Kitchener Court File No.: CV-21-00000095-0000
St. Thomas Court File No.: CV-21-08
Welland Court File No.: CV-21-00013361-0000

ONTARIO
SUPERIOR COURT OF JUSTICE

B E T W E E N:

THE ATTORNEY GENERAL OF ONTARIO

Applicant

-and-

TRINITY BIBLE CHAPEL, JACOB REAUME, WILL SCHUURMAN, DEAN WANDERS, RANDY FREY, HARVEY FREY, and DANIEL GORDON

Respondents

A N D B E T W E E N:

HER MAJESTY THE QUEEN IN ONTARIO

Applicant

-and-

THE CHURCH OF GOD (RESTORATION) AYLMER, HENRY HILDEBRANDT, ABRAM BERGEN, JACOB HIEBERT, PETER HILDEBRANDT, SUSAN MUTCH, ELVIRA TOVSTIGA, and TRUDY WIEBE

Respondents

A N D B E T W E E N:

WELLANDPORT UNITED REFORMED CHURCH

Applicant

-and-

HER MAJESTY THE QUEEN AS REPRESENTED BY THE ATTORNEY GENERAL OF ONTARIO

Respondent

A N D B E T W E E N:

STEPHEN RICHARDSON

Applicant

-and-

THE ATTORNEY GENERAL OF ONTARIO

Respondent

AFFIDAVIT OF MATTHEW HODGE
(Affirmed July 2, 2021)

I, MATTHEW HODGE, of the City of [redacted] in the Province of Ontario, **AFFIRM**:

I. BACKGROUND

1. I am a licensed medical practitioner who practices Public Health & Preventive Medicine ("**PHPM**") and Emergency Medicine in Ontario.[1] I joined Public Health Ontario ("**PHO**") in October 2020 and was the co-lead for Epidemiology & Surveillance activities within the Incident Management System ("**IMS**") structure of the Health Protection division of PHO from November, 2020 until April 9, 2021. The global COVID-19 pandemic (the "**Pandemic**") constitutes a public health emergency, so many organizations, including PHO, have established IMS structures to redeploy staff and prioritize activities. In my role within IMS, I was responsible for strategic input and work on data management, analyses and reporting. Currently, I work as a consultant with PHO. Throughout the pandemic, I have continued practicing emergency medicine at the Scarborough General site of the Scarborough Health Network. My work there includes caring for patients with COVID-19 infections over the past sixteen months.

2. I graduated with an MD (1996) and PhD (Epidemiology & Biostatistics, 1995) from McGill University and completed PHPM specialty training at the University of Toronto in 2000. Over the past twenty-one years, my practice has included multiple roles in public health, including Associate Medical Officer of Health, City of Hamilton (2005-2007), United Nations agencies (WHO: 1999-2001, UNICEF: 2001-2002, UNFPA: 2008-2010), Cancer Care Ontario (2010-2011), two positions with the Ontario Ministry of Health and Long-Term Care (2003-2004, 2015-2016), and a wide range of consulting work. I also completed Harvard's Masters in Health Care

[1] Public health and preventative medicine is a population or society focused discipline. This can be contrasted with infectious disease medicine which is focused on individual patients.

Management in 2011. I am also a peer reviewer for the Canadian Medical Association Journal and occasionally for the Canadian Journal of Public Health.

3. Following the province's declaration of an emergency in response to the Pandemic on March 17, 2020, I worked for six months assisting Peel Public Health's Pandemic response. My work there included guiding the implementation of the provincial Case & Contact Management system.

4. My *curriculum vitae* is attached to this affidavit as **Exhibit "A"**.

5. I have been asked to provide an expert opinion answering the questions relevant to this court proceeding that are set out below. My signed Acknowledgment of Expert's Duty is attached to this Affidavit as **Exhibit "B"**. Where I have relied on a document or data in forming my opinion, I have set out the citation to that document or data in the footnotes. Where I have relied on information provided to me by others, I have stated the source of that information and I believe it to be true.

II. OVERVIEW

6. I have been asked to answer the following questions in this expert affidavit:

   a. What are the harms caused by COVID-19 disease?

   b. How is COVID-19 disease transmitted?

   c. What are the risk factors for transmission?

   d. Why are measures to limit COVID-19 transmission needed in Ontario?

   e. Why do limits on religious gatherings contribute to reducing COVID-19 transmission and harms from COVID-19?

   f. Can the risk of transmission at indoor religious gatherings be adequately addressed by rules requiring physical distancing and face coverings or other personal protective equipment?

g. Do you agree or disagree with the affidavits of Dr. Warren dated April 6, 2021, Dr. Schabas and Dr. Kettner?

7. My answers are detailed below. I make three preliminary observations. First, my opinions are informed by the realities of public health practice in Ontario, including the need to prepare advice and make decisions with imperfect information, and the challenge of minimizing adverse effects of measures that establish limits on human behaviour. Ontario's Health Plan for an Influenza Pandemic, ("OHPIP"), cited by experts retained by the Applicant, explicitly recognizes this reality of incomplete information, noting that 'the OHPIP severity model includes an initial stage before severity is known when the limited availability of surveillance data does not allow for confident identification of severity. The severity may not be clearly known until after an influenza pandemic is over'.[2] For COVID-19, the rise of variants with increased transmissibility and, for some variants, increased severity of illness, adds additional uncertainty.

8. Second, public health measures in Ontario must take into account the precautionary principle. The OHPIP states 'The MOHLTC does not await scientific certainty before taking action to protect health'.[3] The application of the precautionary principle is particularly relevant during the early stages of a pandemic when scientific evidence on the severity of a novel virus is limited or, for COVID-19, as new variants are identified whose transmissibility and severity are incompletely understood at the time that government must make decisions to protect Ontarians from infection, illness and death.[4]

9. Third, my opinions are informed by the burden model, which recognizes that it is generally appropriate to implement more restrictive public health measures when an infectious disease

[2] See **Exhibit "C":** Ontario, Ministry of Health and Long-Term Care, Emergency Management Branch, *Ontario's Health Plan for an Influenza Pandemic* (March 2013) at p. 14, online: https://www.health.gov.on.ca/en/pro/programs/emb/pan_flu/docs/ch_01.pdf. See also pp. 10-13.
[3] See **Exhibit "C"**, *supra* note 2 at p. 11.
[4] For an example in the context of influenza, see **Exhibit "C"**, *supra* note 2 at p. 11.

imposes a higher burden. This notion of burden can be understood as a function of the prevalence of the disease (i.e. number of cases in a population), the exposure risk (i.e. the probability that one infected person will infect others), and the consequences of infection, such as hospitalization and death.

10. When Ontario enacted more stringent public health measures during each of the three waves of the pandemic to date, there was increasing community prevalence of COVID-19, growing numbers of new cases, and concerns about hospital and ICU occupancy. Accordingly, in my opinion it was a reasonable public health measure to restrict religious gatherings temporarily while community spread of COVID-19 posed this potential (wave 1) or real (waves 2 & 3) burden on Ontario's health care system. Furthermore, the emergence of variants of concern ("VOC"), with initial uncertainty about their transmissibility and severity, borne out by evidence of higher transmissibility (alpha & delta variants) and more severe illness (alpha variant) mandated a more stringent public health response. The pace of easing temporary limits on indoor religious gatherings is one of a suite of measures designed to keep Ontario from entering a fourth wave of the pandemic.

III. WHAT ARE THE HARMS CAUSED BY COVID-19?

11. COVID-19 illness is caused by a coronavirus that infects the respiratory system. Infection causes symptoms of upper respiratory tract infection including cough, fever and sore throat. COVID-19 infection also appears to cause a characteristic loss of taste and smell for many infected people. Based on Ontario's COVID-19 experience, 5% of people with COVID-19 will require hospital-based care, typically for oxygen at a minimum and often, ICU-level care. Complications leading to ICU admission or death may include respiratory failure, acute respiratory distress syndrome, sepsis and septic shock, thromboembolism, and/or multiorgan failure, including injury

of the heart, liver or kidneys.[5] As of June 24, 2021 in Ontario, 543,571 people have been diagnosed with COVID-19, and 9,101 (approximately 1.7%) have died.[6] The number of cumulative cases of COVID-19 in Ontario is likely higher than the number of recorded cases since some individuals who acquire COVID-19 are not tested and diagnosed. This was particularly the case during the early months of the COVID-19 pandemic.

12. The number of reported COVID-19 infections, hospitalizations, and deaths as of June 24, 2021 (Ontario), June 29, 2021 (Canada), or June 30, 2021 (global) are set out in the table below:

TABLE 1: Cases, hospitalizations, and deaths

	Cases	Hospitalizations	Deaths
Ontario[7]	543,571	27,643	9,101
Canada[8]	1,414,736	74,044	26,273
Global[9]	181,521,067	Unavailable	3,937,437

13. COVID variants are expected to arise due to high rates of viral transmission globally. Over the sixteen months of the pandemic, Ontario's context has evolved with increases in the prevalence of VOCs. As an example of the impact of VOCs in Ontario, the B117 variant (recently designated as the alpha variant) was reported to be more transmissible and cause more severe illness, contributing to an increased percentage of people with COVID-19 who need hospitalization and

[5] See **Exhibit "D":** World Health Organization, "Coronavirus disease (COVID-19)" (October 12, 2020), online: <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/question-and-answers-hub/q-a-detail/coronavirus-disease-covid-19>.
[6] See **Exhibit "E":** Public Health Ontario, "Ontario COVID-19 Data Tool", online: <https://www.publichealthontario.ca/en/data-and-analysis/infectious-disease/covid-19-data-surveillance/covid-19-data-tool?tab=summary> (accessed 24 June 2021).
[7] See **Exhibit "E"**, *supra* note 6.
[8] See **Exhibit "F":** Canada, "COVID-19 Daily Epidemiology Update" (June 29, 2021), online: <https://health-infobase.canada.ca/covid-19/epidemiological-summary-covid-19-cases.html?stat=num&measure=total&map=pt#a2>.
[9] **Exhibit "G"**: World Health Organization, "WHO Coronavirus (COVID-19) Dashboard" (June 30, 2021), online: <https://covid19.who.int/> .

ICU care, including younger people in their 40s and 50s.[10] The alpha variant that drove the third wave during early 2021 is currently being supplanted by the delta variant about which knowledge is rapidly evolving.[11]

14. The number of COVID-19 cases and hospitalizations in Ontario have increased with each of the three COVID 'waves', periods marked by rising case loads and concomitant rising pressures on Ontario's health system. Numbers of hospitalizations are relevant to COVID-19 decision-making because Ontario has the lowest rate of hospital beds per 1000 population (1.4) compared to the Canadian average (2.0). Overall, Canada's hospital capacity is among the lowest of the OECD countries, with 20% more in the USA (2.4/1000), 30% more in Italy (2.6/1000) and 55% more in France (3.1/1000).[12] Given that Canada has relatively few beds and Ontario has the fewest in Canada, the threshold above which the burden of COVID-19 infections and illness could push Ontario' acute care system past the point of being able to provide care to patients is logically lower than in other countries or even other Canadian provinces.

15. Ontario's response to COVID hospitalizations has, by virtue of this lower number of hospital beds compared to other comparable jurisdictions, involved moving substantial numbers of patients from the hospital at which they arrived to one with an available bed, often far from their community[13] and, at a societal level, implementing non-pharmaceutical interventions ("NPIs").

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[10] See **Exhibit "H":** Tuite AR, Fisman DN, Odutayo A, et al. "COVID-19 hospitalizations, ICU admissions and deaths associated with the new variants of concern" (2021) 1:18 *Science Briefs of the Ontario COVID-19 Science Advisory Table,* online: <https://covid19-sciencetable.ca/wp-content/uploads/2021/03/Science-Brief_VOC-Prognosis_20210329_published4.pdf>.

[11] See **Exhibit "I":** Public Health Ontario, "Weekly Epidemiological Summary: SARS-CoV-2 Whole Genome Sequencing in Ontario, June 23, 2021", online: <https://www.publichealthontario.ca/-/media/documents/ncov/epi/covid-19-sars-cov2-whole-genome-sequencing-epi-summary.pdf?la=en>.

[12] Ontario Hospital Association, "Ontario Hospitals – Leaders in Efficiency" (December 2019).

[13] Kelly Grant, "How COVID-19 exposed long-term health-care issues at Brampton hospital" (June 21, 2021) *The Global and Mail,* online: <https://www.theglobeandmail.com/canada/article-how-the-covid-19-pandemic-exposed-long-term-health-care-issues-at/>. Ontario Health data cited by the Globe and Mail note 3219 transfers between mid-November, 2020 and the end of May, 2021.

NPIs comprise a bundle of measures, including temporary restrictions on mobility and gatherings, designed to reduce COVID-19 transmission and thus hospitalization and death, both to mitigate threats to the integrity of health care and to 'minimize serious illness and overall deaths through appropriate management of Ontario's health system.'[14]

16. A health system in which every available bed is occupied by someone infected with COVID-19 has no way to respond to people with heart attacks, hip fractures or strokes, potentially adding to the elevated mortality attributable to COVID-19. Put simply, the harms caused by COVID-19 would be compounded with additional preventable deaths due to heart attacks, hip fractures and other health conditions if there are no beds and no staff available to care for patients with these conditions. Once overwhelmed, the acute care system would likely face a prolonged recovery period, hence the relevance of the precautionary principle to decision making aiming to ensure the integrity of the health system.

17. Given that different jurisdictions have applied a different mix of policy responses to the COVID-19 pandemic, and that there are real harms associated with the restrictive nature of the temporary public health measures implemented across dozens of countries, it may be instructive to examine these in comparative terms. At its simplest, a key question is 'what would have been the mortality from COVID-19 if Ontario had chosen less restrictive measures?'; the table below summarizes the results from three jurisdictions described as less restrictive by the Applicant's expert, Dr. Schabas, as compared to Ontario's mortality rate.

[14] See **Exhibit "C"**, *supra* note 2 at p. 10 (Objective #1).

