EVIDENCE SYNTHESIS BRIEFING NOTE

TOPIC: CONTACT TRACING FOR COVID-19

Information finalized as of November 18, 2020.[a]

This Briefing Note was completed by the Research, Analysis, and Evaluation Branch (Ministry of Health) based on information provided by members of the COVID-19 Evidence Synthesis Network. Please refer to the Methods section for further information.

Purpose: This note summarizes the evidence and jurisdictional experiences on contact tracing approaches used to contain the COVID-19 pandemic.

Key Findings:

- No relevant evidence-based guidelines were identified.
- Best practices that appear to improve the effectiveness of contact tracing include:
  - **Response Times**: Swift response times (e.g., two to three days) in isolating cases and quarantining at least 80% of contacts may be associated with better control of COVID-19. When the number of new cases has been controlled, it is necessary to maintain contact tracing for several months and to do so in combination with other public measures.
  - **High Surveillance and Contact Tracing Capacity**: Well-trained and adequately staffed contact tracing teams are crucial for mounting a proactive pandemic response. Although manual contact tracing is the preferred approach, it is very resource-intensive and may rapidly become overwhelmed. Human resource capacity for contact tracing in most jurisdictions is achieved through redeploying and training employees and volunteers across sectors (e.g., health care workers, armed forces, police).
  - **Digital Contact Tracing Approaches**: Bluetooth, global positioning systems, and cloud-based technologies may serve as useful tools for supporting contact tracing, particularly in densely populated areas where the infected individual may not know all contacts. The efficacy of these approaches is largely unknown, but they may help curb epidemic growth if combined with robust public health efforts.
    - Due to uptake, privacy, and usability concerns, digital tools may best serve as supplementary measures to traditional contact tracing approaches, in which contacts are identified through a thorough review of available data (e.g., telephone interviews with the infected individual; medical, travel, or police records). This approach has been recommended by the World Health Organization.
- Enabling contextual factors that may improve the effectiveness of contact tracing across jurisdictions include:
  - **Emergency Preparedness**: Pre-existing pandemic or natural disaster emergency infrastructure facilitates a rapid whole-of-government response.
  - **Cross-Sectoral Collaboration**: An "all hands-on deck" approach facilitates a rapid and comprehensive response and supports human resource/redeployment needs for contact tracing.
  - **Local Public Health Units**: These units are essential for implementing contact tracing protocols, maintaining the number of cases within a manageable range, building rapport with the community, and piloting new outreach approaches (e.g., home-based testing or symptom monitoring).
  - **Science-Focused Strategic Communication**: Transparent, evidence-informed public communication, delivered by experts, builds public trust and may facilitate public cooperation with contact tracing strategies.

Analysis for Ontario:

- On April 27, 2020, the Government of Ontario released its framework document for reopening the province, echoing the need to strengthen public health capacity for timely contact tracing and case management.
- Public Health Ontario, in collaboration with the Ministry of Health and the Canadian federal government, is leading the COVID-19 Contact Tracing Initiative.

Implementation Implications: Large-scale manual contact tracing is key in most contexts, but can be further supplemented with digital contact tracing approaches if privacy and usability limitations are addressed.

[a] This briefing note includes available evidence as of the noted date - this is an update to the original briefing note published in June 2020. It is not intended to be an exhaustive analysis, and other relevant findings may have been reported since completion.

Context and Terminology

Contact tracing is the process of identifying, assessing, and managing people who have been exposed to a disease to prevent onward transmission. A study (May 27, 2020) on contact tracing for coronavirus disease 2019 (COVID-19) described traditional and digital contact tracing approaches:

- **Traditional Contact Tracing**: Public health officials interview an infected individual, identify contacts, and advise exposed contacts to self-monitor for symptoms, self-quarantine, or obtain medical evaluation and treatment. This approach has had success in reducing infection transmission in many epidemics, including severe acute respiratory syndrome-associated coronavirus (SARS-CoV) and Ebola. However, some limitations of this approach include being labour- and time-intensive, making it challenging to scale.
- **Digital Contact Tracing**: Electronic information has the potential to address limitations of traditional contact tracing, such as scalability, notification delays, recall errors, and contact identification in public spaces.
    - Bluetooth-Based Approaches: Most COVID-19 contact tracing application (apps) use Bluetooth signal strength to infer distance and define exposure status based on distance from and duration of proximity to an individual subsequently identified as infected.
    - Location-Based Approaches: These contact tracing approaches do not require Bluetooth. Instead, they use cell phone network data, Global Positioning System (GPS), Wi-Fi signals, and other smartphone sensors to identify the geolocations of users and proximity to infected individuals.[1]
        - A Briefing Note on Using Quick Response (QR) Codes for Contact Tracing is available on the Evidence Synthesis Network website.

Supporting Evidence

Table 1 below summarizes the scientific evidence and jurisdictional experiences regarding contact tracing approaches during the COVID-19 epidemic. In terms of information on jurisdictional experience, most of the information presented is based on case study findings on how Germany, Iceland, Israel, Singapore, South Korea, and Taiwan contained the COVID-19 epidemic through rigorous contact tracing.[b] Additional information on other jurisdictions was included if available.

Additional details about the case study findings from the six jurisdictions are provided in Table 2 (for a summary of the case studies, including testing and contact tracing criteria, processes, capacity, responsible parties, and timelines) and Figure 1 (for a summary of the features of contact tracing digital approaches) in the Appendix.

