the majority of coronavirus cases,” The Conversation, 5 Jun 2020. [Online]. Available: https://theconversation.com/a-few-superspreaders-transmit-the-majority-of-coronavirus-cases-139950. [Accessed 7 Jun 2020].

[384] M. Cleevely et al, “A Workable Strategy for Covid-19 Testing: Stratified Periodic Testing rather than Universal Random Testing,” 15 Apr 2020. [Online]. Available: https://https://www.inet.ox.ac.uk/publications/a-workable-strategy-for-covid-19-testing-stratified-periodic-testing-rather-than-universal-random-testing/. [Accessed 7 Jun 2020].

[385] O. Reich et al, “Modeling COVID-19 on a network: super-spreaders, testing and containment,” *From medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.30.20081828.],* 2020.

[386] NUS Saw Swee Hock School of Public Health, “COVID-19 Science Report: Exit Strategies,” 29 May 2020. [Online]. Available: DOI: 10.25540/g7z2-sy92. [Accessed 5 Jun 2020].

[387] C. I. Jarvis et al, “Quantifying the impact of physical distance measures on the transmission of COVID-19 in the UK,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.31.20049023],* 2020.

[388] D. M. Feehan and A. Mahmud, “Quantifying interpersonal contact in the United States during the spread of COVID-19: first results from the Berkeley Interpersonal Contact Study,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.13.20064014],* 2020.

[389] J. A. Backer et al, “The impact of physical distancing measures against COVID-19 transmission on contacts and mixing patterns in the Netherlands: repeated cross-sectional surveys,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.05.18.20101501],* 2020.

[390] Y. Zhang , B. Jiang, J. Yuan and Y. Tao, “The impact of social distancing and epicenter lockdown on the COVID-19 epidemic in mainland China : A data-driven SEIQR model study,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.04.20031187],* 2020.

[391] Z. Voko and J. Pitter, “The effect of social distance measures on COVID-19 epidemics in Europe: An interrupted time series analysis,” *GeroScience.*

[392] T. Vopham et al, “Effect of social distancing on COVID-19 incidence and mortality in the US,” *From medRxiv (preprint) [Available at: doi:10.1101/2020.06.10.20127589],* 2020.

[393] H. S. Badr et al, “Association between mobility patterns and COVID-19 transmission in the USA: a mathematical modelling study,” *Lancet Infect Dis,* vol. 3099, no. 20, pp. 30553-3, 2020.

[394] P. Bryant and A. Elofsson, “Estimating the impact of mobility patterns on COVID-19 infection rates in 11 European countries,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.13.20063644],* 2020.

[395] J. Zhang et al, “Changes in contact patterns shape the dynamics of the COVID-19 outbreak in China,” *Science,* 2020.

[396] R. A. Post et al, "How did governmental interventions affect the spread of COVID-19 in European countries?," *From medRxiv (preprint) [Available at: doi: 10.1101/2020.05.27.20114272],* 2020.

[397] V. Sypsa et al, "Modelling the SARS-CoV-2 First Epidemic Wave in Greece: Social Contact Patterns for Impact Assessment and an Exit Strategy from Social Distancing Measures," *medRxiv (preprint) [Available at: doi: 10.1101/2020.05.27.20114017],* 2020.

[398] J. M. Brauner et al, "The Effectiveness and Perceived Burden of Nonpharmaceutical Interventions against COVID-19 Transmission," *From medRxiv (preprint) [Available at: doi: 10.1101/2020.05.28.20116129],* 2020.

[399] M. L. Li et al, "Forecasting COVID-19 and Analyzing the E,ect of Government Interventions," *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.06.23.20138693],* 2020.

[400] S. Guo et al, "Social Distancing Interventions in the United States : An Exploratory Investigation of Determinants and Impacts," *From medRxiv (preprint) [Available at: doi: 10.1101/2020.05.29.20117259],* 2020.

[401] D. Delen et al, "No Place Like Home : Cross-National Data Analysis of the Efficacy of Social Distancing During the COVID-19 Pandemic," *JMIR Public Health And Surveillance,* 2020.

[402] K. Deforche et al, "Behavioral changes before lockdown, and decreased retail and recreatio mobility during lockdown, contributed most to the successful control of the COVID-19 epidemic in 35 Western countries," *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.06.20.20136382],* 2020.

[403] E. Leeuwen, "Augmenting contact matrices with time-use data for fine-grained intervention modelling of disease dynamics: A modelling analysis," *From medRxiv (preprint) [Available at: doi: 10.1101/2020.06.03.20067793],* 2020.

[404] G. Pullano et al, "Population mobility reductions during COVID-19 epidemic in France under lockdown," *From MedRxiv (preprint) [Availability: doi:https://doi.org/10.1101/2020.05.29.20097097.t],* 2020.

[405] D. Canning, M. Karra, R. Dayalu, M. Guo and D. E. Bloom, "The association between age, COVID-19 symptoms, and social distancing behaviour in the United States," *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.19.20065219],* 2020.

[406] I. Ricon-Becker et al, "A seven-day cycle in COVID-19 infection and mortality rates: Are inter-generational social interactions on the weekends killing susceptible people?," *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.05.03.20089508],* 2020.

[407] S. H. Ebrahim and Z. A. Memish, "COVID-19 – the role of mass gatherings," *Travel Medicine and Infectious Disease [Journal Pre-proof],* 2020.

[408] E. Brooks-Pollock, J. M. Read, T. House, G. F. Medley, M. J. Keeling and L. Danon, "The Population Attributable Fraction (PAF) of cases due to gatherings and groups with relevance to COVID-19 mitigation strategies," *medRxiv (preprint) [Avaailable at: https://doi.org/10.1101/2020.03.20.20039537],* 2020.

[409] J. McCurry, "Workers in Tokyo's red-light district to be tested for coronavirus after new spike," *The Guardian,* 8 Jun 2020.

[410] Park et al, "Coronavirus Disease Outbreak in Call Center, South Korea," *Emerging Infectious Diseases,* vol. 26, no. 8, 2020.

[411] Public Health England, "Guidance on social distancing for everyone in the UK," Crown copyright, 2020. [Online]. Available: https://www.gov.uk/government/publications/covid-19-guidance-on-social-distancing-and-for-vulnerable-people/guidance-on-social-distancing-for-everyone-in-the-uk-and-protecting-older-people-and-vulnerable-adults. [Accessed 23 Mar 2020].