TABLE 2

	Ontario	Sweden	Brazil	Florida
Population	14,000,000	10,159,183	213,956,756	21,600,000
COVID-19 Deaths	9,101[15]	14,619[16]	507,109[17]	37,772[18]
Crude Death Rate[19]	0.65/1000	1.44/1000	2.37/1000	1.75/1000
Projected Additional Deaths in Ontario[20]	NA (zero)	+11,060 (+122%)	+24,080 (+265%)	+15,400 (+169%)

IV. HOW IS THE VIRUS TRANSMITTED?

18. COVID-19 is caused by the SARS-CoV-2 virus and its variants (together, "**COVID-19**" or the "**Virus**"), which spreads between people, through respiratory particles of varying sizes, mainly when an infected person is in close contact with another person.[21]

19. COVID-19 can spread from an infected person's mouth or nose in small liquid particles when they cough, sneeze, speak, sing, or breathe heavily. These liquid particles are different sizes, ranging from larger respiratory droplets to smaller aerosols. While the science is still evolving, these particles travel further indoors than outdoors and their survival on surfaces appears to be

[15] See **Exhibit "E"**, *supra* note 6.
[16] World Health Organization, "Sweden: WHO Coronavirus Disease (COVID-19) Dashboard With Vaccination Data", online: <https://covid19.who.int/region/euro/country/se> (accessed 26 June 2021).
[17] World Health Organization, "Brazil: WHO Coronavirus Disease (COVID-19) Dashboard with Vaccination Data", online: <https://covid19.who.int/region/amro/country/br> (accessed 26 June 2021).
[18] "Tracking Coronvirus in Florida: Latest Map and Case Count", *The New York Times,* online: <https://www.nytimes.com/interactive/2021/us/florida-covid-cases.html> (accessed 26 June 2021).
[19] Number of reported cases/population; age-adjustment would yield slightly more accurate figures but the change due to age adjustment is insufficient to explain the greater than 2-fold variation.
[20] Calculated as (death rate in jurisdiction – death rate in Ontario)*population of Ontario.
[21] See **Exhibit "J":** Public Health Ontario, "Synthesis: COVID-19 Transmission Through Large Respiratory Droplets and Aerosols…What We Know So Far" (May 21, 2021), online: <https://www.publichealthontario.ca/-/media/documents/ncov/covid-wwksf/2021/05/wwksf-transmission-respiratory-aerosols.pdf?la=en>.

greater indoors than outdoors. Whether indoors or outdoors, people can contract COVID-19 when the Virus enters their mouth, nose, or eyes.[22]

20. Many people infected with COVID-19 show no symptoms (asymptomatic) or experience several days between when they are infected and when they develop symptoms (presymptomatic). This is particularly challenging as transmission risk seems to be highest prior to symptoms appearing, meaning that most infected people will unknowingly infect others before they themselves have symptoms.[23] Thus, to reduce COVID-19 transmission and the harms, including hospitalization and death that such transmission can cause, NPIs need to apply to people who do not exhibit COVID-19 symptoms in order to be effective.

V. WHAT ARE THE RISK FACTORS FOR TRANSMISSION?

21. Risk factors for virus transmission include being in close contact for prolonged periods, higher voice volume, being indoors, inconsistent use of face coverings (such as removing a face covering to talk or shout, eat or drink), improper use of face coverings (e.g. not covering the nose or wearing one that is too loosely fitted), and background infection rates in the community(s) from which a gathering's attendees are drawn.

22. The World Health Organization provides the '3C' framework for assessing risks of COVID-19 transmission: crowded places, close contact, confined spaces. Risks of Virus transmission are increased when two or more of these conditions occur together.[24] In addition, risks increase with increasing degrees of the 3Cs, including:

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[22] See **Exhibit "K":** World Health Organization, "Coronavirus disease (COVID-19): How is it transmitted?" (updated April 30, 202), online: <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/question-and-answers-hub/q-a-detail/coronavirus-disease-covid-19-how-is-it-transmitted>.

[23] *Ibid*.

[24] See attached **Exhibit "L"**: World Health Organization, "Avoid the Three Cs", online: <https://www.who.int/images/default-source/wpro/countries/malaysia/infographics/three-3cs/final-avoid-the-3-cs-poster.jpg?sfvrsn=638335c1_2>.

a. being in close contact for longer periods causes greater risk than shorter periods;[25]

b. higher voice volume likely increases both droplet production and projection;[26]

c. being indoors increases risk, as droplets persist in indoor environments longer than outdoors;[27] and

d. inconsistent or improper use of face coverings, such as removing a face covering to sing or consume food and beverages or leaving the nose uncovered, increases risk.

23. The risk from any particular setting is also determined by the likelihood that other persons present are infected with COVID-19. Community prevalence describes the percentage or rate of COVID-19 infection in a population. When community prevalence is elevated, even lower risk activities can contribute to pressures on the integrity of the health system as more infections lead to increased numbers of persons needing hospitalization.

24. After the first wave of COVID-19 in Ontario when COVID-19 spread widely within institutional settings such as long-term care homes ("LTCHs"), transmission risks now appear to be highest in non-institutional settings such as workplaces and households. Secondary attack rates (the number of cases among contacts of a case) within households have been estimated to be 5-10 fold higher than in non-institutional , non-household settings.[28] The transmissibility of COVID-19 within households is complex and determined by still poorly understood interactions of density (persons per room), social interaction patterns among household members, use of personal

[25] See **Exhibit "J"**, *supra* note 21.
[26] See **Exhibit "M"**: Valentyn Stadnytskyi et al, "The airborne lifetime of small speech droplets and their potential importance in SARS-CoV-2 transmission", (2020) 119:22 PNAS 11875-11877, online: <https://www.pnas.org/content/117/22/11875>.
[27] See **Exhibit "J"**, *supra* note 21.
[28] See **Exhibit "N":** Sarah A. Buchan et al., "Increased household secondary attack rates with Variant of Concern SARS-CoV-2 index cases" (March 31, 2021), *Public Health Ontario* (April 5, 2021 pre-print), online: <https://www.medrxiv.org/content/10.1101/2021.03.31.21254502v1> (accessed 26 June 2021).

protective equipment within the home, and social and cultural norms determining roles and behaviours within households. As these are not amenable to policy action on the time scale of COVID-19 transmission, the cornerstone of evidence-informed actions to reduce the burden of COVID-19 in Ontario is reducing risks of COVID-19 being introduced into households, thus reducing COVID-19 transmission and subsequent incidences of clinical illness, hospitalization and death.

25. At a population level, the overall risk of transmission is further increased when community prevalence of the Virus is higher, since any encounter carries a higher chance of involving a person infected with COVID-19. In addition, gatherings that draw individuals from different households together increase risks of transmission to more households, increasing the expected burden of COVID-19. High rates of household transmission, with entire families being hospitalized during the most recent period of heightened incidence, highlight the importance of implementing public health measures that reduce the chances of COVID-19 entering a household.

Risk of transmission at religious gatherings

26. As set out above, the risk of COVID-19 transmission at an event or gathering depends on a number of factors, including the number of people attending, adherence to physical distancing, mask wearing, duration of the event or gathering, ventilation, whether there is singing or high-volume talking, and background infection rates in the community(s) from which the gathering's attendees are drawn.

27. Religious gatherings often feature several heightened risk factors for COVID-19 transmission, including singing or high-volume speaking, chanting or preaching. The scientific basis for this is understood to be greater production of respiratory particles with increasing

volume.[29] While it is uncertain whether there is an independent increased risk from singing when compared to speech at the same volume, it appears reasonable that even if the singing effect is a pure volume effect, the reality that singing occurs at higher volumes than speaking confers increased risk of producing COVID-19-containing respiratory particles.

28. Ontario COVID-19 outbreak data suggest that when COVID-19 outbreaks occur in association with religious gatherings, more cases are identified than from outbreaks in other non-institutional settings. Through June 18, 2021, Ontario's 34 local public health units reported 59 outbreaks associated with places of worship with 526 associated cases, for an average of 8.9 cases per outbreak. While not diminishing the toll of COVID-19 in LTCHs and other institutional settings (4032 outbreaks, 49304 associated cases) and acknowledging that while places of worship may be workplaces (2616 outbreaks, 24000 associated cases) for some persons, appropriate comparable settings would be other indoor locations into which individuals from different households voluntarily enter, such as restaurants, retail establishments and recreational fitness establishments. This grouping of other settings comprises 979 outbreaks with 5283 associated cases, for an average of 5.4 cases per outbreak.

29. Taken together, these Ontario data on declared COVID-19 outbreaks in places of worship indicate that the number of cases per outbreak is 65% higher in places of worship than in comparable non-workplace settings (8.9 versus 5.4). From the point of view of reducing COVID-19 transmission, these data support temporary limits on religious gatherings as part of a bundle of measures designed to reduce COVID-19 transmission since outbreaks associated with places of

[29] See **Exhibit "O":** Sima Asadi et al., "Aerosol emission and superemission during human speech increase with voice loudness" (2019) 9:2348 *Nature,* online: <https://www.nature.com/articles/s41598-019-38808-z> (accessed 26 June 2021).

worship yield more identified infections than outbreaks in comparable non-institutional, non-workplace[30] settings.

D. WHY ARE MEASURES TO LIMIT COVID-19 TRANSMISSION NEEDED IN ONTARIO?

30. Seeking to protect persons from mortality and morbidity from COVID-19 and to reduce the likelihood the acute care system would be overwhelmed by persons requiring hospital care for COVID-19 infection, the government of Ontario has implemented a bundle of temporary public health measures, generally referred to as non-pharmacologic interventions ("NPIs"). NPIs seek to reduce close contact among persons from different households, and thus reduce COVID-19 transmission risk. NPIs implemented temporarily in Ontario are broadly similar to those implemented in most if not all OECD jurisdictions and include limits on occupancy of indoor spaces, mobility limits, limits on and prohibitions of gatherings and events, and school closures.

31. These policy interventions are complemented by individual-focused**,** evidence-based mitigation measures such as requirements for face covering and physical distancing. Together these measures, both individual and policy level, can reduce, but not eliminate, the risk of COVID-19 transmission. Vaccination, once high levels of population coverage are achieved, is expected to obviate the need for NPIs. Ontario's *Roadmap to Reopening* explicitly links the end of NPIs to increasing levels of vaccination among Ontarians. It is hoped that vaccinations will eventually render these NPIs unnecessary, however with only 30% of Ontario's adult population fully vaccinated as of June 29, 2021,[31] levels of vaccination coverage are as yet insufficient to cease all NPIs.

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[30] Data summarized by Public Health Ontario as of June 18, 2021.
[31] Noah Little, *COVID-19 Tracker Canada* (2020), online: <https://covid19tracker.ca/provincevac.html?p=ON> (accessed June 29, 2021).

E. WHY DO LIMITS ON RELIGIOUS GATHERINGS CONTRIBUTE TO REDUCING COVID-19 TRANSMISSION AND HARMS FROM COVID-19?

32. In a society as diverse as Ontario, religious gatherings encompass a wide range of practices which may include singing, preaching, close contact for the purposes of greetings or other verbal and/or physical exchanges, and the passing of religiously significant physical material from person to person.

33. From an epidemiologic perspective, all gatherings as a class pose risks that rise with the number of attendees, reflecting the declining probability that every person present will be COVID-free as the number of persons increases. Experts retained by the Applicants have attempted to estimate this risk. Acknowledging that any such model involves estimates and assumptions, the table below asks a more basic policy-relevant question: for gatherings of different numbers of people and with different proportions of COVID-19 infection in the community, what is the chance that at least one person who is infected with COVID-19 will be present and thus able to transmit COVID-19 to others?

34. The 1 case/500 people proportion column aligns with the Applicant's expert's (Dr. Kettner's) estimated incidence of 1 case/5000 people/day with correction for the epidemiologic reality that infected people can transmit COVID-19 to others for roughly 10 days. Furthermore, from a community perspective, effects are multiplicative, such that a community with 10 gatherings of 10 attendees where 1 out of every 500 attendees has COVID-19 has a greater than 18% chance of someone having COVID at at least one gathering. If ten gatherings are held once/week for 10 weeks, that risk of having at least one attendee with COVID-19 at any one of those 100 gatherings rises to greater than 86%. Put another way, over 10 weeks, 10-person gatherings for religious services in 10 locations within a community yields an 86% chance that at least one attendee at at least one service has COVID-19. While the gathering-specific transmission

risks would be determined by multiple factors including mask use, ventilation and distancing, the 86% chance of COVID-19 being present highlights the importance of temporary limits on gatherings, religious or otherwise.

TABLE 3

Table entries are % chance of at least one attendee with COVID-19, where higher numbers mean a greater chance of someone with COVID-19 attending a gathering[32]

Number of People Attending	1 of Every 100 Attendees Have COVID-19	1 of Every 500 Attendees Have COVID-19	1 of Every 1000 Attendees Have COVID-19
10	9.5%	2%	<1%
100	63%	18%	9.5%
1000	>99.9%	86%	63%

35. In addition, specific religious practices such as those listed above increase risks of transmission, notably when voice volume is increased, as with singing and preaching, and when people are in close contact. In addition, entry and egress into many places of worship will bring people into close contact due to the near-simultaneous arrival of attendees to points of entry and egress.

36. Data on outbreaks associated with places of worship gathered by Public Health Ontario summarized above in para. 28 highlight the greater transmission risks among identified outbreaks associated with places of worship when compared to comparable non-institutional, non-workplace settings.

37. Both Drs. Schabas & Kettner, experts retained by the Applicants, have noted that few deaths are directly attributable to transmission in places of worship, yet overlook the reality that

[32] Assuming independence of infection risk among attendees, prob (at least one attendee with COVID-19) = (1-(Prob that all are uninfected) = (1-% of attendees with COVID)^number of attendees.

many people who attend religious gatherings also work outside their homes, whether as essential workers in LTCHs or transit operators or dentists who, if infected at a place of worship can then transmit COVID-19 to those they care for, drive for or serve, in addition to transmitting COVID-19 to uninfected household members. As a transmission location cannot be identified for many of the thousands of cases of COVID-19 deemed to be community transmission, temporary restrictions have been imposed on a wide range of settings and gatherings. Given that reducing COVID-19 transmission (as the upstream cause of COVID-19 harms including illness, hospitalization and death) is a major policy focus of government action regarding COVID-19, temporary limits on gatherings are a reasonable element of the bundle of NPIs aiming to reduce COVID-19 transmission and subsequent harms.

38. The Applicants' experts make reference to 'safety plans' (Dr. Kettner) and provide an admonition that 'public health should work constructively with religious congregations to find ways to allow religious services to continue to function at an acceptable risk' (Dr. Schabas). Given the diversity of religious practices and the venues where religious gatherings occur, the policy rationale for diverting sparse public health resources to working with individual religious organizations seems based on the assertion that cooperation will be forthcoming from all groups, which experience (including the experience of some of the applicants in this case) teaches may not happen in practice.

39. It may be theoretically possible to argue that contact tracing would be a reasonable alternative, arguing that if an infection occurred, then attendees could be contacted and advised to self-isolate, be tested or follow other public health advice. However, contact tracing requires being able to identify by name people who may have been in contact with a confirmed case of COVID-19 so that these persons can be directed to testing and advised to self-isolate. This argument, if

valid, assumes three critical elements: that people are truthful and complete when asked about places they have been, that an accurate and complete list of attendees for each place of worship is maintained by every place of worship and that society has the resources to contact each identified person. Even if all three elements are present, the significant likelihood of asymptomatic or presymptomatic COVID-19 transmission means infection of others is expected to occur before the index case is confirmed which is the necessary step that would trigger contact tracing. Ontario's COVID-19 experience to date suggests that the theoretical impact of contact tracing has not been realized, due to both the biology of COVID-19 and the reality that any single case will likely have infected others before test results are available to initiate contact tracing.

40. In keeping with Ontario's commitment to reduce illness and mortality from pandemic infectious disease, and noting the far higher death rates seen in jurisdictions that opted for less restrictive measures than in Ontario, the Province of Ontario implemented temporary limits on gatherings, including those at places of worship and for religious observance. As discussed above, in addition to the risk associated with any gathering, COVID-19 outbreaks have been reported from places of worship and these have been more severe than outbreaks in other settings as demonstrated by the increased number of cases per outbreak.