[b] The North American Observatory on Health Systems and Policies conducted six rapid jurisdictional case studies, including an environmental scan of the academic and grey literature and key informant interviews, to learn about contact tracing approaches. The six jurisdictions were selected based on the following criteria: 1) evidence of containment of COVID-19 spread which has been sustained until late April 2020 based on a declining incidence of new cases; 2) evidence of gradual easing of large-scale public health restrictions; 3) evidence of use of new technologies for case/contact management; and 4) evidence of sufficient availability of public and academic information, as well as ability to reach key informants for consultation (NAO, May 2020).

Table 1: Summary of Scientific Evidence and Jurisdictional Experiences on Contact Tracing Approaches for COVID-19

Scientific Evidence	• **Guidelines**: No relevant evidence-based guidelines for contact tracing for COVID-19 have been identified.[2]
	• **Effectiveness of Contact Tracing (in general)**:
	  ○ Response Times: A systematic review (preprint; July 25, 2020) reported that observational and modelling studies suggest contact tracing is associated with better control of COVID-19, depending on several factors (e.g., how many and how fast contacts are traced and quarantined). A cautious interpretation suggests that to stop the spread of COVID-19, two to three days from the time a new case develops symptoms are needed to isolate the case and quarantine at least 80% of its contacts. Once isolated, cases and contacts should infect zero new cases. Less efficient tracing may slow, but will not stop, the spread of COVID-19. Inefficient tracing (with delays of four or more days or less than 60% of contacts quarantined with no further transmission) may not contribute meaningfully to controlling COVID-19.[3]
	  ○ Duration: Two reviews (June 30 and October 2, 2020) suggested that when the number of new cases has been controlled, it is still necessary to maintain contact tracing for several months in combination with other measures (e.g., social distancing, mask wearing, public transportation control, work at home strategies, self-isolation).[4,5]
	• **Cost-Effectiveness of Contact Tracing (in general)**:
	  ○ A systematic review (preprint; June 11, 2020) reported that observational and modelling studies suggest swift contact tracing, in combination with other public health measures, may be cost-effective during COVID-19. For H1N1 influenza, contact tracing was estimated to be 4,363 times more cost-effective than school closures.[6]
	• **Digital Contact Tracing**:
	  ○ Types: A systematic review (August 10, 2020) identified 63 mobile apps being used for COVID-19: 25 from Google Play store and Apple App store in India, and 19 each from the United States (US) and United Kingdom (UK). Eighteen apps were developed for sharing up-to-date information, eight were for contact tracing, and nine showed features of both. On the Mobile Application Rating Scale (MARS), the overall scores ranged from 2.4 and 4.8 (out of five), with apps scoring high in areas of functionality and lower in engagement.[7,c]
	  ○ Effectiveness:
	  ▪ A systematic review (August 19, 2020) found no empirical evidence of the effectiveness of automated contact tracing regarding contacts identified or transmission reduction for COVID-19, severe acute respiratory syndrome, Middle East respiratory syndrome, influenza, or Ebola virus. Digital contact tracing may reduce transmission with sufficient population uptake; however, concerns regarding privacy, equity, effectiveness, and integration of manual and automated systems

[c] The MARS evaluation tool is divided into three broad sections: app overall quality, app subjective quality, and app specific quality. It consists of 23 questions that are designed to help analyze engagement, functionality, aesthetics, information, and subjective quality of the mobile applications. In addition, there are six final app specific questions that can be tailored to represent the target health behaviour/ function of the application/study. The mean score for each of the four subscales (Engagement, Functionality, Aesthetics, and Information) was calculated, and the mean score of those subsections was used to rate the total quality score of the app ranged from zero to five (Davalbhakta, Aug 2020).

	should be considered. Thus, large-scale manual contact tracing is still key in most contexts.[8] ▪ A Cochrane rapid review (August 18, 2020) concluded that digital contact tracing technologies are largely unproven in real-world outbreak settings. Thus, it is unlikely that digital technologies would be the sole method of contact tracing during an outbreak; they would likely be used alongside manual methods.[9] ○ Challenges: Research suggests that digital contact tracing approaches may: breach privacy; detect individuals who have not been exposed but who have had contact; or fail to detect individuals who are exposed if the app is deactivated, the mobile device is absent, or Wi-Fi or cellphone connectivity is inadequate.[10,11,12,13] Moreover, a review (October 2, 2020) noted that large segments of the private sector are individually developing workplace-, school-, and consumer-focused apps. This has resulted in a fragmented system of unconnected applications deploying different technologies, making it nearly impossible to achieve the level of adoption of 60% suggested to be required to make such technology successful.[14]
International Scan	• **Traditional Contact Tracing Approaches**: Germany, Iceland, Israel, Singapore, South Korea, and Taiwan primarily rely on traditional contact tracing approaches, in which contacts are identified through a thorough review of available data (e.g., telephone interviews with the infected individual, family, and/or physician; travel or police records; credit card transactions; closed-circuit television footage). In general, contact tracing teams within local public health units call infected individuals to communicate test results and/or inquire about any contacts that occurred in the days preceding symptom onset.[15] • **Digital Contact Tracing Approaches**: The most commonly used digital approaches involve smartphone apps using GPS (e.g., Israel, Iceland) or Bluetooth data (e.g., Singapore, Australia, United Kingdom, Germany),[d] as well as linked data and cloud-based technologies (e.g., South Korea, Taiwan).[16,17,18,19] Other digital approaches include: ○ Quick Response (QR) Codes[e] added to public venues to enable identification of contacts should an outbreak occur (e.g., Singapore, New Zealand).[20,21] For example: ▪ New Zealand's NZ COVID Tracer voluntary app creates a digital diary of the places users visit by users scanning QR code posters that contain information about the name and location of businesses.[22] It is meant to support manual contact tracing conducted by public health units and the National Close Contact Service.[23] ○ Germany launched a smartwatch app that collects pulse, temperature, and sleep pattern data to screen for signs of viral illness. Data are presented on an online, interactive map in which authorities can assess the likelihood of COVID-19 incidence across the country.[24] ○ Massachusetts Institute of Technology (MIT) Review's Covid Tracing Tracker is a database that captures details (e.g., mandatory vs. voluntary, number of users and