[412] WHO, "Key planning recommendations for mass gatherings in the context of the current COVID-19 outbreak: interim guidance," 14 Feb 2020. [Online]. Available: https://apps.who.int/iris/handle/10665/331004. [Accessed 2 Arp 2020].

[413] B. McCloskey et al, "Mass gathering events and reducing further global spread of COVID-19: a political and public health dilemma," *The Lancet (Published Online),* 2020.

[414] P. Cachero, "Isolated and sequestered in their homes, Chinese citizens report anxiety and depression while on lockdown amid the coronavirs outbreak," *Business Insider US,* 24 Feb 2020.

[415] China National Health Commission, "Guidelines for local authorities to promote psychological crisis intervention related to COVID-19," China NHC, 2020. [Online]. Available: www.nhc.gov.cn/jkj/s3577/202001/6adc08b966594253b2b791be5c3b9467.shtml. [Accessed 29 Feb 2020].

[416] Z. Ma et al, “Increased stressful impact among general population in mainland China amid the COVID-19 pandemic : A nationwide cross-sectional study conducted after Wuhan city’s travel ban was lifted,” *International Journal of Social Psychiatry,* pp. 1-10, 2020.

[417] N. Jacobson et al, “Flattening the Mental Health Curve: COVID-19 Stay-at-Home Orders are Associated with Alterations in Mental Health Search Behavior in the United States,” *JMIR Preprints,* 2020.

[418] E. Milman et al, “Social isolation and the mitigation of coronavirus anxiety: The mediating role of meaning,” *Death Studies,* pp. 1-13, 2020.

[419] L. Renzo et al, “Eating habits and lifestyle changes during COVID-19 lockdown: An Italian survey,” *Journal of Translational Medicine, 18(1),* vol. 18, no. 1, 2020.

[420] L. Gallo et al, “The Impact of Isolation Measures Due to COVID-19 on Energy Intake and Physical Activity Levels in Australian University Students,” *From Nutrients 2020. doi: 10.3390/nu12061865,* 2020.

[421] S. Moore et al, “Impact of the COVID-19 virus outbreak on movement and play behaviours of Canadian children and youth: A national survey,” *International Journal of Behavioral Nutrition and Physical Activity,* vol. 17, no. 1, 2020.

[422] S. Park et al, “Social Distancing and Outdoor Physical Activity During the COVID-19 Outbreak in South Korea: Implications for Physical Distancing Strategies.,” *Asia-Pacific Journal of Public Health.*

[423] S. Benzell et al, “Rationing Social Contact During the COVID-19 Pandemic: Transmission Risk and Social Benefits of US Locations,” *From SSRN Electronic Journal, 2–4. doi: https://doi.org/10.2139/ssrn.3579678Benzell, S. G.,,* 2020.

[424] “Coronavirus live: Coronavirus outbreak,” The Guardian, 17 Mar 2020. [Online]. Available: https://www.theguardian.com/world/live/2020/mar/18/coronavirus-live-news-updates-outbreak-us-states-uk-australia-europe-eu-self-isolation-lockdown-latest-update?page=with:block-5e720aa58f088d7575595a15. [Accessed 19 Mar 2020].

[425] C. Jackson et al, “The Effects of School Closures on Influenza Outbreaks and Pandemics: Systematic Review of Simulation Studies,” *PLOS ONE,* vol. 9, no. 5, 2014.

[426] D. J. Earn , D. He , M. B. Loeb , K. Fonseca and B. E. Lee et al, “Effects of school closure on incidence of pandemic influenza in Alberta, Canada.,” *Annals of Internal Medicine,* vol. 156, p. 173–1, 2012.

[427] S. Cauchemez, A.-J. Valleron , P.-Y. Boelle and A. Flahault , “Estimating the impact of school closure on influenza transmission from Sentinel data,” *Nature,* vol. 452, p. 750–754, 2008.

[428] A. Heymann , G. Chodick , B. Reichman , E. Kokia and J. Laufer , “Influence of school closure on the incidence of viral respiratory diseases among children and on health care utilization,” *Pediatric Infectious Disease Journal,* vol. 23, no. 7, p. 675–677, 2004.

[429] W. Wu et al, “Comparison of clinical course of patients with severe acute respiratory syndrome among the multiple generations of nosocomial transmission,” *Chinese medical journal,* vol. 117, no. 1, pp. 14-18, 2004.

[430] H. Stage et al, “Shut and Re-open: The Role of Schools in the Spread of COVID-19 in Europe,” *From medRxiv (preprint). doi: 10.1101/2020.06.24.20139634,* 2020.

[431] T. Moberly, “Covid-19: school closures and bans on mass gatherings will need to be considered, says England’s CMO,” *BMJ,* p. Available at: doi: 10.1136/bmj.m806, 2020.

[432] J. Bayham and E. P. Fenichel, “The Impact of School Closure for COVID-19 on the US Healthcare Workforce and the Net Mortality Effects,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.09.20033415],* 2020.

[433] E. T. Chin, B. Q. Huynh, N. C. Lo, T. Hstie and S. Basu, “Healthcare worker absenteeism, child care costs, and COVID-19 school closures: a simulation analysis,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.19.20039404],* 2020.

[434] G. Wang, Y. Zhang, J. Zhao, J. Zhang and F. Jiang, “Mitigate the effects of home confinement on children during the COVID-19 outbreak,” *The Lancet (Published online) [Available at: https://doi.org/10.1016/S0140-6736(20)30547-X],* 2020.

[435] R. Armitage and L. B. Nellums, “Considering inequalities in the school closure response to COVID-19,” *The Lancet [Published Online],* 2020.

[436] M. Russel et al, “School closure and management practices during coronavirus outbreaks including COVID-19: a rapid systematic review,” *Lancet Child Adolesc Health,* vol. 4, p. 397–404, 2020.

[437] M. Rothstein et al, “Quarantine and Isolation: Lessons Learned from SARS. A Report to the Centers for Disease Control and Prevention.,” Institute for Bioethics, Health Policy and Law; University of Louisville

School of Medicine , 2003. [Online]. Available: https://biotech.law.lsu.edu/blaw/cdc/SARS_REPORT.pdf. [Accessed 3 Mar 2020].

[438] N. P. Johnson and J. Mueller , “Updating the accounts: Global mortality of the 1918–1920 “Spanish” influenza pandemic.,” *Bulletin of the History of Medicine,* vol. 76, no. 1, p. 105–115, 2002.