41. Specific features of religious services including singing, preaching and close contact all increase risks of COVID-19 transmission. Furthermore, persons who attend places of worship may become infected and transmit to others in their households and workplaces. Taken together, these factors lead me to conclude that temporarily limiting religious gatherings is a public health measure which contributes to reducing COVID-19 transmission and thus harms from COVID-19. At such time as COVID-19 incidence rates decline significantly, reducing and eventually eliminating temporary limits on religious gatherings would be appropriate, as occurred when

regions moved into lower zones of Ontario's *Keeping Ontario Safe and Open Framework*, and as is already happening with the current *Roadmap to Reopening*.[33]

VI. CAN THE RISK OF TRANSMISSION AT INDOOR RELIGIOUS GATHERINGS BE ADEQUATELY ADDRESSED BY RULES REQUIRING PHYSICAL DISTANCING AND MASKS OR OTHER PERSONAL PROTECTIVE EQUIPMENT ("PPE")?

42. Evidence-based mitigation measures such as face covering and physical distancing can reduce, but not eliminate, the risk of Virus transmission. The ongoing global pandemic highlights the reality that adherence with these measures is imperfect, and the imposition of regulatory fines has not eliminated non-compliance.

43. At religious gatherings, rules requiring the use of face coverings and physical distancing are inadequate to prevent COVID-19 transmission when community transmission is heightened. First, individuals may refuse to comply with such rules and reactive measures (i.e. enforcement actions) such as penalties or other sanctions for non-compliance imposed after the fact will do nothing to stop a COVID-19 outbreak caused by transmission that has already occurred at a gathering. At the height of the third wave, given the high prevalence of COVID-19 variants and the pressures on Ontario's hospital and ICU capacity, even isolated incidents of non-compliance with physical distancing and face covering requirements at religious gatherings would have had grave public health implications.

44. Second, the risks associated with religious gatherings further include the risk that participants may acquire or spread COVID-19 when they travel to and from the place of worship. As noted above, these risks are increased when community prevalence of COVID-19 is heightened.

[33] See **Exhibit "P":** Ontario, "Reopening Ontario", online: <https://www.ontario.ca/page/reopening-ontario#section-1> (accessed July 1 2021).

45. Although a religious leader, (e.g. Rabbi, Imam, Pastor, etc.) if present, may be able to ensure compliance with physical distancing and face covering requirements, the sense of community at religious gatherings may also prompt people to approach within two metres of each other to exchange greetings or sing at a high volume, particularly when such activities are an integral part of observance, increasing the risk of transmission. Further, a religious leader's ability to monitor and promote compliance risks being compromised in larger gatherings where it is more difficult to keep track of all participants. Even isolated incidents of non-compliance with physical distancing and face covering requirements at religious gatherings may lead to COVID-19 transmission, hospitalizations, and add to the significant pressures on Ontario's health care system.

VII. DO YOU AGREE OR DISAGREE WITH THE AFFIDAVITS OF DR. WARREN, DR. SCHABAS, AND DR. KETTNER?

i) Dr. Warren's affidavit

46. I have reviewed the affidavit of Dr. Warren.

47. With regard to Dr Warren's analogy of tuberculosis for COVID-19, the differing burden of each of these infectious diseases renders this analogy inapt. As discussed above, the notion of burden can be understood as a function of the prevalence of the disease (i.e., number of cases in a population), the exposure risk (i.e., the probability that one infected person will infect others), and the consequences of infection, such as hospitalization and death. To summarize, approximately 300 cases of tuberculosis are diagnosed in the City of Toronto each year.[34] Even if all 300 persons diagnosed with tuberculosis required hospitalization (which would be unheard of), 300 hospitalizations over a year is insignificant in comparison to the 25-35 hospitalizations/day from

[34] See **Exhibit "Q":** City of Toronto, "Programs & Services for Tuberculosis (TB)", online: <https://www.toronto.ca/community-people/health-wellness-care/health-programs-advice/tuberculosis-tb/programs-services-for-tuberculosis-tb/> (accessed April 22, 2021).

COVID-19 in April 2021 alone. For public health practice, higher burdens are an important motivator for more restrictive measures.

48. Similar considerations apply to Dr. Warren's reliance on influenza. While the prevalence of influenza is higher than tuberculosis, the consequences of acquiring influenza are generally less severe, with significantly lower mortality and hospitalization rates. Accordingly, seasonal outbreaks of influenza do not result in the same pressures on hospital and ICU capacity. It should also be pointed out that influenza has been thoroughly studied whereas COVID-19 is a new disease with even newer variants. The public health response to influenza has been finely tuned over the years – while obvious, it bears noting that there simply has not been the same lengthy period available for finely tuned public health measures to COVID-19.

49. In short, the important differences between COVID-19 and tuberculosis and influenza obligate public health officials to recommend a different public health response commensurate with the relative burdens of each infectious disease.

50. The limits on religious gatherings have been an important part of Ontario's broader public health response to the COVID-19 pandemic. If no limits were placed on religious gatherings, as Dr. Warren urges, this could be expected to push infection rates higher, increase the number of people hospitalized with COVID-19, and bring Ontario's health system nearer to the point where it would be unable to care not only for people infected with COVID-19 but also for others who need hospital based care.

51. Accordingly, I do not agree with Dr. Warren's statement that no limits should be placed on religious gatherings aside from physical distancing. The burden associated with COVID-19 in Ontario's health system, the higher risks of transmission associated with aspects of religious gatherings such as singing, and the greater number of cases per outbreak all support my opinion

that temporary limits on religious gatherings are a reasonable measure to protect Ontarians from COVID-19 and Ontario's health system from collapse due to COVID-19.

ii) Dr. Schabas' affidavit

52. I have reviewed the affidavit of Dr. Schabas. The affidavit makes repeated references to an undefined notion of 'lockdown'. It seems reasonable to assess Dr Schabas' assertions about lockdowns with regard to temporary limits on religious gatherings which is the matter at issue in this proceeding. Dr Schabas asserts the following points with my response set out below each point:

1. Temporary limits on religious gatherings have been arbitrary and capricious because they are not necessary or effective.

Temporary limits on religious gatherings are neither arbitrary nor capricious when considered in light of the evidence of elevated risks of COVID-19 transmission associated with elements of religious observance (e.g. singing) and Ontario's COVID-19 outbreak data showing 65% more cases from outbreaks associated with places of worship than with comparable non-institutional, non-workplace settings. Moreover, these temporary limits have been part of a bundle of NPIs which, when implemented with increasing stringency in each of the three waves to date, have been followed by decreases in the daily case count and growth rates.

2. Temporary limits on religious gatherings cause more harm (to mental health) than good (preventing COVID-19 related mortality and morbidity).

Dr. Schabas provides no evidence to support this assertion. Seeking the mental health benefits of attending religious gatherings, adherents to a wide range of diverse observances have established virtual gatherings, drive-in gatherings, and as conditions have improved, outdoor gatherings and larger indoor gatherings, suggesting that it is possible both to reap the health benefits of observance for adherents and to reduce risks of COVID-19 transmission in the wider population.

3. The initial temporary limits on religious gatherings in March 2020 were based on inaccurate models, including an overestimate of the Infection Fatality Rate ("IFR") by at least four times (especially outside of LTCs).

Dr. Schabas provides no details of the models which he describes as 'inaccurate'. The precautionary principle, coupled with the novelty of COVID-19 provides an adequate basis for implementing NPIs in line with Ontario's pandemic plan.

4. Temporary limits on religious gatherings have not been used in the past for respiratory contagions, including for influenza. Currently tobacco is more deadly than COVID-19.

My response regarding respiratory contagions, including influenza, is detailed in my response to Dr. Warren. Tobacco is not comparable as it is not a communicable disease and thus does not require restrictions on gatherings to reduce its transmission to others. Moreover, the government

of Ontario, as many other governments, has implemented significant permanent restrictions on the ability to smoke in places where second-hand smoke could cause harm to others (see e.g. *Smoke-free Ontario Act*).

5. COVID is a serious public health problem but affects mostly old people. The measure of years of life lost must be used to recognize this reality. Diarrheal illness in children has a greater impact than COVID-19.

Years of lives lost is just one measure of the deadliness of a virus. Since the matter at issue in this proceeding is actions taken by the government of Ontario, a more appropriate comparison would be years of life lost or deaths from diarrhea in Ontario.[35]

6. Public Health data shows that incidence of spread at religious gatherings is low. In any event, it is very low where there is no overcrowding, singing and well-ventilated.

Fifty-nine outbreaks have been identified at places of worship with an average of 8.9 cases per outbreak. While reducing or eliminating overcrowding and singing and improving ventilation would all contribute to lower risks of transmission, the role of the government in a pandemic emergency context is generally to establish rules for each sector rather than to inspect and create safety plans for each individual place of worship. If Dr. Schabas is of the view that such detailed plans should be created by the government, some evidence of precedent and/or operational consideration for how this would take place in thousands of places of worship would seem a reasonable expectation from an expert in public health.

7. VOCs are more transmissible – and therefore require stricter temporary limits on religious gatherings. It is not the right path to impose increasingly stricter measures.

The precautionary principle behooves government to be more cautious, not less cautious, when dealing with uncertainty. The biology of COVID-19 variants (notably alpha and delta), by being more transmissible than the variants they displaced, increases the risk of overwhelming the health system, suggesting that more stringent public health measures should be put in place, not less stringent measures. Dr. Schabas acknowledges that the science related to "many aspects of covid is uncertain" and recognizes that decisions on which public health measures to employ "are of necessity based on judgment as much as science."

iii) Dr. Kettner's affidavit

53. I have reviewed the affidavit of Dr. Kettner. In my opinion, Dr. Kettner provides a flawed modelling approach as the basis for his conclusions that the "probability of transmission of

[35] In fact, COVID-19 is more deadly than diarrhea. The CDC states that 2195 children die each day from diarrhea while the WHO reported deaths from COVID-19 amount to >7,000/day. UNICEF data indicate that approximately 2000 children under age 5 die each year in Canada and that diarrhea accounts for 8% of global child mortality. Applying this to Ontario suggests an upper limit of 64 deaths annually from diarrhea. Over the 16 months of the COVID-19 pandemic, this would amount to approximately 85 deaths from diarrhea compared to 9101 from COVID-19. UNICEF data available online: <https://data.unicef.org/resources/data_explorer/unicef_f/?ag=UNICEF&df=CME&ver=1.0&dq=CAN.CME_TMM0+CME_TMY0T4..&startPeriod=2016&endPeriod=2021>.

COVID-19 in church services with attendees from with (sic) current rates of infections similar to that of the Niagara health region" (para 95).

54. Dr. Kettner begins by choosing a municipality that is not the one in which the Wellandport church is located; Wellandport is a hamlet located in West Lincoln, Ontario, not within the municipality of Welland. Data provided by Public Health Ontario indicate that this is slightly to the advantage of his analysis as the cumulative incidence for West Lincoln is 30/100,000 while that for Welland is 38.3/100,000. Regardless of the incidence rate chosen, Dr. Kettner provides no evidence that all attendees are drawn from a single municipality whose incidence can then be used for the calculations that follow.

55. Dr. Kettner's modeling approach appears to overlook the reality that many individuals attending religious gatherings will do so as members of household groups. COVID-19 secondary attack rates within households are reported to be higher for asymptomatic and presymptomatic cases than for symptomatic cases and these rise further for VOCs, such that VOCs were determined to have a household secondary attack rate 1.31 times higher than non-VOC for symptomatic cases, 1.91 times higher for asymptomatic VOC cases, and 3.41 times higher for presymptomatic cases.[36] The non-independence of COVID-19 infection risk among members of a household, coupled with high secondary attack rates in the time of VOCs' emergence, undermines Dr. Kettner's model as a basis for prudent decision making.

56. Furthermore, Dr. Kettner's model assumes a constant (i.e. the same number of new cases every day) incidence rate over a period when incidence varied substantially in Niagara region.

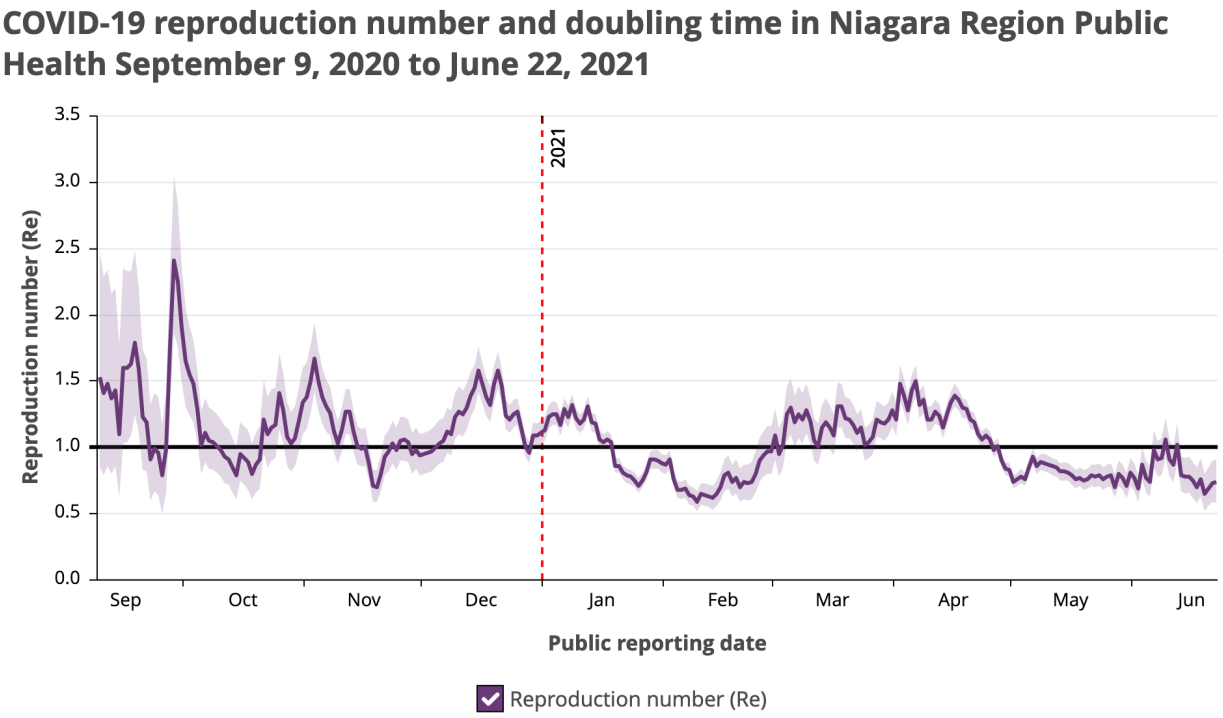
[36] See **Exhibit "N"**, *supra* note 28.

Using the day with the highest number of new cases, (200 cases, April 12, 2021), Kettner's 1/5000 estimate would more correctly be 1/1937, or 2.58 times greater.