[d] Digital apps, installed on an individual's personal mobile device, can use the phone's location data and Bluetooth signals to determine: 1) whether the individual has come into contact with someone infected with SARS-CoV-2; and 2) which individuals the infected person has come into contact with and potentially exposed (NAO, May 2020).
[e] QR codes are barcodes that are readable by smartphones. A Briefing Note on Using Quick Response (QR) Codes for Contact Tracing is available on the Evidence Synthesis Network website.

penetration rate, centralized vs. decentralized, data destruction, type of technology) of automated contact tracing efforts backed by national governments around the world.[25,f]
    - A summary of available contact tracing solutions is presented here (as of November 2020).[26]
- **Maintaining Surveillance and Capacity**: Key factors that may have contributed to effective contact tracing include:
    - Mounting an Early Response: Many jurisdictions began implementing public health measures before the first imported case was detected (e.g., activating taskforces, initiating testing among symptomatic international travellers), which enabled them to coordinate multiple sectors of government for a proactive response.[27]
    - Human Resource Capacity: Although manual contact tracing is the preferred approach, it is very resource-intensive and may rapidly become overwhelmed. Human resource capacity for contact tracing in most jurisdictions was achieved through redeployment and training of employees and volunteers across governmental and non-governmental sectors (e.g., health care workers, medical students, armed forces, police).[28,29]
        - The number of contact tracers range from: five per 20,000 inhabitants in Germany (as of late April 2020), 52 contact tracers in Iceland (as of late March 2020), 200+ in New Zealand (as of May 29, 2020), 240 in San Francisco (as of late April 2020), more than 1,300 in Singapore (as of September 2020), and 1,800 teams, each with at least five members, in Wuhan, China (as of late February 2020).[30,31,32,33]
        - In Taiwan, central and regional governmental epidemiologists lead local health department teams in contact tracing. The first round of case investigation is usually completed within 10 hours, accomplished by teams working extended hours (as of July 2020).[34]
- **Effectiveness**: It may not be possible to directly attribute containment of the COVID-19 epidemic to any single public health measure. Nonetheless, Singapore, Iceland, Taiwan, and South Korea did not impose a national lockdown, which supports at least partial effectiveness of contact tracing approaches. For instance, Taiwan and Singapore have had success in containing the outbreak without a lockdown initially and over time. Moreover, Iceland presents compelling evidence supporting the effectiveness of rigorous contact tracing to limit further transmission, with high rates of accurate identification of imported versus community-linked COVID-19 cases and those in isolation or quarantine.[35,36]
    - Bluetooth, global positioning system, and cloud-based technologies may serve as useful tools for supporting contact tracing, particularly in densely populated areas where not all contacts may be known to the infected individual.[37]
        - However, due to privacy and usability concerns, digital contact tracing tools may best serve as supplementary measures to traditional contact tracing. This approach has been recommended by the World Health Organization.[38]
    - A research commentary noted that Germany, Singapore, and South Korea have successfully adopted and integrated digital contact tracing technologies, which may be associated with the early flattening of incidence curves and low mortality rates.[39]
- **Challenges**: Some jurisdictions are experiencing low uptake of digital contact tracing apps due to privacy, technology, and strategy limitations:

[f] The tool does not keep track of the underlying protocols that will feed into apps, early-stage initiatives to build new products, experimental apps that have no government backing or connection to public health services, or manual contact tracing efforts (MIT Technology Review, May 7, 2020).

	○ In South Korea, sharing outbreak data has created public discrimination and prevented people from getting tested.[40] ○ Israelis have started using cellphone holsters to block location tracking.[41] ○ France's centralized app has been limited by user uptake, as it continues to experience battery drain, collects more personal information than advertised, and is not interoperable with neighbours' decentralized apps.[42] ○ The US falls behind other countries that have used technology to augment traditional contact tracing strategies in the COVID-19 response as a result of privacy concerns and the absence of a coordinated national strategy (requiring states to develop their own approaches).[43] ○ In Singapore, population uptake of the TraceTogether app was not sufficient to replace manual contact tracing (less than one-fifth of the population had downloaded the app two months after its launch). Issues included privacy concerns, technical limitations, and necessity for a smartphone for participation.[44]
Canadian Scan	• The Public Health Agency of Canada developed guidance for federal/provincial/territorial public health authorities to support the management of cases and contacts of COVID-19 within their jurisdictions. It includes recommendations for frequency and type of follow-up stratified by exposure risk level (low, medium, or high).[45] ○ For example, British Columbia (May 15, 2020) and Nova Scotia (May 22, 2020) have issued interim guidance on case and contact management for COVID-19.[46,47] • Only one province was identified that has moved towards using a digital contact tracing approach. ○ Alberta's ABTraceTogether is a mobile contact tracing app using Bluetooth that can be voluntarily downloaded by users to let them know if they have been exposed to or have exposed others to COVID-19. It is a tool to complement traditional manual contact tracing completed by public health officials who work at Alberta Health Services (AHS). Personal data is only stored on the user's phone for 21 days in an encrypted format; it can only be shared with AHS contact tracers with the user's permission.[48] • The Canadian firm, BlueDot,[9] disseminates near-real-time insights on COVID-19 movements to clients, including governments, hospitals, and airlines, based on over 40 pathogen-specific datasets reflecting disease mobility and outbreak potential.[49] • According to a review (September 3, 2020), the Directorate of Force Health Protection within the Canadian Armed Forces will be developing training for allied health professionals to assist with contact tracing and follow-up, and will ensure adequate resources are in place to manage surge capacity for COVID-19.[50]
Ontario Scan	• On April 27, 2020, the Government of Ontario released its framework document for reopening the province, echoing the need to strengthen public health capacity for rigorous testing, timely contact tracing, and case management.[51] ○ One of the criteria being considered for determining when to ease public health measures and for ongoing monitoring of progress is that approximately 90% of new