[439] T. C. Germann , K. Kadau, I. J. Longini and C. A. Macken , “Mitigation strategies for pandemic influenza in the United States,” *Proceedings of the National Academy of Sciences,* vol. 103, no. 15, p. 5935–5940, 2006.

[440] Z. Low, G. Cheung and E. Cheung, “Coronavirus: Hongkongers in panic buying of rice, toilet paper and essentials as government stays mum on impending quarantine measures,” *South China Morning Post,* 6 Feb 2020.

[441] H. M. Ang, “FairPrice imposes purchase limits for paper products, rice and instant noodles amid coronavirus outbreak,” *Channel News Asia,* 9 Feb 2020.

[442] Y. Low, “The Big Read: Panic buying grabbed the headlines, but a quiet resilience is seeing Singaporeans through COVID-19 outbreak,” *Channel News Asia,* 17 Feb 2020.

[443] R. M. Anderson, H. Heesterbeek, D. Klinkenberg and T. D. Hollingsworth, “How will country-based mitigation measures influence the course of the COVID-19 epidemic?,” *The Lancet,* vol. 395, 2020.

[444] A. Clark et al, “Global, Regional, and National Estimates of the Population at Increased Risk of Severe COVID-19 due to Underlying Health Conditions in 2020: A Modelling Study,” *The Lancet Global Health,* vol. 20, 2020.

[445] R. Armitage and L. B. Nellums, “COVID-19 and the consequences of isolating the elderly,” *The Lancet (published online},* 2020.

[446] J. Tsai and M. Wilson, “COVID-19: a potential public health problem for homeless populations,” *Lancet Public Health [Published online 11 March],* 2020.

[447] S. Kilic and G. C. Gray, “Nonpharmaceutical Interventions for Military Populations During Pandemic Influenza,” *Turk Silahli Kuvvetleri Koruyucu Hekim Bul,* vol. 6, no. 4, p. 285–290, 2007.

[448] Z. J. M. Ho, J. Y. F. Hwang and V. J. M. Lee, “Emerging and re-emerging infectious diseases: challenges and opportunities for militaries,” *Military Medical Research,* vol. 1, no. 21, 2014.

[449] C. Harrington et al, “Nurse Staffing and Coronavirus Infections in California Nursing Homes,” *SAGE Journals,* 2020.

[450] Prison Studies , “News on COVID-19 and prisons,” Prison Studies, 2020. [Online]. Available: https://www.prisonstudies.org/news/news-covid-19-and-prisons. [Accessed 6 Apr 2020].

[451] J. Matthew et al, “Flattening the Curve for Incarcerated Populations — Covid-19 in Jails and Prisons.,” *NEJM,* 2020.

[452] A. Liem et al, “The neglected health of international migrant workers in the COVID-19 epidemic,” *The Lancet,* 2020.

[453] CNA, “COVID-19 fears spark Thailand prison riot,” *Channel News Asia,* 29 Mar 2020.

[454] CNA, “Italy prison riots over coronavirus leave 12 dead,” *Channel News Asia,* 11 Mar 2020.

[455] NYMag, “Coronavirus Fears Spark Prison Strikes, Protests, and Riots Around the World,” *NYMag,* 27 Mar 2020.

[456] R. T. Gilman et al, “Modelling interventions to control COVID-19 outbreaks in a refugee camp,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.07.07.20140996],* 2020.

[457] Bloomberg, “Hotels Pivot to Virus Battle as N.Y. Lodges Health Workers,” *Bloomberg,* 31 Mar 2020.

[458] C. S. Ho et al, “Mental Health Strategies to Combat the Psychological Impact of COVID-19 Beyond Paranoia and Panic,” 2020. [Online]. Available: http://www.annals.edu.sg/pdf/special/COM20043_HoCSH_2.pdf . [Accessed 6 Apr 2020].

[459] Intercept, “Rikers Island Prisoners are being offered PPE and $6 an hour to dig mass graves,” *Intercept,* 31 Mar 2020.

[460] SCMP, “Coronavirus: Taiwan uses prison labour to meet demand for face masks,” *SCMP,* 11 Mar 2020.

[461] UNICEF, “COVID-19 pandemic could devastate refugee, migrant and internally displaced populations without urgent international action Statement by UNICEF Executive Director Henrietta Fore.,” *UNICEF,* 1 Apr 2020.

[462] Amnesty, “Qatar: Migrant workers in labour camps at grave risk amid COVID-19 crisis.,” *Amnesty,* 20 Mar 2020.

[463] The Guardian, “Covid-19 lockdown turns Qatar's largest migrant camp into 'virtual prison',” *The Guardian,* 20 Mar 2020.

[464] CNA, “Gulf's massive migrant workforce fears virus limbo,” *Channel News Asia,* 30 Mar 2020.

[465] United Nations, “Basic principles for the treatment of prisoners, Adopted and Proclaimed by General Assembly resolution 45/111 of 14 December 1990,” United Natons, 1990. [Online]. Available: https://www.ohchr.org/en/professionalinterest/pages/basicprinciplestreatmentofprisoners.aspx . [Accessed 6 Apr 2020].

[466] G. Malloy et al, “The Effectiveness of Interventions to Reduce COVID-19 Transmission in a Large Urban Jail,” *From medRxiv (preprint) [Available at: doi: 10.1101/2020.06.16.20133280],* 2020.

[467] D. Rose et al, “Screening for SARS-CoV-2 Infection Within a Psychiatric Hospital and Considerations for Limiting Transmission Within Residential Psychiatric Facilities — Wyoming,” *Morbidity and Mortality Weekly Report,* 2020.

[468] UK Government, “Flu Pandemic. As a retailer are you prepared?,” Retail Business Continuity Forum, Mar 2007. [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/85917/flu_retailers_guide.pdf. [Accessed 20 Feb 2020].

[469] Centers for Disease Prevention and Control, “Get Your Workplace Ready for Pandemic Flu,” CDC, US, 2017. [Online]. Available: https://www.cdc.gov/nonpharmaceutical-interventions/pdf/gr-pan-flu-work-set.pdf. [Accessed 14 Feb 2020].

[470] Neiman , “Challenges for Businesses,” Neiman Foundation for Journalism Harvard, (undated). [Online]. Available: https://nieman.harvard.edu/wp-content/uploads/pod-assets/microsites/NiemanGuideToCoveringPandemicFlu/PandemicPreparedness/ChallengesForBusinesses.aspx.html. [Accessed 14 Feb 2020].