57. Finally, Dr. Kettner's model fails to consider transmission dynamics over time. Using his rate of 1/5000 per day with the first infection on a Monday and services on Sunday, 7/5000 people will be infected by the first Sunday, 5 will be within Dr. Kettner's 10 days of infectiousness and 2 within Kettner's period of presymptomatic COVID (para 53). Using Dr. Kettner's 8% risk of transmission, the risk of infection from a symptomatic case on the first Sunday would be 5/5000*0.08 = 0.00008 (1 in 12500), but a week later the risk would have increased to 12/5000*0.08 = 0.000192 (1 in 5208), and that ignores the secondary cases, both within households and in the wider community. Dr. Kettner's model does not appear to account for the effective reproduction rate ("Re") during the period under consideration (March 14, 2020- April 29, 2021). Data provided by Public Health Ontario and shown in Figure 1 below indicate that the effective reproduction rate varied during this period and was greater than 1 for several weeks. Re greater than 1 means that exponential growth in the number of new cases is occurring yet Dr. Kettner's model picks 1/5000 as the constant correct rate and applies it across the entire time

period. This oversimplification fails to acknowledge the rapid growth rates of COVID-19 cases that occurred during the peaks of the second and third waves of COVID in Ontario.

FIGURE 1[37]



58. In summary, a model that uses the wrong geography, makes no account for household transmission dynamics, assumes a constant incidence over a period when incidence varied

[37] See **Exhibit "R":** Public Health Ontario, "Ontario COVID-19 Data Tool", online: <https://www.publichealthontario.ca/en/data-and-analysis/infectious-disease/covid-19-data-surveillance/covid-19-data-tool?tab=retd> (accessed 27 June 2021; configured to Niagara Region Public Health, 09 Sep 2020 – 22 Jun 2021).

significantly and included weeks with exponential growth (Re> 1), and which ignores the effects of time in transmission dynamics is not one to be recommended as a basis for policy decisions.

AFFIRMED by video conference by MATTHEW HODGE of the City of [redacted] in the Province of Ontario before me on this 2nd Day of July, 2021 in accordance with O Reg 431/20, Administering Oath or Declaration Remotely

Commissioner for the Taking of Affidavits

MATTHEW HODGE

This is "**Exhibit A**"
to the Affidavit of Matthew Hodge,
affirmed this 2nd day of July, 2021

A Commissioner, etc.

MATTHEW HODGE, MDCM, PhD, CCFP(EM), FRCPC

Informatics and metrics-savvy physician leader committed to quality improvement, developing people, value-for-money and reliable operational excellence supported by data and information systems. Results-focused physician executive with leadership experience in public health, health care delivery, and international health organizations; public health & preventive medicine specialist and practicing ER physician.

PROFESSIONAL EXPERIENCE & ACCOMPLISHMENTS

EMERGENCY DEPARTMENT PHYSICIAN, Toronto, ON **June 2011 - ongoing**
Providing clinical services in hospitals ranging from Rainy River to major academic centres in Toronto, currently at SRH, General & Birchmount sites and locum small hospital work in Grey-Bruce and NE Ontario.

CONSULTANT PHYSICIAN **June 2011 - ongoing**
Recent engagements include defining an analytic strategy to position a public health organization to focus its program efforts in early child development, redesigning public health inspection services, and ED operations consulting with Canadian startup Metricaid. Previous engagements have included LEAN-driven Emergency Department improvement projects, review and recommendations for restructuring and reorienting surveillance activities in a public health organization, and assessment of efficiency and provider mix in primary care. COVID work has included engagements with PHAC, PHO & Peel Region Public Health.

MEDICAL MANAGER, RMFCU. APFRB, MOHLTC, Toronto, ON **January 2016 – April 2017**
Providing clinical expertise to Risk Management & Fraud Control Unit (RMFCU) within the Corporate Services Division of the MOHLTC. Developed a strategic framework focused on deterrence, recovery and value to prioritize efforts and established analytic platform for post-payment review of expenditures.

CANCER CARE ONTARIO, Toronto, ON **March 2010 – June 2011**
Chief Medical Information Officer, & Director, Informatics
Led 140 informatics staff supporting cancer service management and Access-to-Care (Ontario-wide wait times for surgery, diagnostic imaging and Emergency Department care); represented CCO at provincial bodies including ER-ALC expert panel. Managed budget of CDN$16M.

Developed 'one informatics' plan to i) unify disparate informatics resources across the organization, ii) rationalize processes using LEAN and iii) engage and support hospitals and other health care delivery organizations directly in their performance improvement efforts; aligned enterprise architecture development, $2M electronic data warehouse project and business intelligence strategy around shared vision of the patient journey; led division with highest staff satisfaction scores.

UNITED NATIONS POPULATION FUND (UNFPA), New York, NY **January 2008 – February 2010**
Chief, Evaluation Branch, Division of Oversight Services
Led review and revision of evaluation program; subsequently promoted to Chief, Evaluation. Conducted or supervised 8 evaluations of country programmes with internal auditors; resulting tools established a shared audit & evaluation risk-based framework for evaluating relevance and strategic alignment of the Fund's country programmes, comprising $300M in annual expenditures. Reduced time from fieldwork to final report from over 360 days to 30 days. Led and participated in cross-functional audit/evaluation teams in the field in Africa and Asia. Contributed to the Fund's development of an evaluation policy.

CITY OF HAMILTON PUBLIC HEALTH SERVICES, Hamilton, ON **February 2005 – October 2007**
Associate Medical Officer of Health
Led epidemiology & evaluation within municipal public health department including responsibility for surveillance and emergency planning. Transformed $800K Public Health Research Education and Development (PHRED) program from unaccountable fund to competitive grants program; developed and implemented program evaluation cycle with self-assessment, epidemiologic best-evidence and peer review; led investigation, media and provincial liaison during legionella outbreak (2006) and provided ongoing medical expertise to communicable disease and environmental health investigations; represented Canada's

pubic health practitioners on Integration Working Group for Canada Health Infoway-funded communicable disease surveillance system (Panorama), 2006 - 2008

MCMASTER UNIVERSITY, Hamilton, ON **July 2005 - ongoing**

Associate Professor, Clinical Epidemiology & Biostatistics
Developed management education for Public Health & Preventive Medicine residents, course director 2012, 2013, 2014, 2016.

UNIVERSITY HEALTH NETWORK, Toronto, ON **January 2001 – April 2012**

Staff Physician, Emergency Department
Member, Practice Plan & Finance Committees

UNITED NATIONS CHILDREN'S EMERGENCY FUND (UNICEF) October 2003 – June 2004

Consultant, Evaluation Office
Completed thematic evaluations of midterm progress on Strategic Plan goals in immunization and HIV/AIDS; policy development for HIV/AIDS care and support and technical support to UNICEF-funded projects to prevent mother-to-child transmission of HIV infection in 11 countries.

MINISTRY OF HEALTH & LONG-TERM CARE, Toronto, ON **September 2002 – March 2003**

Senior Medical Consultant, Public Health Branch

Negotiated terms of MOHLTC pilot funding for colorectal cancer screening to be implemented by Cancer Care Ontario; SARS response.

UNITED NATIONS CHILDREN'S EMERGENCY FUND (UNICEF) September 2001 – September 2002

Senior Health Advisor, HIV/AIDS

WORLD HEALTH ORGANIZATION (WHO), Geneva, SUI **January 1999 – July 2001**

Medical Officer

EDUCATION AND PROFESSIONAL CERTIFICATIONS

MS, **Masters of Health Care Management, Harvard University**, 2011 (Mid-career physician management and leadership training program offered by Harvard School of Public Health)
MSIT, **Master of Science (Inf. Technology), Carnegie Mellon University,** 2008
MSc, **Development Finance, University of London**, 1999
MDCM, **McGill University**, 1996
PhD, **McGill University,** 1995 (MD-PhD Program, Thesis Title: Methods for Geographic Analyses of Health Services Use)
BA, **Economics, Yale University**, 1987
College of Physicians & Surgeons of Ontario (CPSO): Medical License #70425
Fellow, Royal College of Physicians and Surgeons of Canada, 2000
Public Health & Preventive Medicine
Diplomate, American Board of Preventive Medicine, 2007
Clinical Informatics Certification, American Board of Preventive Medicine, 2013
Certificate of Special Competence in Emergency Medicine, (CCFP(EM)), 2012

COMMUNITY CONTRIBUTIONS

Advisor, MARS Discovery District: providing advice to start-ups in the Health practice, 2014-ongoing
Public Health Physicians of Canada, formerly National Specialty Society for Community Medicine
President, 2009 – 2011; Treasurer, 2008 - 2009
Event Physician, Athletics Canada National Cross Country Championships, 2007 – 2010

PUBLICATIONS

Available upon request

This is "**Exhibit B**"
to the Affidavit of Matthew Hodge,
affirmed this 2nd day of July, 2021

A Commissioner, etc.

Kitchener Court File No.: CV-21-00000095-0000
St. Thomas Court File No.: CV-21-08
Welland Court File No.: CV-21-00013361-0000

ONTARIO
SUPERIOR COURT OF JUSTICE

BETWEEN:

THE ATTORNEY GENERAL OF ONTARIO

Applicant

-and-

TRINITY BIBLE CHAPEL, JACOB REAUME, WILL SCHUURMAN, DEAN WANDERS, RANDY FREY, HARVEY FREY, and DANIEL GORDON

Respondents

AND BETWEEN:

HER MAJESTY THE QUEEN IN ONTARIO

Applicant

-and-

THE CHURCH OF GOD (RESTORATION) AYLMER, HENRY HILDEBRANDT, ABRAM BERGEN, JACOB HIEBERT, PETER HILDEBRANDT, SUSAN MUTCH, ELVIRA TOVSTIGA, and TRUDY WIEBE

Respondents

AND BETWEEN:

WELLANDPORT UNITED REFORMED CHURCH

Applicant

-and-

HER MAJESTY THE QUEEN AS REPRESENTED BY THE ATTORNEY GENERAL OF ONTARIO

Respondent

AND BETWEEN:

STEPHEN RICHARDSON

Applicant

-and-

THE ATTORNEY GENERAL OF ONTARIO

Respondent

ACKNOWLEDGMENT OF EXPERT'S DUTY

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1. My name is Dr. Matthew Hodge. I live in the City of [redacted] in the Province of Ontario.

2. I have been engaged by the Attorney General of Ontario to provide evidence in relation to the above-noted court proceeding.

3. I acknowledge that it is my duty to provide evidence in relation to this proceeding as follows:

(a) to provide opinion evidence that is fair, objective and non-partisan;

(b) to provide opinion evidence that is related only to matters that are within my area of expertise; and

(c) to provide such additional assistance as the court may reasonably require, to determine a matter in issue.

4. I acknowledge that the duty referred to above prevails over any obligation which I may owe to any party by whom or on whose behalf I am engaged.

Date: July 2nd, 2021

Dr. Matthew Hodge

This is "**Exhibit C**"
to the Affidavit of Matthew Hodge,
affirmed this 2nd day of July, 2021

A Commissioner, etc.

Ontario Health Plan for an Influenza Pandemic

Chapter 1: Introduction

March, 2013

Ontario

Ministry of Health and Long-Term Care
Emergency Management Branch
1075 Bay Street, Suite 810
Toronto, Ontario
Canada M5S 2B1
416-212-8022 (local); 1-866-212-2272 (long distance)
emergencymanagement.moh@ontario.ca

Ontario Health Plan for an Influenza Pandemic

Chapter 1: Introduction

Audience

- health sector employers, health care providers and other health workers, emergency planners, health administrators and other provincial health system partners

Chapter objectives

- to introduce and orient readers to the 2013 Ontario Health Plan for an Influenza Pandemic (OHPIP)

Introduction

The Ministry of Health and Long-Term Care (MOHLTC) leads the development of the OHPIP to support the provincial health system to prepare for and respond to an influenza pandemic.

Since the release of the first iteration of the plan in 2004, the OHPIP has been regularly updated to reflect new knowledge, information and best practices. This process is supported by the OHPIP Steering Committee – which consists of representatives from health associations, unions, regulatory bodies and government organizations – and a variety of workgroups (See Appendix A – OHPIP Steering Committee and workgroup members).

The OHPIP supported the provincial health system's response to the 2009 H1N1 influenza pandemic (pH1N1). Although a number of simulated scenarios have been held over the years to exercise components of the OHPIP, pH1N1 was the first opportunity to use the plan to guide the response to a pandemic.

The 2013 version of the OHPIP was updated to incorporate the priority lessons learned and best practices from pH1N1. More information about Ontario's evaluation of the response to pH1N1 can be found in Pandemic (H1N1) 2009: A Review of Ontario's Response and The H1N1 Pandemic – How Ontario Fared: A Report by Ontario's Chief Medical Officer of Health.

Previous versions of the OHPIP have used World Health Organization (WHO) and Public Health Agency of Canada (PHAC) response plans as a conceptual foundation. These pandemic response plans are in the process of being revised based on the lessons learned and best practices from pH1N1. Some concepts that were previously incorporated in the OHPIP aren't in the 2013 iteration as they haven't yet been updated by the WHO and PHAC. For example, the WHO's six-phase description of a pandemic featured in previous versions of the OHPIP and Canadian Pandemic Influenza Plan for the Health Sector (CPIP). An evaluation by an external review committee on the functioning of the International Health Regulations (2005) in relation to pH1N1 recommended that the WHO simplify the pandemic phase structure. As the WHO has not released an updated plan since the evaluation was released, the phase structure is not included in this version of the OHPIP.

This is the final iteration of the OHPIP. The Ontario Influenza Response Plan *(*OIRP) will eventually replace it. Through this new plan, the provincial health system's focus will shift from preparing for an influenza pandemic to creating and building effective seasonal influenza responses and escalating those measures during a pandemic. The OIRP will link to updated pandemic response plans from the WHO and PHAC, and it will also address the next steps documented in this version of the OHPIP and outstanding lessons learned and best practices from pH1N1. The OIRP will outline influenza responses for the entire health system, including government, primary health care, community care, hospitals and public health.

Roles and responsibilities

All health system partners have a role to play during the response to an influenza pandemic, from the WHO at the international level to health sector employers and health workers at the community level.

The MOHLTC leads the Government of Ontario's response to an influenza pandemic through health system coordination and direction.[1] Within the MOHLTC's emergency response structure, there are many individuals and groups who provide operational and/ or strategic direction to guide the response. For example, the Chief Medical Officer of Health (CMOH) has legislated responsibilities under the Health Protection and Promotion Act (HPPA) and is the MOHLTC's Executive Lead during the response to an influenza pandemic. This means that the CMOH provides strategic leadership for the MOHLTC's response.

In the OHPIP, references to the MOHLTC include the Minister, CMOH and other individuals/ groups in the MOHLTC (e.g., Deputy Minister, Ministry Action Group). Please see the Ministry Emergency Response Plan for more detail on the MOHLTC's emergency response structure and decision-making process.

Table 1 outlines general roles and responsibilities of health system partners during an influenza pandemic. Each OHPIP chapter includes more detailed roles and responsibilities relevant to the chapter topic.

[1] As per the Emergency Management and Civil Protection Act, the MOHLTC assumes the role of primary ministry for emergencies, declared and undeclared, when the primary Government of Ontario response falls under the ministry's emergency responsibilities of "human health, disease and epidemics" or "health services during an emergency" as assigned by Order in Council (OIC) 1157/2009. The MOHLTC responds to the impacts on the health of Ontarians and on the health system.