[9] BlueDot specializes in automated infectious disease surveillance and uses machine learning and natural language processing techniques to sift through news reports in 65 languages, forum and blog posts, airline ticketing data, animal disease networks, and other sources to pick up indications and news of unusual, unfolding events and possible disease outbreaks. The firm employs trained epidemiologists to further analyze outbreak results obtained by automated means before releasing them to its clients (BlueDot; June 1, 2020).

	COVID-19 contacts are being reached by local public health officials within one day, with guidance and direction to contain community spread.[52] • Public Health Ontario, in collaboration with the Ministry of Health and the federal government, is leading the COVID-19 Contact Tracing Initiative. To date, contact tracing is led by Ontario's public health units, but additional capacity is required because of the rising number of cases and contacts to manage.[53]

Methods

The COVID-19 Evidence Synthesis Network is comprised of groups specializing in evidence synthesis and knowledge translation. The group has committed to provide their expertise to provide high-quality, relevant, and timely synthesized research evidence about COVID-19 to inform decision makers as the pandemic continues. The following members of the Network provided evidence synthesis products that were used to develop this Evidence Synthesis Briefing Note:

- Bhatia, D., Morales-Vazquez, M., Song, K., Roerig, M., Allin, S., & Marchildon, G. (May 2020). COVID-19 Case and Contact Tracing: Policy Learning from International Comparisons. Toronto: North American Observatory on Health Systems and Policies. *Rapid Review* (No. 30).
- Dulong, C., & Severn, M. (May 1, 2020). Contact Tracing for Potential Exposure to SARS-CoV-2 Virus: Guidelines. The Canadian Agency for Drugs and Technologies in Health.
- Ontario Health (Cancer Care Ontario). (May 18, 2020). Personal Communication to Research, Analysis and Evaluation Branch.
- Ontario Health (Quality). (May 18, 2020). Personal Communication to Research, Analysis and Evaluation Branch.
- Unity Health – St. Michael's Hospital. (May 18, 2020). Personal Communication to Research, Analysis and Evaluation Branch.

For more information, please contact the Research, Analysis and Evaluation Branch (Ministry of Health).

APPENDIX

Table 2: Summary of the Case Studies on Six Jurisdictions regarding Testing, Case Management, and Contact Tracing[54]

Germany	
Date of first case	January 28, 2020
Total cases / deaths (May 2020)	168,551 cases / 7,369 deaths (total population of over 83 million)
Party responsible for testing and contact tracing	Robert Koch Institute (RKI) oversight, including guidelines and recommendations; contact tracing implemented through 375 local public health units.
Testing criteria	Laboratory testing is recommended for individuals with: • Acute respiratory tract infection and history of close contact with a confirmed or probable case in 14 days prior to symptom onset. • Clinical or radiologic characteristics of viral pneumonia in the context of increased number of pneumonias in care facilities or hospitals. • Clinical or radiologic characteristics of viral pneumonia with no indication of any other cause, and no contact with a confirmed case. • Acute respiratory tract infection and (a) history of medical related activities, (b) a pre-existing medical condition, or (c) no known risk factors. German residents are encouraged to immediately, irrespective of symptoms, contact their health office, get in touch with a doctor or call the non-emergency medical service, and stay at home if they have contact with a person with confirmed SARS-CoV-2 infection. The operator from the non-emergency medical service decides whether testing is warranted and discusses the next steps.
Testing capacity	• End of April: 141,815 tests per day or 860,494 tests per week. • May 13: 157,150 tests per day or 1,038,223 tests per week. • PCR test processing: 134 laboratories of university hospitals, research institutions, and clinical and outpatient settings were equipped for processing samples on May 13. • Testing capacity has both been increasing with the regard to the number of laboratories equipped to process the tests and the number of tests processed per laboratory. • Total of 3,147,771 tests have been performed in Germany by May 13.
Contact definition	There are three categories of contact with specific follow-up instructions for each. Broadly, close contacts are defined as: • Speaking to the confirmed case for at least 15 minutes; or • Being coughed or sneezed on at a time when the confirmed case was infectious (i.e., 2 days before symptom onset).
Contact tracing and case management process	1. Local public health unit registers positive SARS-CoV-2 test result. 2. Contact tracing team situated within the public health unit calls the infected individual to communicate test results and inquire about any contacts that occurred in the 2 days preceding symptom onset. 3. Due to strict privacy laws, the use of digital tools to support contact tracing is not widespread; SORMAS app is used by public health units to contact exposed individuals in Berlin; Corona App (Bluetooth exposure notification app) is in development. 4. Contacts are called by contact tracers and informed of exposure. Contacts are classified into 3 categories, depending on the nature of exposure. Recommendations vary depending on contact category, but generally, they are advised to isolate for 14 days. 5. Contacts' symptoms are monitored through regular calls from contact tracers; if symptoms develop or worsen, individuals are advised to call a health office or a non-emergency medical service hotline to determine whether a test may be warranted. 6. If individuals are unable to leave the house, public health units or outreach teams of ambulatory physicians may dispatch a healthcare worker to perform the diagnostic test at the individual's home.