[471] E. Rochelle et al , “Tackle the Problem When It Gets Here: Pandemic Preparedness Among Small and Medium Businesses,” *Qualitative Health Research,* vol. 18, no. 7, pp. 902-912, 2008.

[472] D. C. Burton et al , “A qualitative study of pandemic influenza preparedness among small and medium-sized businesses in New York City,” *J Bus Contin Emer Plan.,* vol. 5, no. 3, pp. 267-79., 2011.

[473] Continuity Central, “Business continuity planning and actions in relation to COVID-19,” 2020. [Online]. Available: https://www.continuitycentral.com/index.php/news/business-continuity-news/4901-business-continuity-planning-and-actions-in-relation-to-covid-19. [Accessed 20 Feb 2020].

[474] M. Fadel, J. Salomon and A. Descatha, “Coronavirus outbreak: the role of companies in preparedness and responses,” *Lancet Public Health (published online),* pp. Available at: https://doi.org/10.1016/S2468-2667(20)30051-7, 2020.

[475] MOM, “General advisory for workplace measures in response to DORSCON Orange situation in Singapore,” Ministry of Health, Singapore, 7 Feb 2020. [Online]. Available: https://www.mom.gov.sg/2019-ncov/general-advisory-for-workplace-measures . [Accessed 13 Feb 2020].

[476] Enterprise Singapore, “Guide on Business Continuity Planning for 2019 novel coronavirus,” 2020. [Online]. Available: https://www.enterprisesg.gov.sg/-/media/esg/files/media-centre/media-releases/2020/jan-2020/guide-on-business-continuity-planning-for-2019-ncov_2nd-edition_final_08022020.pdf. [Accessed 13 Feb 2020].

[477] CIDRAP, “Doing Business During an Influenza Pandemic: A Toolkit for Organizations of All Sizes. Human Resource Policies, Protocols, Templates, Tools, & Tips,” Center for Infectious Disease Research and Policy (CIDRAP) at the University of Minnesota, with assistance from the Society for Human Resource Management (SHRM), and with contractual support from the Centers for Disease Control and Prevention (CDC), 2009. [Online]. Available: http://www.cidrap.umn.edu/sites/default/files/public/downloads/cidrap-shrm-hr-pandemic-toolkit.pdf . [Accessed 13 Feb 2020].

[478] Harvard Business Review, “Coronavirus and Business: The Insights You Need from Harvard Business Review,” 26 Mar 2020. [Online]. Available: https://store.hbr.org/product/coronavirus-and-business-the-insights-you-need-from-harvard-business-review/10440. [Accessed 30 Mar 2020].

[479] Fisher Philips, “Comprehensive And Updated FAQs For Employers On The COVID-19 Coronavirus,” Fisher Phillips LLP, 23 Mar 2020. [Online]. Available: https://www.fisherphillips.com/faqs. [Accessed 24 Mar 2020].

[480] HR Hero Line, “Employers Should Be Prepared in Case Swine Flu Strikes,” 2009. [Online]. Available: https://hrdailyadvisor.blr.com/2009/06/11/employers-should-be-prepared-in-case-swine-flu-strikes/. [Accessed 13 Feb 2020].

[481] Gartner, "Business disruptions like coronavirus mean turmoil for employees and work. Answer these 10 questions in your HR outbreak management and pandemic plan," Gartner Inc, 10 Feb 2020. [Online]. Available: https://www.gartner.com/smarterwithgartner/10-questions-for-an-hr-pandemic-plan/. [Accessed 14 Feb 2020].

[482] HK LD , "Guidelines for Employers and Employees– Prevention of Human Swine Influenza(Influenza A H1N1)," Hong Kong Labour Department, 2009. [Online]. Available: https://www.labour.gov.hk/eng/public/oh/Guidelines_H1N1.pdf. [Accessed 14 Feb 2020].

[483] OSHA , "Guidance on Preparing Workplaces for an Influenza Pandemic," U.S. Department of Labor, Occupational Safety and Health Administration , 2009. [Online]. Available: https://www.osha.gov/Publications/OSHA3327pandemic.pdf . [Accessed 14 Feb 2020].

[484] smallbusiness UK, "Small Business UK," 2020. [Online]. Available: https://smallbusiness.co.uk/ . [Accessed 14 Feb 2020].

[485] HM Government, "Pandemic influenza checklist for businesses," Cabinet Office. London, [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/61986/060516flubcpchecklist.pdf. [Accessed 14 Feb 2020].

[486] S. A. Boone and C. P. Gerba , "Significance of fomites in the spread of respiratory and enteric viral disease.," *Appl Environ Mirobiol,* vol. 73, p. 1687–1696..

[487] D. R. Contrera et al, "Assessing virus infection probability in an office setting using stochastic simulation.," *Journal of Occupational and Environmental Hygiene,* vol. 17, no. 1, 2019.

[488] K. Elkana et al, "Impact of a hygiene intervention on virus spread in an office building.," *International Journal of Hygiene and Environmental Health,* vol. 222, no. 3, pp. 479-485, 2019.

[489] Reynolds et al , "The healthy workplace project: reduced viral exposure in an office setting," *Arch. Environ. Occup. Health,* vol. 71, pp. 157-162, 2016.

[490] P. A. Tambyah, "The Middle East Respiratory Syndrome Coronavirus (MERS-CoV) and Singapore," *Annals Academy of Medicine,* vol. 42, no. 8, 2013.

[491] A. M. Stern and H. Markel, "International efforts to control infectious diseases. 1851 to the present," *Journal of the American Medical Association. 2004;292(12):,* vol. 292, no. 12, p. 1474–1479, 2004.

[492] M. Sakib et al, "Considerations for an Individual-Level Population Notification System for Pandemic Response: A Review and Prototype," *Journal of Medical Internet Research,* vol. 22, no. 6, 2020.

[493] P. Shao, "Impact of city and residential unit lockdowns on prevention and control of COVID-19," *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.13.20035253],* 2020.

[494] B. Espinoza et al, "Mobility Restrictions for the Control of Epidemics: When Do They Work?," *PLoS ONE,* vol. 15, no. 7, 2020.