TABLE 1. GENERAL INFLUENZA PANDEMIC RESPONSE ROLES AND RESPONSIBILITIES[2]

Party	Roles and responsibilities
WHO	Coordinate international response activities under the International Health Regulations Perform international surveillance and provide an early assessment of pandemic severity in order to help countries determine the level of intervention needed in the response Declare an influenza pandemic Select the pandemic vaccine strain and determine the time to begin production of the pandemic vaccine
PHAC	Coordinate national pandemic influenza response activities, including nation-wide surveillance, international liaison and coordination of the vaccine response, as outlined in the CPIP

[2] The information in this table is intended to provide general information about roles and responsibilities of different parties during an influenza pandemic. It is not a comprehensive listing of roles or obligations of a party. Roles, responsibilities and obligations of a party vary in specific circumstances.

Party	Roles and responsibilities
MOHLTC (through the Ministry Emergency Operations Centre (MEOC))	Liaise with PHAC and other provinces and territories Collaborate with Public Health Ontario (PHO) to use surveillance information to determine severity Develop recommendations[3] and provincial response strategies[4] for the provincial health system, as well as others affected by public health measures Communicate with provincial health system partners through situation reports, Important Health Notices (IHNs), the Health Care Provider Hotline, the Health Stakeholder Teleconference, the MOHLTC website and other methods Develop and issue directives[5], orders and requests as per the HPPA, Long-Term Care Homes Act and other relevant provincial legislation[6] Communicate with the public through media briefings, the MOHLTC website and other methods Solicit and respond to feedback and input from provincial health system partners Deploy supplies & equipment from the MOHLTC stockpile to health workers and health sector employers Deploy antivirals from the MOHLTC stockpile to community-based pharmacies and other dispensing sites

[3] This term refers to best practices as well as guidance on the risk posed by the pandemic. Recommendations related to occupational health and safety (OHS) may be considered by health sector employers to be reasonable precautions in the application of the Occupational Health and Safety Act (OHSA).

[4] Provincial response strategies include the surveillance strategy, public health measures strategy, outpatient care & treatment strategy, antiviral distribution strategy, immunization strategy and supplies & equipment strategy

[5] Directives are sent from the CMOH to health care providers or other health entities as per the HPPA.

[6] The OHSA continues to apply during an influenza pandemic and prevails when there is a conflict between that act and any other legislation.

Party	Roles and responsibilities
Public Health Ontario (PHO) (through the MEOC)	Support the MOHLTC to use surveillance information to determine severity Lead and coordinate the provincial surveillance strategy Coordinate and provide provincial influenza laboratory testing Provide scientific and technical advice to the MOHLTC (e.g., advice on infection prevention and control measures) Generate knowledge translation tools and offer training opportunities to supplement the MOHLTC's recommendations, directives and response strategies
Ministry of Labour (MOL)	Provide OHS advice to the MOHLTC (through the MEOC) Enforce the OHSA and its regulations
Emergency Management Ontario	Coordinate the provincial response to an influenza pandemic, with an emphasis on coordinating responses to non-health system impacts and consequences as outlined in the Provincial Coordination Plan for an Influenza Pandemic
Local Health Integration Networks (LHINs)[7]	Liaise between transfer payment (TP) organizations and the MOHLTC Participate in the coordination of local care & treatment
Public health units (PHUs)[8]	Follow MOHLTC recommendations, directives, orders and requests Develop and issue orders[9] Lead local implementation of the surveillance strategy Lead local implementation of immunization Participate in the coordination of local care & treatment Lead local implementation of public health measures Continue to provide other public health services

[7] Other LHIN roles during an influenza pandemic are currently under development.

[8] Throughout the OHPIP, PHU includes boards of health, medical officers of health (MOHs) and other PHU health workers (e.g., public health inspectors, epidemiologists, public health nurses, etc.). See the HPPA and Ontario Public Health Standards for more information on the roles and responsibilities of various PHU parties.

[9] This refers to orders made by MOHs and public health inspectors as per the HPPA.

Party	Roles and responsibilities
Health liaison organizations (provincial associations, unions and regulatory bodies)	Liaise between members and the MOHLTC (see Chapter 2: Health Sector Communications) Share best practices among sector/ membership
Health workers and health sector employers[10]	Follow MOHLTC recommendations, directives, orders and requests Follow PHU orders Continue to provide safe and effective care Participate in the coordination of local care & treatment Participate in research and surveillance activities Practice and role model appropriate behaviour to protect clients/ patients/ residents (C/P/Rs) and prevent further spread of influenza (e.g., get immunized; practise respiratory etiquette and hand hygiene; stay home when sick)
Other employers	Implement public health measures Follow MOHLTC orders and requests Follow PHU orders Encourage immunization among employees Be immunized as soon as possible
Public	Follow public health measures such as staying home when symptomatic, performing hand hygiene and keeping commonly touched surfaces clean Follow MOHLTC and PHU orders Be immunized as soon as possible

Ontario's approach to an influenza pandemic

The 2013 OHPIP is a response document. As opposed to providing detailed planning guidance for provincial health system partners, it outlines anticipated response activities

[10] See Chapter 5: Occupational Health & Safety and Infection Prevention & Control and Chapter 9: Primary Health Care.

based on the severity of the pandemic virus. The actual response activities will be confirmed by the MOHLTC at the time of a pandemic based on the epidemiology of the virus (see Chapter 3: Surveillance), impacts on the provincial health system and behavioural responses of the public. Before these things are known, the MOHLTC considers the precautionary principle in making decisions. During the planning phase, provincial health system partners are encouraged to review the response activities outlined in the OHPIP and take steps to ensure they are able to perform their role during an influenza pandemic. Health system partners are also encouraged to have continuity of operations plans in place that enable them to respond to any type of business disruption, including an influenza pandemic.

The MOHLTC recognizes that planning to respond to an influenza pandemic is not enough.

To ensure an effective pandemic response, health workers and health sector employers need to appropriately respond to seasonal influenza each year – including consistently applying appropriate OHS & infection prevention & control (IPAC) measures; effectively promoting and administering influenza immunization programs for C/P/Rs, health workers and members of the public; implementing timely epidemiological and laboratory surveillance; engaging and tailoring interventions to the needs of vulnerable populations; and promoting appropriate public health measures

Preparedness tip

Health organizations should develop a continuity of operations plan to support their ability to respond to emergencies, such as an influenza pandemic. PHUs can use the Ontario Public Health Standards' Public Health Emergency Preparedness Protocol to guide their planning.

Ontario's influenza pandemic response objectives

The objectives of the MOHLTC's response to an influenza pandemic are consistent with those in the CPIP:

- first, to minimize serious illness and overall deaths through appropriate management of Ontario's health system
- second, to minimize societal disruption in Ontario as a result of an influenza pandemic

Guiding principles

The actions of the MOHLTC during a pandemic response are based on the following guiding principles. Many of these principles are useful in guiding the decision making of

other parties, including health sector employers, health workers, emergency planners and other public health leaders.

Evidence

The MOHLTC uses scientific and technical evidence to inform decision-making, including evidence on the risk posed by the pandemic. The MOHLTC partners closely with PHO to obtain, understand and communicate the evidence.

Legislation

The MOHLTC responds based on provincial legislative requirements and responsibilities.

Precautionary principle

The MOHLTC does not await scientific certainty before taking action to protect health. For example, the MOHLTC considers the precautionary principle when developing recommendations and directives related to OHS & IPAC measures, especially during the early stages of an influenza pandemic when scientific evidence on the severity of the novel virus is limited.[11]

See Chapter 5: Occupational Health & Safety and Infection Prevention & Control for more information on the application of the precautionary principle to OHS.

Ontario Public Service values

The MOHLTC uses the Ontario Public Service values to inform decision making during an influenza pandemic.

Work is underway federally to develop an ethical framework for the CPIP. Future versions of the OIRP will include an ethical framework that aligns with that in the CPIP.

Health equity

The MOHLTC considers the needs of vulnerable populations[12] when developing response and recovery measures.

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[11] As outlined in the HPPA, the CMOH must consider the precautionary principle when issuing a directive to a health care provider or health care entity related to health worker health and safety in the use of any protective clothing, equipment or device.

[12] The OHPIP defines vulnerable populations as a group of people who, because of the determinants of health, are more likely to be exposed to influenza, more likely to

To accomplish this, the MOHLTC may use the Health Equity Impact Assessment (HEIA), a decision support tool developed by the ministry to identify how a health program, service or policy impacts population groups in different ways. Work is underway at the MOHLTC to adapt the HEIA for a health emergency management context to ensure that provincial and local interventions do not exacerbate health disparities during an emergency.

Communication principles

The MOHLTC bases its communications with the provincial health system and the public on the following principles[13]:

- timeliness
- transparency
- accessibility
- credibility

Assumptions

The 2013 OHPIP is based on the following assumptions:

Origin and Timing

- The next pandemic could emerge anywhere in the world – including in Ontario.
- The next pandemic could emerge at any time of year.
- Ontario has little lead time between when a pandemic virus is first identified and when it arrives in the province.

Transmission

- The pandemic virus behaves like seasonal influenza viruses in significant ways, including the incubation period, period of communicability and methods of transmission.
- The pandemic strain is primarily community spread; that is, it is transmitted from person-to-person in the community as well as in institutional settings.

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experience a serious impact because of exposure, less likely to benefit from response and recovery measures and/ or who may be negatively affected by response and recovery measures.

[13] See Chapter 2: Health Sector Communications for more information on the application of these principles to the MOHLTC's two-way communications with the health system.

Pandemic Epidemiology

- An influenza pandemic consists of two or more waves – or intense periods – of viral transmission.
- The novel influenza virus displaces other circulating seasonal strains during the pandemic.

Clinical Features

- As with seasonal influenza, the severity of the pandemic cannot be predicted, may be partially determined by the effectiveness of interventions such as treatment with antivirals and is not easily determinable at the start of an outbreak. (See Severity of an influenza pandemic for more information on the scenarios used to guide the development of the 2013 OHPIP).
- As with seasonal influenza, the clinical severity of the illness experienced by Ontarians who are infected by the pandemic virus varies considerably: some individuals who are infected do not display any clinical symptoms, while others become quite ill and may require hospitalization and may even die.
- The groups at increased risk for severe disease and complications during an influenza pandemic are similar to those for seasonal influenza; however, there may be additional high-risk groups because of specific features of the pandemic virus.
- Vulnerable populations that typically experience a disproportionate burden of negative health outcomes, or are more vulnerable to these outcomes, because of the effects of the social determinants of health are more severely affected by the pandemic than other members of the community. This includes Ontarians with low incomes, who face language barriers, and who are homeless.

Interventions

- Vaccine is available in time to have an impact on the overall pandemic; however, it is not available for the first wave.
- The MOHLTC maintains an antiviral stockpile to provide treatment for individuals that meet its clinical recommendations.
- The efficacy and dose requirements of antivirals are not known until the pandemic begins and may differ from that of seasonal influenza; therefore, recommendations may change.

Severity of an influenza pandemic

Given that the severity of a pandemic cannot be known in advance, the anticipated response activities outlined in the 2013 OHPIP are based on a number of severity scenarios adapted from draft work undertaken by the Centers for Disease Control and Prevention. In this model, severity is measured along two dimensions – transmissibility of the virus and clinical severity of illness. There are four severity scenarios – ranging from a mild scenario that is similar to seasonal influenza (low transmissibility and low

clinical severity) to the most severe scenario with high transmission and high clinical severity rates.

As well, the OHPIP severity model includes an initial stage before severity is known when the limited availability of surveillance data does not allow for confident identification of severity. The severity may not be clearly known until after an influenza pandemic is over. The MOHLTC uses surveillance data to estimate severity (see Chapter 3: Surveillance).

This model has been used to provide information on the types of responses that may be used during an influenza pandemic. As more information about the severity of an influenza pandemic is available, the MOHLTC will establish and communicate the provincial response strategies such as the outpatient care & treatment strategy, immunization strategy, public health measures strategy, antiviral distribution strategy and surveillance strategy.

Figure 1 outlines the four severity scenarios used in the OHPIP. Table 2 outlines how various influenza pandemics and seasonal epidemics are categorized in this model and the major health system impacts.

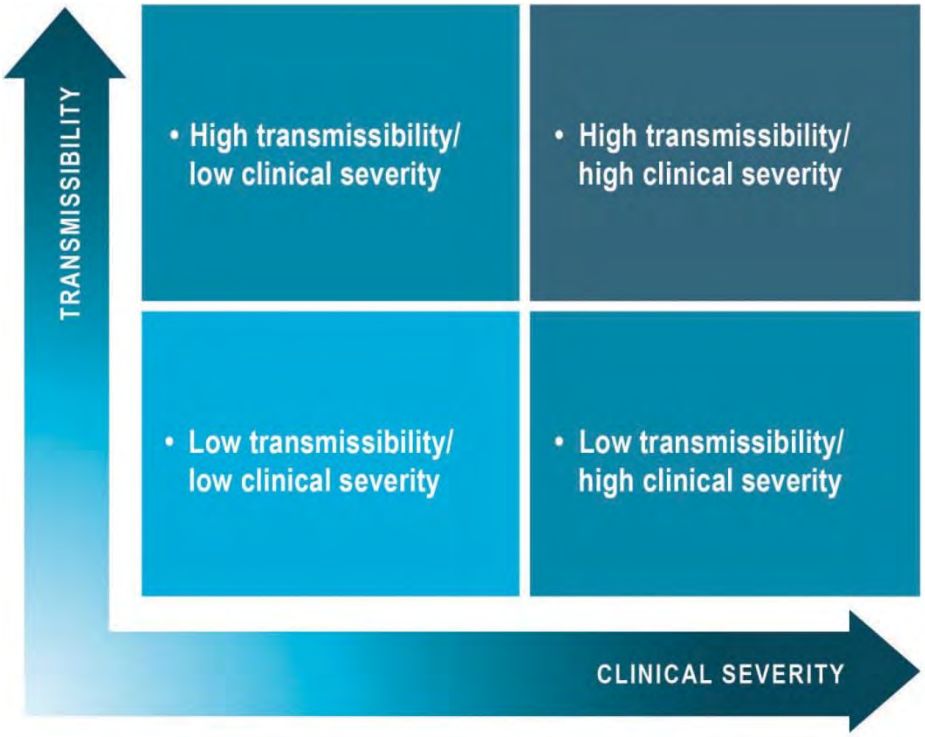

FIGURE 1. FOUR SEVERITY SCENARIOS USED IN THE OHPIP

TABLE 2. EXAMPLES AND IMPACT OF SEVERITY SCENARIOS

Overall severity	Characteristics	Examples	Impact on health system
Before severity is known	Limited surveillance data available	Either in the pre-pandemic phase or early in the pandemic, before there is enough information available to determine the severity of the pandemic	Unknown
Low transmissibility & low clinical severity	Cumulative attack rate[14]: < 21% R_0 (basic reproduction number)[15]: <1.6 Case Fatality Rate (CFR)[16]: <0.25%	Typical seasonal influenza epidemics 2009 influenza pandemic 1968 influenza pandemic	Comparable to seasonal influenza
High transmissibility & low clinical severity	Cumulative attack rate: ≥21% $R_0 \geq 1.6$ CFR: <0.25%	1927-28 seasonal influenza epidemic	Significant workplace absenteeism High burden on outpatient and acute services
Low transmissibility & high clinical severity	Cumulative attack rate: < 21% R_0: <1.6 CFR: ≥0.25%	1957 influenza pandemic	High burden on critical health care services

[14] The cumulative attack rate is the percentage of people who (are expected to) become symptomatic at some point during the influenza pandemic.