	7. Some cities use "corona taxis", in which healthcare providers and medical students visit confirmed cases in their homes to monitor their symptoms, perform a medical exam, and escalate management if necessary (i.e., transfer the patient to the hospital). 8. Voluntary smartwatch app "Corona Data Donation", released in early April, allows cases to record their symptoms alongside other biometrics; when aggregated at zip code level, these data may help identify "hotspots" (see Appendices C and D for detail).
Contact tracing capacity	• Germany's goal is to have a team of 5 contact tracers per 20,000 inhabitants (amounting to 21,000 individuals nationally). • To meet this capacity goal, medical students, healthcare workers, and public employees from other areas of the bureaucracy have been redeployed into contact tracing teams, with additional assistance from the armed forces in the most affected areas.
Effectiveness of contact tracing	• Germany's viral basic reproduction factor (R0) was estimated to be at 0.76 on May 5. • This change may not be attributed to testing and contact tracing alone, as Germany implemented border closures and large-scale restrictions throughout early to mid March.
Iceland	
Date of first case	February 28, 2020
Total cases / deaths (May 2020)	1,801 cases / 10 deaths (total population of over 360,000)
Party responsible for testing and contact tracing	Department of Civil Protection and Emergency Management (National Commissioner of Icelandic Police) in collaboration with Directorate of Health and Chief Epidemiologist, mandated by the Minister of Health.
Testing criteria	• Those presenting with symptoms (any severity) should contact their primary care clinic or call a designated helpline to determine whether a test is warranted, based on physician judgment. • Healthcare workers and persons whose medical history may put them at risk of experiencing more severe symptoms are prioritized for testing.
Testing capacity	• Outbreak peak (March-April): 1,000 tests per day. • Current: 500 tests per day. • Tests done outside primary care clinics on a drive-through basis. • Total of 51,663 tests completed (141,931 tests per million individuals). • PCR test processing: 1 central lab (National University Hospital in Reykjavík, NUHI). • Test results turnaround time: 24 hours.
Contact definition	Individuals that, within the 14 days preceding diagnosis, have been within 1-2 meters of: • A symptomatic person. • A confirmed case.
Contact tracing and case management process	1. Contact tracing team within Civil Protection Department receives test results from NUHI. 2. Contact tracers call the infected individual to administer a questionnaire re: 14-day history before symptoms onset (dates, locations, individuals contacted). 3. For unknown contacts, use: police records, travel records, open source info (e.g., social media), employer of the patient (if relevant/available). 4. Voluntary app "Ranking C-19", released in early April, tracks the user's 14-day GPS history; upon COVID-19 diagnosis, user may submit these data to the contact tracing team to supplement efforts to identify unknown contacts (see Appendices C and D for detail). 5. Contacts are instructed to quarantine for 14 days immediately. 6. Time to trace all contacts: 8 hours (March); 2 hours (May). 7. Contacts' symptoms monitored with regular calls from the contact tracers; if symptoms develop, individuals advised to call primary care clinic or helpline to determine if test is warranted. 8. If diagnosed, individuals isolate primarily at home. Those unable to isolate safely at home may book a hotel room. Hotels also available for foreign workers and houseless individuals.
Contact tracing capacity	• Early March: team of 6 individuals (detectives, criminologists, healthcare workers) • Current (May): 52 individuals (civil servants, healthcare workers, students)
Effectiveness of contact tracing	• May 6: each of 1,799 cases confirmed up to that point identified as either imported or community-linked. • May 12: 19,694 individuals have completed a 14-day quarantine, 564 were in quarantine, 18 were in isolation, and 1 was hospitalized (no ICU).

	• 57% of individuals eventually diagnosed with COVID-19 were already undergoing quarantine at the time of diagnosis.
Israel	
Date of first case	February 21, 2020
Total cases / deaths (May 2020)	16,444 cases / 245 deaths (total population of over 9 million)
Party responsible for testing and contact tracing	• Testing: centralized through Magen David Adom (MDA), national EMS service (February); de-centralized through four national HMOs (current). • Contact tracing: district-level Health Bureaus of the Ministry of Health (7 districts).
Testing criteria	Eligibility for testing is decided by physicians. Symptomatic individuals may be eligible if they: • Had close contact with a confirmed case in the past 14 days. • Were in the same location as a confirmed case in the past 14 days. • Have travelled to Israel from abroad in the past 14 days. • Have a severe health condition. Mass testing in special groups: • Healthcare workers in some hospitals. • Elderly individuals in long-term care (LTC). • Marginalized groups (asylum seekers, foreign workers, houseless individuals, ultra-orthodox communities, Arab communities) in urban centers as recruited by NGOs, e.g., Physicians for Human Rights, Levinsky clinic (clinic for STIs).
Testing capacity	• Outbreak peak (April): 10,000 tests per day. • Current: 8,000 tests per day. • Tests done at home, HMO clinics, 4 stationary units (metropolitan areas), 8 drive-through facilities (for non-quarantined individuals). • MDA is staffed with 2,500 salaried workers and 24,000 volunteers. • Total of 245,460 individuals tested, with 96,065 in drive-through facilities, 88,272 in their homes, and 61,123 in LTC. • PCR test processing: 1 lab (National Virology Laboratory at Sheba Medical Center) in early March; 17 labs in late March; further increased since HMO involvement in testing. • Processing capacity increased through repurposing of existing research and hospital labs and recruiting and training lab technicians.
Contact definition	• Contact with individual with diagnosed COVID-19 within 2 meters of distance for at least 15 minutes.
Contact tracing and case management process	1. Ministry of Health has a record of all individuals that have a COVID-19 diagnosis. 2. Contact tracing teams in district-level Health Bureaus of the Ministry of Health call the infected individual to administer a questionnaire re: 14-day history (dates, locations, individuals contacted). 3. De-identified listing and map of all locations that infected individuals have visited in the past 14 days, with times, are posted publicly on the Ministry of Health website. 4. As contact tracing capacity became strained with increasing number of cases, Shin Bet secret services' cellphone tracking apparatus was involved in March to notify individuals of exposure (see Appendices C and D for detail). 5. Voluntary app "HaMagen", released in late March, cross-references the user's 14-day GPS history with the location history of confirmed cases and notifies users of possible exposure (see Appendices C and D for detail). 6. Contacts (identified by contact tracers or self-identified) are instructed to quarantine for 14 days immediately and to submit an online report to the Ministry of Health. 7. If contacts develop symptoms, they are advised to call their HMO clinic, their HMO hotline, the Ministry of Health hotline, or the MDA emergency hotline. 8. MDA emergency hotline operator screens the caller for epidemiological or clinical criteria consistent with COVID-19; if criteria are met, individual transferred to MDA's COVID-19 hotline, manned by EMS dispatchers and Ministry of Health staff. 9. Contacts' symptoms monitored with regular calls; a paramedic may be dispatched to the individual's home to administer a test, if deemed warranted by a physician. 10. Mid-March: all diagnosed cases isolated in hospitals, regardless of symptom severity.