[495] R. J. Moran et al, "Estimating required 'lockdown' cycles before immunity to SARS-CoV-2: Model-based analyses of susceptible population sizes, 'S0', in seven European countries including the UK and Ireland," Academic Neurosciences Centre, Centre for Neuroimaging Sciences, London, 2020. [Online]. Available: https://arxiv.org/ftp/arxiv/papers/2004/2004.05060.pdf. [Accessed 23 Apr 2020].

[496] X. Wang, W. Tian, X. Lv, Y. Shi, X. Zhou and W. Yu, "Effects of Chinese strategies for controlling the diffusion and deterioration of novel coronavirus–infected pneumonia in China," *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.10.20032755],* 2020.

[497] D. Li et al , "Estimating the Efficacy of Traffic Blockage and Quarantine for the Epidemic Caused by 2019-nCoV (COVID-19)," *medRxiv (preprint),* p. Available at: https://doi.org/10.1101/2020.02.14.20022913, 2020.

[498] X. Zhu et al , "Spatially Explicit Modeling of 2019-nCoV Epidemic Trend based on Mobile Phone Data in Mainland China," *medRxiv (preprint),* p. Available at: https://doi.org/10.1101/2020.02.09.20021360, 2020.

[499] S. Zhao and H. Chen, "Modeling the Epidemic Dynamics and Control of COVID-19 Outbreak in China," medRxiv (preprint), 2020. [Online]. Available: https://doi.org/10.1101/2020.02.27.20028639.

[500] M. U. G. Kraemer et al, "The effect of human mobility and control measures on the COVID-19 epidemic in China," medRxiv (preprint) , 2020. [Online]. Available: https://doi.org/10.1101/2020.03.02.20026708.

[501] S. Lai et al, "Effect of non-pharmaceutical interventions for containing the COVID-19 outbreak: an observational and modelling study," medRxiv (preprint) , 2020. [Online]. Available: https://doi.org/10.1101/2020.03.03.20029843.

[502] C. Wang et al, “Evolving Epidemiology and Impact of Non-pharmaceutical Interventions on the Outbreak of Coronavirus Disease 2019 in Wuhan, China,” medRxiv (prepring), 2020. [Online]. Available: https://doi.org/10.1101/2020.03.03.20030593.

[503] H. Wan, J.-a. Cui and G.-J. Yang, “Risk estimation and prediction by modeling the transmission of the novel coronavirus (COVID-19) in mainland China excluding Hubei province,” medRxiv (preprint0, 2020. [Online]. Available: https://doi.org/10.1101/2020.03.01.20029629.

[504] K. Prem et al, “The effect of control strategies that reduce social mixing on outcomes of the COVID-19 epidemic in Wuhan, China,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.09.20033050.],* 2020.

[505] W. Wang et al, “Transmission dynamics of SARS-COV-2 in China: impact of public health interventions,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.24.20036285],* 2020.

[506] Y. Zou et al, “Outbreak analysis with a logistic growth model shows COVID-1 19 suppression dynamics in China,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.25.20043539],* 2020.

[507] K. Yang et al, “Analysis of epidemiological characteristics of coronavirus 2019 infection and preventive measures in Shenzhen China—a heavy population city,” medRxiv (preprint) , 2020. [Online]. Available: https://doi.org/10.1101/2020.02.28.20028555.

[508] J. Zu et al, “Transmission patterns of COVID-19 in the mainland of China and the efficacy of different control strategies: A data- and model-driven study,” *Infectious Diseases of Poverty,* vol. 9, no. 1, 2020.

[509] M. P. Hossain et al, “The effects of border control and quarantine measures on global spread of COVID-19,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.13.20035261],* 2020.

[510] M. Kochanczyk, F. Grabowski and T. Lipniacki, “Impact of the contact and exclusion rates on the spread of COVID-19 pandemic,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.13.20035485],* 2020.

[511] H. Lau et al, “The positive impact of lockdown in Wuhan on containing the COVID-19 outbreak in China,” *J Travel Med,* 2020.

[512] H. Fag, L. Wang and Y. Yang, “Human Mobility Restrictions and the Spread of the Novel Coronavirus (2019-nCoV) in China,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.24.20042424].*

[513] J. Zhang et al, “Evolving epidemiology and transmission dynamics of coronavirus disease 2019 outside Hubei province, China: a descriptive and modelling study,” *Lancet Infect Dis (Published Online),* 2020.

[514] E. D. Brouwer, D. Raimondi and Y. Moreau, “Modeling the COVID-19 outbreaks and the effectiveness of the containment measures adopted across countries,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.02.20046375],* 2020.

[515] K. Leung, J. T. Wu and G. M. Leung, “First-wave COVID-19 transmissibility and severity in China outside Hubei after control measures, and second-wave scenario planning: a modelling impact assessment,” *The Lancet (Published Online),* 2020.

[516] B. F. Maier and D. Brockmann, “Effective containment explains subexponential growth in recent confirmed COVID-19 cases in China,” *Science,* 2020.

[517] A. Pan et al, “Association of Public Health Interventions With the Epidemiology of the COVID-19 Outbreak in Wuhan, China,” *JAMA,* 2020.

[518] N. Zhang et al, “COVID-19 Prevention and Control Public Health Strategies in Shanghai, China,” *Journal of Public Health Management and Practice,* vol. 26, no. 4, 2020.

[519] G. Gaeta, “Data Analysis for the COVID-19 early dynamics in Northern Italy. The effect of first restrictive measures,” 8 Mar 2020. [Online]. Available: https://arxiv.org/abs/2003.03775. [Accessed 16 Mar 2020].

[520] M. Gatto et al, “Spread and dynamics of the COVID-19 epidemic in Italy: Effects of emergency containment measures.,” *PNAS,* 2020.

[521] S. W. Park, K. Sun, C. Viboud, B. T. Grenfell and J. Dushoff, “Potential roles of social distancing in mitigating the spread of coronavirus disease 2019 (COVID-19) in South Korea,” *medRxiv (preprint) [Availability at: https://doi.org/10.1101/2020.03.27.20045815],* 2020.

[522] R. Reis et al, “haracterization of the COVID-19 pandemic and the impact of uncertainties, mitigation strategies, and underreporting of cases in South Korea, Italy, and Brazil,” *Chaos, Solitons & Fractal,* vol. 136, 2020.

[523] B. Strangeland, “How to evaluate the success of the COVID-19 measures implemented by the Norwegian,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.29.20045187],* 2020.