[15] The basic reproductive number is the number of secondary cases one case should produce in a completely susceptible population.

[16] The case fatality rate is the ratio of deaths within a designated population of cases over the course of a pandemic.

Overall severity	Characteristics	Examples	Impact on health system
High transmissibility & high clinical severity	Cumulative attack Rate: ≥21% R_0≥1.6 CFR: ≥0.25%	1918 influenza pandemic	Significant need for public health measures High burden on critical health care services

In addition to the characteristics of the virus, other factors – including the effectiveness of interventions, the behavioural response of Ontarians, the capacity of Ontario's health system and the social determinants of health – determine the impact of the pandemic.

Another consideration is that novel influenza viruses may differentially affect specific populations. For example, while the severity of a pandemic may be comparable to seasonal influenza (low transmissibility and low clinical severity), transmissibility or clinical severity could be significantly higher in specific population groups (e.g., children and youth). Therefore, the MOHLTC may need to develop recommendations and response strategies during an influenza pandemic to address specific population needs.

Next steps

In the development of the OIRP, the MOHLTC will work with its partners to:

- continue to clarify the role of LHINs in influenza pandemic response
- align the OIRP with the CPIP, including
  - the measurement of pandemic severity
  - ethical framework
- further develop strategies to support vulnerable populations, including adapting the HEIA for a health emergency management context

Appendix A – OHPIP Steering Committee and workgroup members

The MOHLTC is grateful to the following organizations and their members for their contributions to the 2012-13 OHPIP Steering Committee, workgroups and consultations:

- Aboriginal Affairs and Northern Development Canada
- Association of Family Health Teams of Ontario
- Association of Iroquois and Allied Indians
- Association of Local Public Health Agencies
- Association of Municipalities of Ontario
- Association of Ontario Health Centres
- Chiefs of Ontario
- Critical Care Services Ontario
- Emergency Management Ontario, Ministry of Community Safety and Correctional Services
- Emergency Nurses Association of Ontario
- Federation of Health Regulatory Colleges of Ontario
- First Nations and Inuit Health Branch, Ontario Region
- Independent First Nations
- Local Health Integration Networks
- Ministry of Children and Youth Services
- Ministry of Community and Social Services
- Ministry of Labour
- Nishnawbe Aski Nation
- Nurse Practitioners Association of Ontario
- Ontario Association for Non-Profit Homes and Services for Seniors
- Ontario Association of Community Care Access Centres
- Ontario Association of Medical Laboratories
- Ontario College of Family Physicians
- Ontario Community Support Association
- Ontario Home Care Association

- Ontario Hospital Association
- Ontario Long-Term Care Association
- Ontario Medical Association
- Ontario Nurses' Association
- Ontario Pharmacists' Association
- Ontario Public Services Employees Union
- Public Health Agency of Canada, Ontario and Nunavut Region
- Public Health Ontario
- Public Services Health & Safety Association
- Registered Nurses' Association of Ontario
- Union of Ontario Indians (Anishinabek Nation)

Appendix B – Glossary

Additional precautions

Additional precautions (i.e., contact precautions, droplet precautions and airborne precautions) that are necessary in addition to routine practices for certain pathogens or clinical presentations. These precautions are based on the method of transmission (e.g., contact, droplet, airborne). (Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in All Health Care Settings).

Adverse event

Adverse events are an unexpected and undesired incident directly associated with the care or services provided to the client/patient/resident (Source: Provincial Infectious Disease Advisory Committee's Best Practices for Infection Prevention and Control Programs in Ontario).

Aerosol-generating medical procedure

Aerosol-generating medical procedures are any procedure carried out on a client, patient or resident that can induce the production of aerosols as a result of manipulation of a person's airway. Examples of aerosol-generating medical procedures include intubation and related procedures (e.g., manual ventilation, open endotracheal suctioning); cardiopulmonary resuscitation; bronchoscopy; sputum induction; nebulized therapy; surgery and autopsy; and bi-level positive airway pressure (i.e., BiPAP) (Source: Canadian Pandemic Influenza Plan for the Health Sector).

Affiliated clients/ patients

Also known as rostered clients/ patients. Affiliated clients/ patients are formally enrolled with a primary health care organization, such as a family health team, community health centre or Aboriginal health access centre. Clients/ patients that are affiliated with a primary health care organization typically do not seek primary health care services in other locations.

Airborne precautions

Airborne precautions are used in addition to routine practices for clients/ patients/ residents known or suspected of having an illness transmitted by the airborne route (i.e., by small droplet nuclei that remain suspended in the air and may be inhaled by others)

(Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in all Health Care Settings).

Client/ patient/ resident

Any person receiving health care services within a health care setting (Source: Provincial Infectious Disease Advisory Committee's Best Practices for Infection Prevention and Control Programs in Ontario).

Client/ patient/ resident environment

The immediate space around a client/ patient/ resident that may be touched by the client/ patient/ resident and may also be touched by the health care provider when providing care. The client/ patient/ resident environment includes equipment, medical devices, furniture (e.g., bed, chair, bedside table), telephone, privacy curtains, personal belongings (e.g., clothes, books) and the bathroom that the client/ patient/ resident uses. In a multi-bed room, the client/ patient/ resident environment is the area inside the individual's curtain. In an ambulatory setting, the client/ patient/ resident environment is the area that may come into contact with the client/ patient/ resident within their cubicle. In a nursery/ neonatal setting, the patient environment is the isolette or bassinet and equipment outside the isolette/bassinet that is used for the infant. Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in all Health Care Settings).

Cohorting

The assignment of a geographic area such as a room or a care area to two or more clients/ patients/ residents who are either colonized or infected with the same microorganism, with staffing assignments restricted to the cohorted group of patients (Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in all Health Care Settings).

Contact tracing

The process of identifying relevant contacts of a person with an infectious disease and ensuring that they are aware of their exposure (Source: Provincial Infectious Disease Advisory Committee's Sexually Transmitted Infections Case Management and Contact Tracing Best Practice Recommendations).

Directives

Instructions that may be issued by the Chief Medical Officer of Health under the terms of the Health Protection and Promotion Act. A health care provider or health care entity that is served with a directive must comply with it.

Eye protection

A device that covers the eyes and is used by health care providers to protect the eyes when it is anticipated that a procedure or care activity is likely to generate splashes or sprays of blood, body fluids, secretions or excretions, or within two metres of a coughing client/patient/resident. Eye protection includes safety glasses, safety goggles, face shields and visors (Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in all Health Care Settings).

Fit-test

A qualitative or quantitative method to evaluate the fit of a specific make, model and size of respirator on an individual. Fit-testing is to be done periodically, at least every two years and whenever there is a change in respirator face piece or the user's physical condition that could affect the respirator fit (Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in all Health Care Settings).

Flu assessment centre

Temporary services during an influenza pandemic provided by primary health care organizations or emergency departments to provide influenza care & treatment services to community members who cannot rapidly access primary health care, with temporary financial and material support of the Ministry of Health and Long-Term Care.

Hand hygiene

A general term referring to any action of hand cleaning. Hand hygiene relates to the removal of visible soil and removal or killing of transient microorganisms from the hands. Hand hygiene may be accomplished using soap and running water or an alcohol-based hand rub. Hand hygiene also includes surgical hand antisepsis (Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in all Health Care Settings).

Health and safety representative

Workplaces with more than five workers and no joint health and safety committee must have a health and safety representative [section 8(1)]. Like joint health and safety committee members, the representative is committed to improving health and safety conditions in the workplace. (Source: Ministry of Labour's A Guide for Joint Health and Safety Committees and Representatives in the Workplace).

Health care-associated infection

A term relating to an infection that is acquired during the delivery of health care services (also known as '*nosocomial infection'*) (Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in all Health Care Settings).

Health care facility

A set of physical infrastructure elements supporting the delivery of health care services. A health care facility does not include a client's/ patient's home or physician offices where health care services may be provided (Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in all Health Care Settings).

Health care provider

Any person delivering health care services to a client/ patient/ resident. This includes, but is not limited to, the following: emergency service workers, physicians, dentists, nurses, respiratory therapists and other health professionals, personal support workers, clinical instructors, students and home health care workers. In some non-acute settings, volunteers might provide care and would be included as a health care provider. See also, *Staff* (Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in all Health Care Settings).

Health Care Provider Hotline

24/7 line for health care providers to contact the Ministry of Health and Long-Term Care's Emergency Management Branch (1-866-212-2272). This Hotline can be used by health system partners to reach the ministry during the response to an emergency. It is also operational during non-emergencies to enable health system partners to inform the ministry of a hazard or risk that has the potential to become an emergency.

Health care setting

Any location where health care services are provided, including settings where emergency care is provided, hospitals, complex continuing care, rehabilitation hospitals, long-term care homes, mental health facilities, outpatient clinics, community health centres and clinics, physician offices, dental offices, offices of allied health professionals and home health care (Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in all Health Care Settings).

Health care services

Direct client/ patient/ resident care, including diagnostic, treatment and care services.

Health Equity Impact Assessment

The Ministry of Health and Long-Term Care's Health Equity Impact Assessment is a decision support tool that walks users through the steps of identifying how a program, policy or similar initiative impacts population groups in different ways. The Health Equity Impact Assessment surfaces unintended potential impacts. The end goal is to maximize positive impacts and reduce negative impacts that could potentially widen health disparities between population groups — in short, more equitable delivery of the program, service or policy.

Health liaison organization

A provincial health association, union or regulatory body that liaises between its members and the Ministry of Health and Long-Term Care during an emergency. These organizations are a critical conduit for information collection, analysis and dissemination. Health liaison organizations typically participate in the Health Stakeholder Teleconference. See Chapter 2: Health Sector Communications for more information.

Health organization

An organization or agency that receive funding from the Ministry of Health and Long-Term Care to provide health services.

Health sector

Part of the economy dealing with health-related issues in society. (Source: WHO's Health System Performance Website)

Health sector employer

A person in a health setting who employs one of more workers or contracts for the services of one or more workers and includes a contractor or subcontractor who performs work or supplies services and a contractor or subcontractor who undertakes with an owner, constructor, contractor or subcontractor to perform work or supply services.(Source: Based on the Occupational Health and Safety Act)

Health services

Services delivered by the health system, including health promotion, disease prevention, diagnostic, treatment and care services.

Health setting

Organizations and agencies that receive funding through the Ministry of Health and Long-Term Care to provide health services.

Health system

The people, institutions and resources, arranged together in accordance with established policies, to improve the health of the population they serve, while responding to people's legitimate expectations and protecting them against the cost of ill-health through a variety of activities whose primary intent is to improve health. (Source: WHO's Health System Performance Website).

Health worker

A person who performs work or supplies services for monetary compensation in a health setting (Source: based on the Occupational Health and Safety Act)

High-risk group

Population with an increased likelihood of becoming ill and/ or suffering serious health outcomes as a consequence of pandemic influenza virus infection.

Infection

The entry and multiplication of an infectious agent in the tissues of the host. Asymptomatic or sub-clinical infection is an infectious process running a course similar to that of clinical disease but below the threshold of clinical symptoms. Symptomatic or clinical infection is on resulting in clinical signs and symptoms (disease) (Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in all Health Care Settings).

Infection prevention & control

Evidence-based practices and procedures that, when applied consistently in health care settings, can prevent or reduce the risk of transmission of microorganisms to health care providers, other clients/patients/residents and visitors (Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in all Health Care Settings).

Infection prevention & control professional(s)

Trained individuals responsible for a health care setting's infection prevention & control activities. In Ontario, an infection prevention & control professional must receive a minimum for 80 hours of instruction in a Community and Hospital Infection Control Association of Canada endorsed infection control program within six months of entering their role and must acquire and maintain Certification in Infection Control when eligible (Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in all Health Care Settings).

Infection prevention & control program

A health care facility or organization (e.g., hospital, long-term care, continuing complex care, home care) program responsible for meeting the recommended mandate to decrease infections in the client/ patient/ resident, health care providers and visitors. The program is coordinated by health care providers with expertise in infection prevention & control and epidemiology (Source: Provincial Infectious Disease Advisory Committee's Best Practices for Infection Prevention and Control Programs in Ontario).

Influenza

A highly contagious, febrile, acute respiratory infection of the nose, throat, bronchial tubes and lungs caused by the influenza virus. It is responsible for severe and potentially fatal clinical illness of epidemic and pandemic proportions (Source: Canadian Pandemic Influenza Plan for the Health Sector).

Influenza-like illness

A cluster of symptoms resembling and that could be caused by influenza, without laboratory confirmation. Case definitions for influenza-like illness vary, and are provided during an influenza pandemic by the Ministry of Health and Long-Term Care,

Integrated Public Health Information System

The information technology system used by public health units to report case information on all reportable communicable diseases that are outlined in the Health Protection and Promotion Act. Public health units are responsible for collecting case information on reportable communicable diseases occurring within their boundaries and entering this information into this system.

Isolation

Separation, for the period of communicability, of infected persons or animals from others in such places and under such conditions as to prevent or limit the direct or

indirect transmission or the infectious agent from those infected to those who are susceptible or who may spread the agent to others. (Source: Canadian Pandemic Influenza Plan for the Health Sector)

Joint health and safety committee

Committee composed of people who represent the workers and the employer, as described under the Occupational Health and Safety Act. Together, they are committed to improving health and safety conditions in the workplace. Committees identify potential health and safety problems and bring them to the employer's attention. As well, members must be kept informed of health and safety developments in the workplace. (Source: Ministry of Labour's A Guide for Joint Health and Safety Committees and Representatives in the Workplace).

Key population groups for immunization

The key population groups for immunization are those groups that are eligible to receive the pandemic vaccine. Given that vaccine availability will increase over time, the key population groups will expand during the course of the pandemic immunization program (i.e., additional population groups will be added as more vaccine becomes available).

Local Health Integration Network transfer payment agency

Also known as Local Health Integration Network Health Service Providers. Organizations that Local Health Integration Networks are responsible for, including hospitals, divested psychiatric hospitals, community care access centres, community support service organizations, community mental health and addictions agencies, community health centres and long-term care homes.

Long-term care

A broad range of personal care, support and health services provided to people who have limitations that prevention them from full participation in the activities of daily living. The people who use long-term care services are usually the elderly, people with disabilities and people who have a chronic or prolonged illness (Source: Provincial Infectious Disease Advisory Committee's Best Practices for Environmental Cleaning for Prevention and Control of Infections).

Mandatory public health measures

Extraordinary actions that are supported by the Health Protection and Promotion Act designed to address and counter specific public health threats.

Ministry Emergency Operations Centre

Site where the Ministry of Health and Long-Term Care coordinates its response to an emergency.

Ministry of Health and Long-Term Care

Throughout the Ontario Health Plan for an Influenza Pandemic, the Ministry of Health and Long-Term Care includes the Minister, Chief Medical Officer of Health and the rest of the Ministry of Health and Long-Term Care. For information on how emergency decisions are made in the MOHLTC, please see the Ministry Emergency Response Plan.

N95 respirator

A personal protective device that is worn on the face and covers the nose and mouth to reduce the wearer's risk of inhaling airborne particles. A National Institute for Occupational Safety and Health-certified N95 respirator filters particles one micron in size, has 95% filter efficiency and provides a tight facial seal with less than 10% leak (Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in All Health Care Settings).