	11. Current: mild cases isolate at home or in "Corona hotels" rented by the Ministry of Health. Those in LTC quarantine in designated LTC units while awaiting test results. All severe cases or those with concurrent medical issues are taken to hospitals.
Contact tracing capacity	In emergency times, Health Bureaus can recruit nurses from district-level mother and child centers to aid contact tracing.
Effectiveness of contact tracing	• Late April to early May: daily number of new cases consistently fell below 100 and number of those recovered has surpassed the number of those actively ill. • May 6: Infection rate in Jerusalem, which experienced the highest burden of COVID-19, dropped from a mid-April high of 23 cases per 10,000 people to 15 per 10,000. • These changes may not be attributed to testing and contact tracing alone, as Israel implemented border closures and large-scale restrictions throughout early to mid March.
Singapore	
Date of first case	January 23, 2020
Total cases / deaths (May 2020)	21,707 cases / 20 deaths (total population of over 5.6 million).
Party responsible for testing and contact tracing	• Ministry of Health responsible for testing and contact tracing, in close collaboration with hospitals, Certis security (private auxiliary police force), Singapore Police Force, and Singapore Civil Defense Force. • Multi-Ministry Taskforce created to manage COVID-19 oversees these processes.

Testing criteria	The following individuals are prioritized for testing:
	• Those diagnosed with pneumonia;
	• Those with symptoms of acute respiratory infection and/or:
	  ○ History of close contact with a confirmed COVID-19 case; and/or
	  ○ Recent travel history.
	All individuals experiencing respiratory symptoms of any severity are advised to visit a primary care physician for close monitoring; if symptoms do not resolve after 5 days, individuals may be referred for further investigation and possible testing. Singapore's 900 Public Health Preparedness Clinics (PHPC) are the first point of contact for symptomatic persons. PHPCs are regular primary care practices whose clinicians and staff are trained in emergency outbreak protocols; this function of the clinics is activated during public health emergencies.
	
	Mass testing in special groups:
	• All 30,000 adult residential care home staff and residents (housing the elderly, houseless individuals, and those with disabilities).
	• Residents of foreign worker dormitories. As of late April, 21,000 individuals have been tested (3,000 individuals per day or 6,500 individuals per 100,000).

Testing capacity	• Early April: 2,900 tests per day. • Current (late April to early May): 8,000 tests per day. • By June/July, test rate expected to increase to 40,000 tests per day. • Total of 2,100 per 100,000 persons tested. • Tests done in acute care hospitals and the National Centre for Infectious Diseases (NCID). • PCR processing: tests processed in laboratories within public hospitals and the National Public Health Laboratory in NCID. The Multi-Ministry Taskforce scaled up processing capacity by repurposing private and research laboratories. • While awaiting test results, individuals are advised to self-isolate in their homes. • Those unable to safely isolate at home are directed to Swab Isolation Facilities (repurposed hotels with 4,000 bed capacity). • Those with severe symptoms or concurrent health conditions are isolated at hospitals.
Contact definition	Contact with individual with diagnosed COVID-19 within 2 meters of distance for 30 minutes or more.
Contact tracing and case management process	1. Contact tracing starts at the hospital; healthcare worker interviews the patient with COVID-19 about their history up to 14 days before symptoms (locations, dates, times, individuals contacted). 2. An "activity map" is produced and submitted by the hospital to the Ministry of Health. 3. Contact tracing team at the Ministry of Health verifies the map by calling the patient and their family/ friends, and reviewing transport records; full activity map is charted within 24 hours of diagnosis.