[524] S. Hsiang et al, “The E↵ect of Large-Scale Anti-Contagion Policies on the Coronavirus (COVID-19) Pandemic,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.22.20040642].*

[525] S. Flaxman et al, “Estimating the number of infections and the impact of non-pharmaceutical interventions on COVID-19 in 11 European countries,” Imperial College COVID-19 Response Team , 30 Mar 2020. [Online]. Available: https://spiral.imperial.ac.uk:8443/bitstream/10044/1/77731/10/2020-03-30-COVID19-Report-13.pdf. [Accessed 21 May 2020].

[526] V. Alfano, “Shut it down: a cross country panel analysis on the efficacy of lockdown measures,” *medRxiv (preprint) [Available at:]] https://doi.org/10.1101/2020.04.12.20062695,* 2020.

[527] A. Kucharski et al, “Effectiveness of isolation, testing, contact tracing and physical distancing on reducing transmission of SARS-CoV-2 in different settings,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.04.23.20077024],* 2020.

[528] A. Davies et al, “Effects of Non-Pharmaceutical Interventions on COVID-19 Cases, Deaths, and Demand for Hospital Services in the UK: A Modelling Study,” *The Lancet Public Health,* vol. 2667, no. 20, 2020.

[529] N. Haug et al, “Ranking the Effectiveness of Worldwide COVID-19 Government Interventions,” *From medRxiv (preprint) [Available at: doi: 10.1101/2020.07.06.20147199],* 2020.

[530] T. Banerjee et al, “A county level analysis to determine if social distancing slowed the spread of COVID-19 in the United States,” *Rev Panam Salud Publica,* 2020.

[531] L. Pellis et al, “Challenges in control of Covid-19: short doubling time and long delay to effect of interventions,” *medRxiv preprint doi: https://doi.org/10.1101/2020.04.12.20059972,* 2020.

[532] M. A. Acuna-Zegarra et al, “The SARS-CoV-2 epidemic outbreak: a review of plausible scenarios of containment and mitigation for Mexico,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.28.20046276],* 28 Mar 2020.

[533] L. Santamaria et al, “COVID-19 apparent reproductive number dropped during Spains nationwide dropdown, then spiked at lower-incidence regions,” *medRxiv (preprint) [Available at: doi: 10.1101/2020.05.30.20117770],* 2020.

[534] A. Adiga et al, “Interplay of global multi-scale human mobility, social distancing, government interventions, and COVID-19 dynamics,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.06.05.20123760],* 2020.

[535] J. Stokdale et al, “Long time frames to detect the impact of changing COVID-19 control measures,” *From MedRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.06.14.20131177],* 2020.

[536] J. H. Fowler, S. J. Hill, R. Levin and N. Obradovich, “The Effect of Stay-at-Home Orders on COVID-19 Infections in the United States,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.13.20063628],* 2020.

[537] J. Gu et al, “Better Strategies for Containing COVID-19 Epidemics–A Study of 25 Countries via an Extended SEIR Model,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.04.27.20081232],* 2020.

[538] S. Pei, S. Kandula and J. Sharman, “Differential Effects of Intervention Timing on COVID-19 Spread in the United States,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.05.15.20103655],* 2020.

[539] T. Hale et al, “Global Assessment of the Relationship between Government Response Measures and COVID-19 Deaths,” *From medRxiv (preprint) [Available at: doi: 10.1101/2020.07.04.20145334],* 2020.

[540] C. Tsay et al, “Modeling, state estimation, and optimal control for the US COVID-19 outbreak,” *Scientific Reports,* 2020.

[541] D. Ternant, “Quantifying hospital flows and occupancy due to COVID-19 outbreak in France. Was French lockdown effective?,” *medRxiv (preprint) [Available at:doi: https://doi.org/10.1101/2020.06.08.20125765],* 2020.

[542] M. Alexandra et al, “Evaluating the Efficacy of Stay-At-Home Orders: Does Timing Matter?,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.05.30.20117853],* 2020.

[543] F. Scullion and G. Scullion, “Testing the effects of the timing of application of preventative procedures against COVID-19: An insight for future measures such as local emergency brakes,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.06.02.20120352],* 2020.

[544] A. Gerli et al, “COVID-19 mortality rates in the European Union, Switzerland, and the UK: effect of timeliness, lockdown rigidity, and population density,” *Minerva Med [Available at: doi: https://doi.org/10.23736/S0026-4806.20.06702-6],* 2020.

[545] W. Koh et al, “Estimating the impact of physical distancing measures in containing COVID-19 : an empirical analysis Estimating the impact of physical distancing measures in containing COVID-19 : an empirical analysis,” *From MedRxiv (preprint) [Available at: doi: https://doi.org/10.1101/],* 2020.

[546] H. Turbe et al, “Impact of public health measures to control SARS-CoV-2Outbreak: a data-driven analysis,” *From MedRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.06.10.20126870],* 2020.

[547] C. Wilasang et al, “Reduction in effective reproduction number of COVID-19 is higher in countries employing active case detection with prompt isolation,” *Journal of Travel Medicine.,* 2020.

[548] D. I. Papadopoulos et al, “The impact of lockdown measures on COVID-19: a worldwide comparison,” *From medRxiv (preprint) [Available at: doi: 10.1101/2020.05.22.20106476],* 2020.

[549] G. Loewenthal et al, “COVID-19 pandemic-related lockdown: response time is more important than its strictness,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.06.11.20128520],* 2020.

[550] Z. Hu, Q. Ge, S. Li, J. Li and M. Xiong, “Evaluating the effect of public health intervention on the global-wide spread trajectory of Covid-19,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.11.20033639],* 2020.

[551] C. Wei, Z. Wnag, Z. Liang and Q. Liu, “The focus and timing of COVID-19 pandemic control measures under healthcare resource constraints,” *medRxiv preprint doi: https://doi.org/10.1101/2020.04.16.20067611,* 2020.

[552] B. Cano, C. Morales and B. Claus, “COVID-19 Modelling: the Effects of Social Distancing,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.29.20046870],* 2020.

[553] G. J. Milne and S. Xie, “The Effectiveness of Social Distancing in Mitigating COVID-19 Spread: a modelling analysis,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.20.20040055],* 2020.

[554] A. Charpentier et al , “COVID-19 pandemic control: balancing detection policy and lockdown intervention under ICU sustainability.,” *medRxiv (preprint) [Available at: Available at https://www.medrxiv.org/content/10.1101/2020.05.13.20100842v1.article-info],* 2020.