Outpatient settings

Pertaining to a health care organization that provides influenza care & treatment services for clients/ patients who are not hospitalized or admitted to a long-term care home. It includes primary health care organizations, hospital emergency departments, community-based pharmacies and home care settings.

Pandemic

An epidemic disease of widespread prevalence around the globe (Source: Canadian Pandemic Influenza Plan for the Health Sector).

Pandemic Precautions

Occupational health & safety and infection prevention & control precautions recommended in health care settings during an influenza pandemic (e.g., use of N95 respirators for health workers at risk of exposure to a client/ patient/ resident with influenza-like illness or that client/ patient/ resident's environment)

Personal protective equipment

Clothing or equipment worn by health workers for protection against hazards (Source: Based on Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in All Health Care Settings).

Point of care

The place where three elements occur together: the client/ patient/ resident, the health care provider, and care or treatment involving client/ patient/ resident contact (Source: Provincial Infectious Disease Advisory Committee's Best Practices for Infection Prevention and Control Programs in Ontario).

Precautions

Interventions to reduce the risk of transmission of microorganisms (e.g., client/ patient/ resident-to-client/ patient/ resident, client/ patient/ resident-to-worker, contact with the environment, contact with contaminated equipment). (Source: PIDAC's Best Practices for Environmental Cleaning for Prevention and Control of Infections)

Precautionary principle

A principle used by the Ministry of Health and Long-Term Care and Chief Medical Officer of Health to guide decision-making during an emergency. According to this principle, reasonable steps to reduce risk should not await scientific certainty (Source: Spring of Fear, Justice Archie Campbell).

Primary health care

Primary care (the provision of integrated, accessible health care services by clinicians who are accountable for addressing a large majority of personal health care needs, developing a sustained partnership with clients/ patients and practicing in the context of family and community), disease prevention, health promotion, population health and community development within a holistic framework, with the aim of providing essential community-focused health care (Sources: World Health Organization, Institute of Medicine). Primary health care organizations include family health teams, community health centres, Aboriginal health access centres, departments of family medicine, nurse practitioner-led clinics and solo practitioners such as family physicians, general practitioners and pediatricians.

Provincial Infectious Disease Advisory Committee

A multidisciplinary scientific advisory body that provides to the Chief Medical Officer of Health evidence-based advice regarding multiple aspects of infectious disease identification, prevention and control (Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in all Health Care Settings).

Public Health Agency of Canada

A national agency that promotes improvement in the health status of Canadians through public health action and the development of national guidelines (Source: Provincial Infectious Disease Advisory Committee's Best Practices for Environmental Cleaning for Prevention and Control of Infections).

Public health measures

Non-pharmaceutical interventions that help to slow the spread of disease in the community.

Public Health Ontario

Formerly known as the Ontario Agency for Health Protection and Promotion. An arm's-length government agency dedicated to protecting and promoting the health of all Ontarians and reducing inequities in health. Public Health Ontario was created by legislation in 2007 and began operations in July 2008 with a mandate to provide scientific and technical advice to those working to protect and promote the health of Ontarians. Its vision is to be an internationally recognized centre of expertise dedicated to protecting and promoting the health of all Ontarians through the application and advancement of science and knowledge (Source: Provincial Infectious Disease Advisory Committee's Best Practices for Infection Prevention and Control in Perinatology).

Recommendations from the Ministry of Health and Long-Term Care

This term refers clinical, occupational health & safety and infection prevention & control guidance. Recommendations related to occupational health & safety may be considered reasonable precautions in the application of the Occupational Health and Safety Act.

Regional Infection Control Networks

Networks that coordinate and integrate resources related to the prevention, surveillance and control of infectious diseases across all health care sectors and for all health care providers, promoting a common approach to infection prevention & control and utilization of best-practices within the region (Source: Provincial Infectious Disease Advisory Committee's Best Practices for Environmental Cleaning for Prevention and Control of Infections).

Respiratory etiquette

Personal practices that help prevent the spread of bacteria and viruses that cause acute respiratory infections (e.g., covering the mouth when coughing, care when disposing of tissues) (Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in all Health Care Settings).

Routine practices

The system of infection prevention & control practices recommended by the Public Health Agency of Canada to be used with all clients/ patients/ residents during all care activities to prevent and control transmission of microorganisms in all health care settings (Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in all Health Care Settings).

Seal-check

A procedure that the health care provider must perform each time an N95 respirator is worn to ensure it fits the wearer's face correctly to provide adequate respiratory protection (Source: Provincial Infectious Disease Advisory Committee's Routine Practices and Additional Precautions in all Health Care Settings).

Sentinel health care provider

A health care provider that participates in a sentinel surveillance system. In Ontario, sentinel health care providers participate in Public Health Agency of Canada's FluWatch Program or the national Sentinel Vaccine Effectiveness Study. Ideally, Ontario would have adequate numbers of sentinel health care providers, representative of the population of the province, so that the information gathered from FluWatch and the Sentinel Vaccine Effectiveness Study could be applied to the population as a whole.

Seroprevalance

The proportion of a population that is seropositive – i.e., has been exposed to the influenza virus.

Surgical mask

Also known as procedure mask. Surgical masks are used as physical barriers to protect users from hazards, such as splashes of large droplets of blood or body fluids. Surgical masks are used for several different purposes, including being placed on sick people to limit the spread of infectious respiratory secretions to others. (Source: Based on United States Department of Labor Occupational Safety and Health Administration Fact Sheet: Respiratory Infection Control).

Surveillance

The systematic ongoing collection, collation and analysis of data with timely dissemination of information to those who require it in order to take action (Source: Provincial Infectious Disease Advisory Committee's Best Practices for Infection Prevention and Control Programs in Ontario).

Syndromic surveillance

The detection of individual and population health indicators of illness (i.e., signs and symptoms of infectious disease) that are discernible before confirmed laboratory diagnoses are made (Source: Provincial Infectious Disease Advisory Committee's Best Practices for Infection Prevention and Control Programs in Ontario).

Vaccine delivery agent

Health care providers who administer immunization outside of a public health unit.

Visitor

An individual who does not have an established relationship with a health organization. Visitors may be household contacts and friends that accompany clients/ patients to outpatient settings or visit clients/ patients/ residents in inpatient settings.

Voluntary public health measures

The behaviours and the environmental supports that create the conditions that support good public health practices.

Vulnerable population

A group of people who, because of the determinants of health, are more likely to be exposed to influenza, more likely to experience a serious impact because of exposure,

less likely to benefit from response and recovery measures and/ or who may be negatively affected by response and recovery measures.

Appendix C – Acronyms

AHAC	Aboriginal health access centre
BAL	bronchoalveolar lavage
CAEFISS	Canadian Adverse Events Following Immunization Surveillance System
CCIS	Critical Care Information System
CDC	Centers for Disease Control and Prevention
CFR	case fatality rate
CHC	community health centre
CMOH	Chief Medical Officer of Health
C/P/R	client/ patient/ resident
CPIP	Canadian Pandemic Influenza Plan for the Health Sector
EDSS	Emergency Department Syndromic Surveillance
EMCPA	Emergency Management and Civil Protection Act
ETT	endotracheal tube
FAC	flu assessment centre
F/P/T	federal - provincial - territorial
FF100	first few hundred
FHT	family health team
HCRF	Health Care and Residential Facilities regulation
HEIA	Health Equity Impact Assessment
HNS	Health Network System
HPPA	Health Protection and Promotion Act
HSR	health and safety representative
IHN	Important Health Notice
ILI	influenza-like illness
IMPACT	Immunization Monitoring Program ACTive
IPAC	infection prevention & control
iPHIS	Integrated Public Health Information System
IRS	internal responsibility system
JHSC	joint health and safety committee
LHIN	Local Health Integration Network

LTCHA	Long-Term Care Homes Act
MEOC	Ministry Emergency Operations Centre
MOH	medical officer of health
MOHLTC	Ministry of Health and Long-Term Care
MOL	Ministry of Labour
MRSA	methicillin-resistant *S. aureus*
NACI	National Advisory Committee on Immunization
NML	National Microbiology Laboratory
NP	nasopharyngeal
OHIP	Ontario Health Insurance Plan
OHPIP	Ontario Health Plan for an Influenza Pandemic
OHS	occupational health & safety
OHSA	Occupational Health and Safety Act
PEOC	Provincial Emergency Operations Centre
PHAC	Public Health Agency of Canada
PHO	Public Health Ontario
PHOL	Public Health Ontario Laboratories
PHU	public health unit
PICB	Performance Improvement and Compliance Branch
PIDAC	Provincial Infectious Disease Advisory Committee
PPE	personal protective equipment
R_0	basic reproduction number
RACE	recognize the hazard, assess the risk, control the risk and evaluate the controls
RICN	Regional Infection Control Network
RIDT	rapid influenza diagnostic testing
RP/AP	routine practices and additional precautions (i.e., PIDAC's Routine Practices and Additional Precautions in All Health Care Settings)
SARS	Severe Acute Respiratory Syndrome
TP	transfer payment
UIIP	Universal Influenza Immunization Program
VDA	vaccine delivery agent
WHO	World Health Organization

Catalogue # 017312 ISBN - 978-1-4606-1033-6 March/2013

Ontario

This is "**Exhibit D**"
to the Affidavit of Matthew Hodge,
affirmed this 2nd day of July, 2021

A Commissioner, etc.

World Health Organization

< Go back to all Coronavirus disease 2019 Q&As

Coronavirus disease (COVID-19)

12 October 2020 | Q&A

Latest update 13 May 2021 - WHO is continuously monitoring and responding to this pandemic. This Q&A will be updated as more is known about COVID-19, how it spreads and how it is affecting people worldwide. For more information, regularly check the WHO coronavirus pages. https://www.who.int/covid-19

What is COVID-19?

What are the symptoms of COVID-19?

What happens to people who get COVID-19?

Among those who develop symptoms, most (about 80%) recover from the disease without needing hospital treatment. About 15% become seriously ill and require oxygen and 5% become critically ill and need intensive care.

Complications leading to death may include respiratory failure, acute respiratory distress syndrome (ARDS), sepsis and septic shock, thromboembolism, and/or multiorgan failure, including injury of the heart, liver or kidneys.

In rare situations, children can develop a severe inflammatory syndrome a few weeks after infection.

Who is most at risk of severe illness from COVID-19?

Are there long-term effects of COVID-19?

How can we protect others and ourselves if we don't know who is infected?

When should I get a test for COVID-19?

What test should I get to see if I have COVID-19?

What about rapid tests?

I want to find out if I had COVID-19 in the past, what test could I take?

What is the difference between isolation and quarantine?

What should I do if I have been exposed to someone who has COVID-19?

How long does it take to develop symptoms?

Is there a vaccine for COVID-19?

What should I do if I have COVID-19 symptoms?

Are there treatments for COVID-19?

Are antibiotics effective in preventing or treating COVID-19?

العربية | 中文 | Français | Русский | Español

WHO TEAM Emergencies Preparedness

Related

COVID-19 hub

Advice for the public

All COVID-19 Q&As

WHO Information Network on Epidemics (EPI-WIN)

Science in 5 series: WHO experts explain the science related to COVID-19

This is "**Exhibit E**"
to the Affidavit of Matthew Hodge,
affirmed this 2nd day of July, 2021

A Commissioner, etc.

Public Health Ontario | Santé publique Ontario

Ontario COVID-19 Data Tool

The Ontario COVID-19 Data Tool provides epidemiological information on COVID-19 activity in Ontario to-date. Explore the most recent COVID-19 data including: daily case counts, hospitalizations and deaths (Case trends), total or recent cases counts by age and sex, map by public health unit, source of COVID-19 infection (acquisition), outbreaks and laboratory testing.

Additions to the Ontario COVID-19 Data Tool as of May 28th, 2021:

- Vaccine uptake data on the Summary, Map and Vaccines sections
- COVID-19 reproduction number and doubling time

The COVID-19 Data Tool is updated Monday to Fridays at 11:30 a.m. except on statutory holidays. For weekend case counts see the **Daily Epidemiological Summary.**

For questions about the data, please contact **EPIR@oahpp.ca**.

Summary | Case trends | Age and sex | Map | Acquisition | Reproduction | Outbreaks | Lab tests | Vaccines | Technical notes | Glossary

Summary +

Date

24 Jun 2021

Confirmed COVID-19 cases in Ontario

As of June 24, 2021

Daily cases, rates, hospitalizations and deaths by public health unit can be found in **Case trends**.

Change in cases

256

Recent cases

5,469

reported in last 14 days
1.0% of cases

Total cases

543,571

3,656.9 per 100,000

Total hospitalized

27,643

186.0 per 100,000
5.1% of cases

Total deaths

9,101

61.2 per 100,000
1.7% of cases

COVID-19 cases in Ontario with a variant of concern detected

As of June 24, 2021

Find daily case counts of COVID-19 variants of concern by public health unit in **Case trends**.

Total case counts for B.1.1.7 include all confirmed COVID-19 cases where lineage B.1.1.7 was identified by genomic analysis and those presumed to be B.1.1.7 based on a positive N501Y and negative E484K mutation.

Total cases

B.1.1.7	**143,035**
B.1.351	**1,161**
P.1	**4,270**

Laboratory tests for COVID-19 in Ontario

As of June 24, 2021

See daily historical data in **Lab tests**.

New tests

26,561

178.7 tests per 100,000

Daily % positive

1.3

Total tests

15,805,892

106,333.7 tests per 100,000

COVID-19 vaccine uptake in Ontario

As of June 23, 2021 Vaccine data are updated weekly on Thursdays.

See the **Vaccine** and **Map** tabs for more vaccination data.

At least one dose

9,753,684

65.6% of population

Fully vaccinated

3,348,673

22.5% of population

Change in cases reflects new cases reported since the previous day.

Recent cases include cases reported within the past 14 days with a three day lag from the time of data extraction.

Rate is per 100,000 population.

Hospitalizations include all cases reported as ever being hospitalized during their infection.

Percent positive refers to the percentage of tests performed that were positive for COVID-19 and does not translate to the number of specimens or persons testing positive.

New tests refer to the number of tests performed and do not reflect the number of specimens or persons tested.

COVID-19 variants of concern (VOC) cases are confirmed COVID-19 cases where a designated VOC was identified by genomic analysis of their SARS-CoV-2 positive specimen. Lineage B.1.1.7 includes cases where lineage B.1.1.7 was identified by genomic analysis and those presumed to be B.1.1.7 based on positive N501Y and negative E484K mutation

- **PANGO lineage B.1.1.7** first detected in England.
- **PANGO lineage B.1.351** first detected in South Africa.
- **PANGO lineage P.1** first detected in Brazil.

Interpret the VOC and mutation case counts with caution. Daily counts may change due to the varying time required to complete VOC testing and/or genomic analysis following the initial positive test for SARS-CoV-2 and may result in totals differing from past publicly reported case counts. Additionally, changes to the VOC testing algorithm may occur over time. Refer to the Technical Notes for more information.

Vaccine series: the number of vaccine doses within a schedule that has been approved by Health Canada. COVID-19 vaccine

products available in Ontario have either a one-dose (i.e. Janssen) or two-dose (i.e. Moderna, Pfizer-BioNTech, AstraZeneca or COVISHIELD) schedule. Note: Janssen vaccines have not yet been distributed in Ontario.