	4. For unknown contacts, contact tracers review the activity maps of other confirmed cases and flag linkages as "hypotheses". 5. Hypotheses are then "proven" or "disproven" through phone interviews with the other cases and field investigations (e.g., street surveys, review of CCTV footage), which may involve engagement of the Police Force. 6. Voluntary app, "TraceTogether", released late March, records anonymized identifiers of nearby phones over 21 days via Bluetooth; upon diagnosis, user may submit these data to the contact tracing team to supplement efforts to identify unknown contacts (see Appendices C and D for detail). 7. SafeEntry QR code check-in/check-out system added to public venues in early May to enable identification of contacts in case of an outbreak (see Appendices C and D for detail). 8. Identified contacts are called and screened for symptoms. Those who are asymptomatic are advised to quarantine for 14 days (from the time of exposure). 9. Symptoms and quarantine adherence are monitored via regular calls from Ministry of Health official 10. Contacts with symptoms are treated as "suspect cases" and may be transported to hospital for testing. 11. Time to trace all contacts: 48 hours after patient diagnosis. 12. Depending on symptom severity and medical history, cases and contacts may quarantine/isolate at home or at government facilities. Only the most severe cases are admitted to hospitals.
Contact tracing capacity	• Ministry of Health epidemiologists and communicable disease experts train and supervise contact tracing teams, composed of redeployed personnel (e.g., medical residents, volunteers from other departments, Civil Defense officers). • February: 5 teams of 10 contact tracers (500 individuals). • Late March: 7 teams of 10 contact tracers (700 individuals). • There are 3 contact tracing teams on duty during any single shift, and 2 contact tracing shifts per day. • April 21: To facilitate rapid triaging, case finding, and contact tracing within foreign worker dormitories, on Taskforce has deployed Forward Assurance and Support Teams (FAST Teams). • Hotels, university hostels, and convention centers converted to quarantine facilities (500-10,000 bed capacity); by end of June, capacity expected increase to 20,000 beds. • Over 200 Certis security services officers deployed to quarantine facilities to assist with check in and check out processes and monitor adherence.
Effectiveness of contact tracing	• Contact tracing was the primary method of containment in Singapore until early April, when the number of cases began increasing due to outbreaks in foreign worker dormitories, at which point a large-scale "circuit breaker" restrictions were imposed. • May 2: average number of new cases was 12 per day.
South Korea	
Date of first case	January 20, 2020
Total cases / deaths (May 2020)	10,936 cases / 258 deaths (total population of over 51.6 million)
Party responsible for testing and contact tracing	Korean Centers for Disease Control (KCDC) and Prevention within the Ministry of Health and Welfare.
Testing criteria	Patients classified as suspected cases and Patients Under Investigation (PUI) may get testing: • Suspected cases are those at high-risk of having been in close contact with a confirmed patient, who developed symptoms within 14 days of contact. • PUIs include those suspected to be a case due to (I) pneumonia of unknown causes, (ii) a fever or respiratory symptoms that occurred within 14 days of traveling to a country with local COVID-19 transmission, or (iii) an epidemiological link to the collective outbreak of COVID-19 in Korea and presence of symptoms.
Testing capacity	• February: 3,000 tests per day. • March: 18,000 tests per day. • Capacity increase attributed to the increase in diagnostic reagent companies approved by the government under emergency use authorization (5 companies approved); under the authorization, tests were distributed not only to the 18 public health labs, but also private labs (which previously needed a lengthy authorization process). By late January, nearly 200 laboratories, 600 testing centers, and numerous private clinics had access to the government-approved test kits.

	• May: Total of 680,890 tests completed, 569 active testing centers across all 9 provinces and 55 drive-through testing facilities in 7 out of 9 provinces.
Contact definition	Close contact with a confirmed case, who developed symptoms within 14 days of contact.
Contact tracing and case management process	1. In cases of widespread transmission, local (rather than central) epidemiological investigation teams perform contact tracing. 2. Investigation phase: obtain information through patient, family, and physician interview to identify transmission route. 3. Risk assessment: the collected information is verified and supplemented by other sources (medical records, cellular GPS data, credit card transactions, CCTV footage). 4. Contacts are classified by risk status (close vs. casual contact). 5. Contacts are then reached by the epidemiological team, informed of their exposure, and counseled regarding next steps (self-quarantine and symptom monitoring). 6. Through collaboration with the Ministry of Land, Infrastructure and Transport, National Police Agency, Credit Finance Association of Korea, 3 telecommunication and 22 credit card companies, the Korean Centre for Disease Control and Prevention developed a COVID-19 data platform; this system draws on real-time GPS, mobile, and credit card transaction information to perform a spatio-temporal analysis. This automated "big data" approach allows to rapidly verify patient reporting and identify infection clusters. 7. This approach reduced the 24-hour manual contact analysis to a 10-minute automated one.
Contact tracing capacity	Not discussed.
Effectiveness of contact tracing	The number of new cases in South Korea stayed primarily in the single digits between mid-April and early May. Given its proximity to high-incidence settings and a lack of a widespread lockdown, the decrease in cases can likely be attributed to the country's effective testing and contact tracing practices.
Taiwan	
Date of first case	January 21, 2020
Total cases / deaths (May 2020)	440 cases / 6 deaths (total population of nearly 24 million)
Party responsible for testing and contact tracing	Taiwan Centers for Disease Control (CDC) in coordination with the National Health Command Center.
Testing criteria	All suspected cases are tested, defined as individuals who were in close contact with a symptomatic confirmed case within 14 days prior to symptom onset, and who present one or more of the following: • Fever (≥ 38) or symptoms of acute respiratory tract infection. • Abnormal sense of smell or taste, or diarrhea of unknown etiology. • Community-acquired pneumonia highly suspected to be COVID-19 by doctors. High-risk groups identified for increased surveillance: • Elderly • Individuals with comorbidities. The first point of contact and triage centre for mild symptomatic cases is the network of Community Healthcare Groups Prepared Clinics (CHGPC). These clinics do not perform testing, but determine whether testing is warranted.
Testing capacity	• April 7: CDC announced establishment of a national testing network of 34 laboratories to expand testing capacity and reduce waiting times for test results. • This resulted in a testing rate of 3,800 tests per day in different settings across Taiwan.
Contact definition	• Individual that had close (less than 2 meters) face-to-face contact for more than 15 minutes with a confirmed COVID-19 case before they received a diagnosis. • In healthcare settings, contacts are medical staff, hospital workers, or other patients that had close contact (less than 2 meters) with a confirmed case for a longer duration than required, without protective equipment.
Contact tracing and case management process	1. The National Health Insurance (NHI) database was a key method of contact tracing in Taiwan. The database contains complete health history, underlying health conditions, recent progression of symptoms, treatments, and hospitalization related to respiratory syndrome.