[555] M.-C. Chang et al, “Modeling the impact of human mobility and travel restrictions on the potential spread of SARS-CoV-2 in Taiwan,” *medRxiv (preprint) [Available at:https://doi.org/10.1101/2020.04.07.20053439],* 2020.

[556] J. Cheatley et al, “The effectiveness of non pharmaceutical interventions in containing epidemics: a rapid review of the literature and quantitative assessment,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.06.20054197],* 2020.

[557] R. Abouk and B. Heydari, “The Immediate Effect of COVID-19 Policies on Social Distancing Behavior in the United States,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.07.20057356],* 2020.

[558] J. R. Koo et al, “Interventions to mitigate early spread of SARS-CoV-2 in Singapore: a modelling study,” *Lancet Infect Dis [Published Online],* 2020.

[559] A. Teslya et al, “Impact of self-imposed prevention measures and short-term government intervention on mitigating and delaying a COVID-19 epidemic,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.12.20034827],* 2020.

[560] A. Ellerson and K. Sneppen, “Estimating cost-benefit of quarantine length for COVID-19 mitigation,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.09.20059790],* 2020.

[561] H. Pasquini-Descomps , N. Brender and D. Maradan , “Value for money in H1N1 influenza: A Systematic review of the cost-effectiveness of pandemic interventions,” *Value Health,* vol. 20, pp. 819-27, 2017.

[562] V. Chernozhukov et al, “Causal Impact of Masks, Policies, Behavior on Early COVID-19 Pandemic in the U.S,” *From medRxiv (preprint) [Available at: doi: 10.1101/2020.05.27.20115139],* 2020.

[563] C. Adoph, K. Amano, B. Bang-Jensen, N. Fullman and J. Wilkerson, “Pandemic Politics: Timing State-Level Social Distancing Responses to COVID-19,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.30.20046326],* 2020.

[564] T. Sardar, S. S. Nadim and J. Chattopadhyay, “Assessment of 21 Days Lockdown Effect in Some States and Overall India: A Predictive Mathematical Study on COVID-19 Outbreak,” *Preprint submitted to Elsevier,* 2020.

[565] R. Gupta et al, “Epidemiological Transition of COVID-19 in India from Higher to Lower HDI States and Territories: Implications for Prevention and Control,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.05.05.20092593],* 2020.

[566] D. Basu et al, “Lockdown Effect on COVID-19 Spread in India: National Data Masking State-Level Trends,” *medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.05.25.20113043],* 2020.

[567] L. Gibson and D. Rush, “Novel Coronavirus in Cape Town Informal Settlements- Feasibility of Using Informal Dwelling Outlines to Identify High Risk Areas for COVID-19 Transmission From A Social Distancing Perspective,” *JMIR Public Health Surveill,* 2020.

[568] J. O. Ferstand et al, “A model to forecast regional demand for COVID-19 related hospital beds,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.26.20044842],* 2020.

[569] L. Willem et al, “SOCRATES: an online tool leveraging a social contact data sharing initiative to assess mitigation strategies for COVID-19,” *BMC Research Notes,* vol. 13, no. 293, 2020.

[570] T. Churches and L. Jorm, ““COVOID”: A flexible, freely available stochastic individual contact model for exploring COVID-19 intervention and control strategies,” *JMIR Public Health and Surveillance,* 2020.

[571] M. D. Verhagen et al, “Forecasting spatial, socioeconomic and demographic variation in COVID-19 health care demand in England and Wales,” *BMC Medicine,* vol. 203, p. 18, 2020.

[572] Imperial College COVID-19 Response Team, “Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand,” Imperial College, London, 2020.

[573] World Health Organisation, “International Health Regulations and Epidemic Control,” 2020. [Online]. Available: https://www.who.int/trade/distance_learning/gpgh/gpgh8/en/index1.html . [Accessed 12 Feb 2020].

[574] S. E. Davies, “‘National Security and Pandemics,” *UN Chronicle.,* pp. Available at: https://www.un.org/en/chronicle/article/national-security-and-pandemics, 2008.

[575] B. Gilmore et al, “Community Engagement for COVID-19 Prevention and Control: A Rapid Evidence Synthesis,” 2020.

[576] G. Elcheroth and J. Drury, “Collective resilience in times of crisis: Lessons from the literature for socially effective responses to the pandemic,” *British Journal of Social Psychology,* 2020.

[577] H. Chen, W. Xu, C. Paris, A. Reeson and X. Li, “Social distance and SARS memory: impact on the public awareness of 2019 novel coronavirus (COVID-19) outbreak,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.11.20033688],* 2020.

[578] G. Graffigna et al, “Measuring Italian Citizens’ Engagement in the Fi 1 rst Wave of the COVID-19 Pandemic Containment Measures: A Cross-sectional Study,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.22.20075234],* 2020.

[579] J. Clements, “Knowledge and Behaviors Toward COVID-19 Among US Residents During the Early Days of the Pandemic: Cross-Sectional Online Questionnaire,” *JMR Public Health and Surveillance,* vol. 6, no. 2, 2020.

[580] E. Y. Chan et al, “Sociodemographic Predictors of Health Risk Perception, Attitude and Behavior Practices Associated with Health-Emergency Disaster Risk Management for Biological Hazards: The Case of COVID-19 Pandemic in Hong Kong, SAR China.,” *International Journal of Environmental Research and Public Health,* vol. 17, no. 11, 2020.

[581] M. Greeven, “Commentary: On sick leave, but China still makes great leap forward in Med Tech,” *Channel News Asia,* 9 Mar 2020.

[582] Q. Ye, J. Zhou and H. Wu, “Using Information Technology to Manage the COVID-19 Pandemic: Development of a Technical Framework Based on Practical Experience in China,” *JMIR Medical Informatics,* vol. 8, no. 6, 2020.

[583] J. Wosik et al, “Telehealth Transformation: COVID-19 and the rise of Virtual Care,” Oxford University Press, Durham, 2020.

[584] A. V. Das, P. K. Rani and P. K. Vaddavalli, “Tele-consultations and electronic medical records driven remote patient care: Responding to the COVID-19 lockdown in India,” *Indian Journal of Ophthalmology,* 2020.

[585] S. Kissler, C. Tedijanto, M. Lipsitch and Y. H. Grad, “Social distancing strategies for curbing the COVID-19 epidemic,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.22.20041079],* 2020.