	2. The NHI Cloud was enriched with patients' 14-day travel history using the Customs and Immigration data of the National Immigration Agency. All hospitals, clinics, and pharmacies in Taiwan have access to patients' travel histories. 3. The NHI-based centralized Taiwan Health Cloud program generates automatic surveillance reports for infectious diseases using hospital electronic medical records.
Contact tracing capacity	Not discussed.
Effectiveness of contact tracing	• Despite its proximity to high-incidence settings and a lack of a national lockdown, Taiwan achieved the lowest incidence of COVID-19 cases per capita globally by late March. • May 1: Taiwan achieved a rate of zero new cases in six consecutive days.

Figure 1: Summary of the Features of Contact Tracing Digital Approaches across Six Jurisdictions[55]

Jurisdiction	Name	Launch date	Device	Tech	Data collected	Data access	Data period	Data storage	Developer	Open source protocol	Mandatory/voluntary	Uptake	Action
Germany	Corona app	June 2020 (expected)	Smartphone (iOS + Android)	Bluetooth, Google/ Apple	Time-linked temporary anon'd IDs of nearby phones, self-reported dx	User only	Unclear	Local (on device)	HA + private partner	Yes (DP-3T)	Voluntary installation for user	NA (need 50% pop'n)	In-app exposure alert
Germany	Corona Data Donation app	April 7, 2020	Fitness wristbands/ smartwatches(iOS + Android)	App algorithms	User-assigned pseudonym, app recognized COVID-19 related symptoms, postcode	User + HA	10 years (can be deleted by the user)	HA server + Local (on device)	HA + private partner	Unclear	Voluntary installation for user	8% of pop'n	No user alert, data transferred constantly, with consent
Germany	SORMAS	April 20, 2020	Smartphone (iOS + Android)	Software	Dx, symptoms hx of patients in clinics	HA + other partners	Unclear	HA server	HA + other partners	Yes	Voluntarily for clinics	One district in Berlin	No user alert, identification of cases and contacts
Iceland	Rakning C-19	April 2, 2020	Smartphone (iOS + Android)	GPS	User phone number, device location hx	User + HA with consent, if user dx	14 days (destroyed on rolling basis)	HA server: user phone number Local (on device): device location hx	HA + private partner	No	Voluntary installation for user	38% of pop'n	No user alert, data transferred if dx, with consent
Israel	Shin Bet cellphone tracking	March 15, 2020	Cellphone	Unclear	Device location, credit card records	User + HA	14 days (unclear if destroyed)	HA	Shin Bet security service	No	Mandatory for user, no installation	Unclear	SMS exposure alert, self-quarantine, self-report to HA
Israel	HaMagen	March 22, 2020	Smartphone (iOS + Android)	GPS	Device location hx	User only	14 days (destroyed on rolling basis)	Local (on device)	HA + private partner	Yes	Voluntary installation for user	17% of pop'n	In-app exposure alert, self-quarantine, self-report to HA
Singapore	TraceTogether	March 20, 2020	Smartphone (iOS + Android)	Bluetooth	User phone number, time-linked temporary anon'd IDs of nearby phones	User + HA with consent, if user dx	21 days (destroyed on rolling basis)	HA server: user phone number	HA + GovTech	Yes (BlueTrace)	Voluntary installation for user	13% of pop'n	No user alert, data transferred if dx, with consent

								Local (on device): anon'd IDs					
Singapore	SafeEntry	May 9-12, 2020	Smartphone or gov't ID card with barcode	QR code or gov't ID card with barcode	User name, NRIC/FIN, user phone number	HA	Unclear	HA	HA + GovTech	Unclear	Mandatory for venues, no user installation	16,000 venues (rollout ongoing)	No user alert
South Korea	Self-health check app	February 12, 2020	Smartphones (iOS + Android)		Self-report symptoms	User + public health authorities	14 days				Mandatory		
South Korea	Self-quarantine safety protection	March 20, 2020	Smartphones (iOS + Android)	GPS	Citizen location information, credit card data	User + public health authorities	14 days		Ministry of the Interior and Safety		Mandatory for in-bound travellers (incl. Korean nationals) and voluntary for Korean residents	91.4% of quarantined individuals	
Taiwan	Big Data	January 27, 2020	NA	Health Cloud	Dx, symptoms hx, travel history, full health records	HA + health settings + pharmacies	Unclear	National centralized health cloud/server	HA	Unclear	Mandatory	100% pop'n	Flag health records or high-risk patients
Taiwan	Entry Quarantine System	February 14, 2020	Smartphones (iOS + Android)	Online survey and SMS	Passport number, name, nationality, flight number, symptoms hx, phone number, landline, and address of quarantine location	HA	Unclear	HA	HA	Unclear	Mandatory	All incoming travelers	No user alert, data transferred to the Health Cloud
Taiwan	Electronic security monitoring system	February 14, 2020	Smartphones (iOS + Android)	GPS	Individual location information	HA + National Police Agency	Unclear	HA server	HA	Unclear	Mandatory	All individualism quarantine or self-isolation	Alert user and police authorities if quarantine is interrupted
Taiwan	Police cloud	February 14, 2020	NA	Police cloud	Information for criminal investigation (individual hx, places, photos, videos, vehicles)	National Police Agency (NPA)	Unclear	NPA cloud (M-cloud)	Unclear	Unclear	Mandatory	All individualism quarantine or self-isolation	No user alert, complements electronic security monitoring system

List of abbreviations: HA (Health Authority); GPS (global positioning system); NA (not applicable); dx (COVID-19 diagnosis); hx (history)

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