[586] A. R. Tuite, D. N. Fisman and A. L. Greer, “Mathematical modeling of COVID-19 transmission and mitigation strategies in the population of Ontario, Canada,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.24.20042705],* 2020.

[587] A. Handel, J. C. Miller, Y. Ge and I. C.-H. Fung, “If containment is not possible, how do we minimize mortality for COVID-19 and other emerging infectious disease outbreaks?,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.13.20034892],* 2020.

[588] Centers for Disease Control and Prevention (CDC), “Correctional Facilities Pandemic influenza Planning Checklist,” 2007. [Online]. Available: https://www.cdc.gov/flu/pandemic-resources/pdf/correctionchecklist.pdf. [Accessed 2 4 2020].

[589] A. Jamieson-Lane and E. Cytrnbaum, “The Effectiveness of Targeted Quarantine fo Minimising Impact of COVID-19,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.01.20049692],* 2020.

[590] A. Burns and A. Gutfraind, “Symptom-Based Isolation Policies: Evidence from a Mathematical Model of Outbreaks of Influenza and COVID-19,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.26.20044750],* 2020.

[591] P. Jenny, D. F. Jenny, H. Gorji, M. Arnoldini and W.-D. Hardt, “Dynamic Modeling to Identify Mitigation Strategies for Covid-19 Pandemic,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.27.20045237],* 2020.

[592] A. James, S. C. Hendy, M. J. Plank and N. Steyn, “Suppression and Mitigation Strategies for Control of COVID-19 in New Zealand,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.26.20044677],* 2020.

[593] Z. Neufeld and H. Khataee, “Targeted adaptive isolation strategy for Covid-19 pandemic,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.23.20041897],* 2020.

[594] B. Adamik et al, “Mitigation and herd immunity strategy for COVID-19 is likely to fail,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.25.20043109],* 2020.

[595] R. M. Cotta, C. Naveira-Cotta and P. Magal, “Modelling the COVID-19 epidemics in Brasil: Parametric identification and public health measures influence,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.31.20049130],* 2020.

[596] Y. Sugishita, J. Kurita, T. Sugawara and Y. Ohkusa, “Forecast of the COVID-19 outbreak, collapse of medical facilities, and lockdown effects in Tokyo, Japan,” *medRxiv preprint doi: https://doi.org/10.1101/2020.04.02.20051490,* 2020.

[597] A. Ugarov, “Inclusive Costs of NPI Measures for COVID-19 Pandemic: Three Approaches,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.03.26.20044552],* 2020.

[598] P. Yang et al, “Feasibility Study of Mitigation and Suppression Intervention Strategies for Controlling COVID COVID-19 Outbreaks in London and Wuhan,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.01.20043794],* 2020.

[599] M. R. Wood et al, “Modelling the impact of COVID-19 in Australia to inform transmission reducing measures and health system preparedness,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.07.20056184],* 2020.

[600] B. Skorup and T. Mitchell, “Aggregated Smartphone Location Data to Assist in Response to Pandemic,” 2 Apr 2020. [Online]. Available: https://www.mercatus.org/publications/covid-19-policy-brief-series/aggregated-smartphone-location-data-assist-response. [Accessed 13 Apr 2020].

[601] F. Biljecki, “Singapore's urban data affirms the compliance with the Circuit Breaker measures,” Urban Analytics Lab, National University of Singapore, 12 Apr 2020. [Online]. Available: https://ual.sg/post/2020/04/12/singapores-urban-data-affirms-the-compliance-with-the-circuit-breaker-measures/. [Accessed 14 Apr 2020].

[602] U. Goldsztejn, D. Schwartzman and A. Nehorai, “Public policy and economic dynamics of COVID-19 spread: a mathematical modeling study,” *medRxiv preprint doi: https://doi.org/10.1101/2020.04.13.20062802,* 2020.

[603] B. Peng and C. I. Amos, “Population simulations of COVID-19 outbreaks provide tools for risk assessment and continuity planning,” *medRxiv preprint doi: https://doi.org/10.1101/2020.04.13.20064253.*

[604] Y. W. Aun and D. B. Raja, “Time-variant strategies for optimizing the performance of non-pharmaceutical interventions (NPIs) in protecting lives,” *medRxiv preprint doi: https://doi.org/10.1101/2020.04.13.20063248,* 2020.

[605] R. Challen et al, “Estimates of regional infectivity of COVID-19 in the United Kingdom following imposition of social distancing measures,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.13.20062760],* 2020.

[606] L. D. Domenico et al, “Expected impact of lockdown in Île-de-France and possible exit strategies,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.13.20063933],* 2020.

[607] R. German, A. n. Djanatliev, L. Maile and P. Bazan, “Modelling exit strategies from COVID-19 Lockdown with a focus on antibody tests,” *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.14.20063750],* 2020.

[608] P. Liu, P. Beeler and R. K. Chakrabarty, "Diminishing Marginal Benefit of Social Distancing in Balancing COVID-19 Medical Demand-to-Supply," *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.09.20059550],* 2020.

[609] W. Lyra et al, "COVID-19 pandemics modeling with SEIR(+CAQH), social distancing, and age stratification. The effect of vertical confinement and release in Brazil," *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.09.20060053],* 2020.

[610] L. Lopez and X. Rodo, "The end of the social confinement in Spain and the COVID-19 re-emergence risk," *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.14.20064766],* 2020.

[611] M. Sasidharan, A. Singh, M. E. Torbaghan and A. K. Parikad, "A vulnerability-based approach to human-mobility reduction for countering COVID-19 transmission in London while considering local air quality," *medRxiv (preprint) [Available at: https://doi.org/10.1101/2020.04.13.20060798],* 2020.

[612] D. M. Cooper et al, "Re-Opening Schools Safely: The Case for Collaboration, Constructive Disruption of Pre-COVID Expectations, and Creative Solutions," *The Journal of Pediatrics (pre-proof),* 2020.

[613] A. Grothey and K. Mckinnon, "Optimizing the COVID-19 Intervention Policy in Scotland and the Case for Testing and Tracing," *From medRxiv (preprint) [Available at; doi: 10.1101/2020.06.11.20128173],* 2020.

[614] K. P. Reddy et al, "Cost-effectiveness of public health strategies for COVID-19 epidemic control in South Africa," *From medRxiv (preprint) [Available at: doi: https://doi.org/10.1101/2020.06.29.20140111],* 2020.