At least one dose: refers to individuals that have received at least one dose of a COVID-19 vaccine. Reflects individuals that have received the first dose of a two-dose series, as well as those that have completed a COVID-19 vaccine series.

At least one dose coverage: the proportion of the total population of Ontario, or a public health unit, that has received at least one dose of a COVID-19 vaccine. Reflects individuals that have received the first dose of a two-dose series, as well as those that have completed a COVID-19 vaccine series

Fully vaccinated: refers to individuals that have received both doses of a two-dose COVID-19 vaccine series (i.e. dose two of two) or one dose of a one-dose COVID-19 vaccine series (i.e. dose one of one). Reflects individuals that have completed a COVID-19 vaccine series.

Fully vaccinated coverage: the proportion of the total population of Ontario, or a public health unit, that has received both doses of a two-dose COVID-19 vaccine series (i.e. dose two of two) or one dose of a one-dose COVID-19 vaccine series (i.e. dose one of one). Reflects individuals that have completed a COVID-19 vaccine series.

« Previous Next »

Related Information

Coronavirus Disease 2019 (COVID-19)

External Resources

COVID-19 case data: All Ontario - Government of Ontario

COVID-19 cases in schools and child care centres - Ministry of Education

COVID-19 Hospitalizations - Government of Ontario

COVID-19 Vaccines Status - Government of Ontario

Updated 30 June 2021

This is "**Exhibit F**"
to the Affidavit of Matthew Hodge,
affirmed this 2nd day of July, 2021

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Government of Canada | Gouvernement du Canada

COVID-19 daily epidemiology update

Updated: June 29, 2021, 7 pm EST

Summary of COVID-19 cases across Canada and over time. Contains detailed data about the spread of the virus over time and in different regions of the country. Includes breakdowns by age and sex or gender. Provides an overview of hospitalizations and deaths, testing, variants of concern and exposures.

Key updates as of June 29, 2021, 7 pm EST

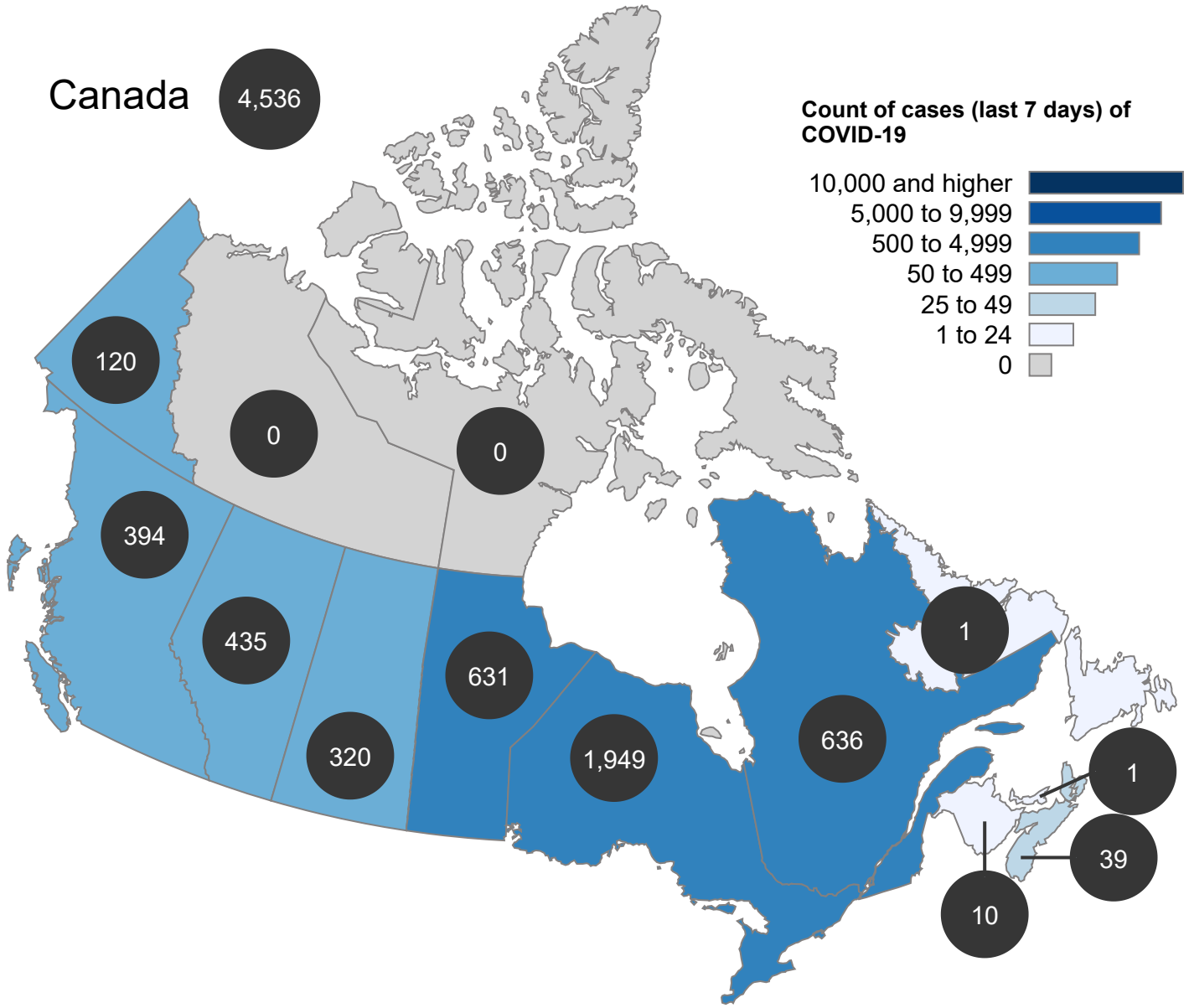
Cases today	Total cases	Active cases	Total resolved	Deaths today	Total deaths
602	1,414,736	7,447	1,381,016	35	26,273

Total tests performed	Daily percent positive (last 7 days)	Daily tests per 100,000 population (last 7 days)
36,705,571	1.2%	156

- We update these sections daily at 7:00 PM EST: Key updates, Current situation and National overview. Laboratory data represents specimens received by labs up to June 27, 2021 to allow time to process results.
- We update these sections every Friday: Epidemic curve, Demographics, How people were exposed, and Severe illness and outcomes.
- Most cases (65.0%) and deaths (77.5%) were reported by Ontario and Quebec.
- Of the 13 jurisdictions reporting updates, no new cases were reported in 3 provinces or territories in the past 24 hours.
- Of the 13 jurisdictions reporting updates, no new deaths were reported in 9 provinces or territories in the past 24 hours.

Current situation

Figure 1a. Count of cases (last 7 days) of COVID-19, by province/territory as of June 29, 2021



The count of cases (last 7 days) of COVID-19 in **Canada** was **4,536** as of June 29, 2021.

This information is based on data our provincial and territorial partners published on cases, deaths, and testing daily, and are current as of the day they are published. Today's numbers are current as of June 29, 2021. For the most up to date data for any province, territory or city, please visit their website. The number of cases or deaths reported on previous days may differ slightly from those on the provincial and territorial websites as these websites may update historic case and death counts as new information becomes available.

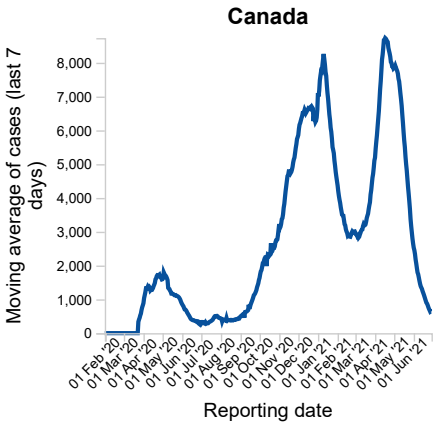
Areas in Canada with cases of COVID-19 as of June 29, 2021

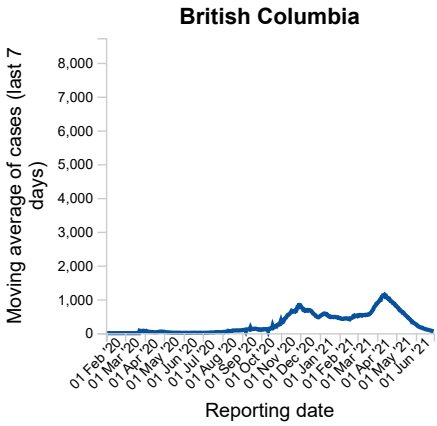
	Total cases		Cases last 7 days		Active cases		Resolved	Deaths		Deaths last 7 days		Total tests performed	Moving average tests performed last 7 days		Moving average positivity last 7 days
Location	Count	Rate*	Count	Rate*	Count	Rate*	Count	Count	Rate*	Count	Rate*	Count	Count	Rate*	Percent
Canada	**1,414,736**	**3,722**	**4,536**	**12**	**7,447**	**20**	**1,381,016**	**26,273**	**69**	**119**	**0**	**36,705,571**	**59,346**	**156**	**1.2%**
British Columbia	147,578	2,867	394	8	893	17	144,931	1,754	34	11	0	2,883,199	5,135	100	1.4%
Alberta	231,911	5,245	435	10	1,132	26	228,480	2,299	52	9	0	4,670,457	5,614	127	1.3%
Saskatchewan	48,823	4,142	320	27	464	39	47,791	568	48	4	0	910,196	1,579	134	3.2%
Manitoba	56,097	4,067	631	46	1,408	102	53,550	1,139	83	10	1	867,383	1,828	133	6.3%
Ontario	544,713	3,697	1,949	13	2,409	16	533,150	9,154	62	72	0	15,747,264	22,492	153	1.3%
Quebec	374,731	4,370	636	7	878	10	362,646	11,207	131	12	0	9,791,320	17,537	205	0.5%
Newfoundland and Labrador	1,385	265	1	0	9	2	1,369	7	1	0	0	300,841	702	135	0.1%
New Brunswick	2,329	298	10	1	26	3	2,258	45	6	0	0	373,609	594	76	0.2%
Nova Scotia	5,832	596	39	4	51	5	5,689	92	9	0	0	935,353	3,519	359	0.2%
Prince Edward Island	207	130	1	1	1	1	206	0	0	0	0	174,182	258	162	0.0%
Yukon	332	790	120	285	176	419	152	4	10	1	2	9,129	N/A	N/A	N/A
Northwest Territories	128	283	0	0	0	0	128	0	0	0	0	24,745	29	65	0.5%
Nunavut	657	1,670	0	0	0	0	653	4	10	0	0	17,817	58	147	0.0%

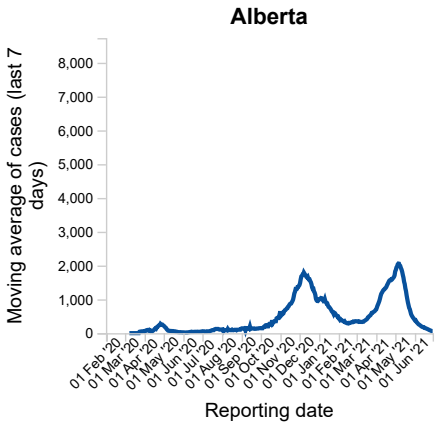
* Rate per 100,000 population

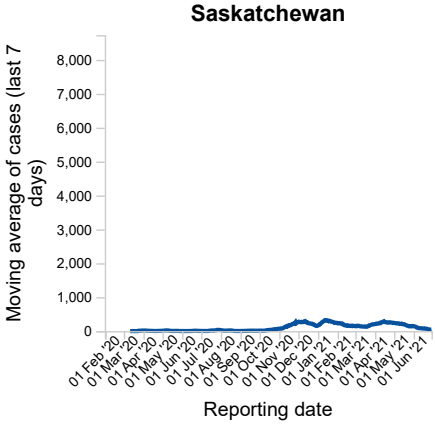
Figure 1b. Moving average of cases (last 7 days) of COVID-19 in Canada as of June 29, 2021, 7 pm EST

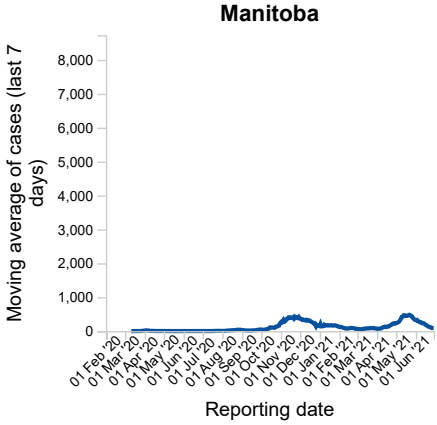
The figures below show cases over time. The range of dates (January 31st, 2020 - present date) is the same for each figure. This allows you to compare the provinces and territories on the same timescale.

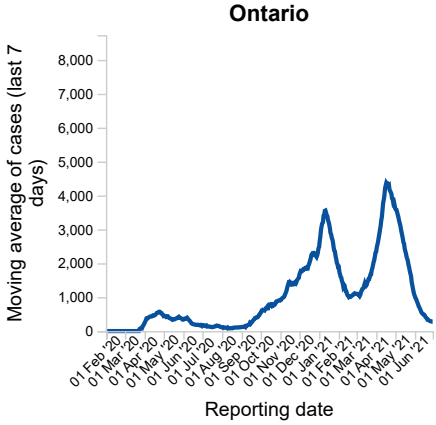


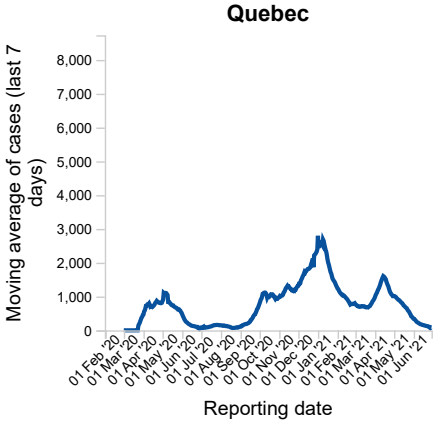


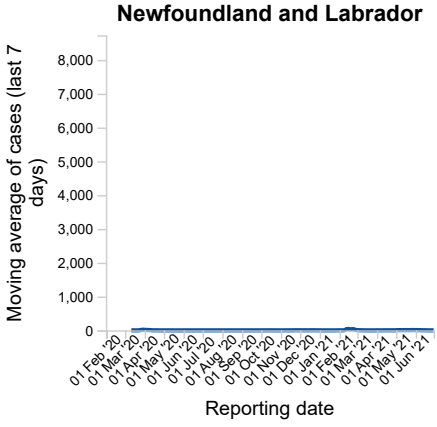


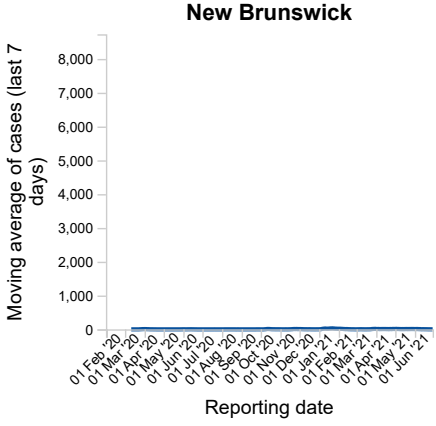


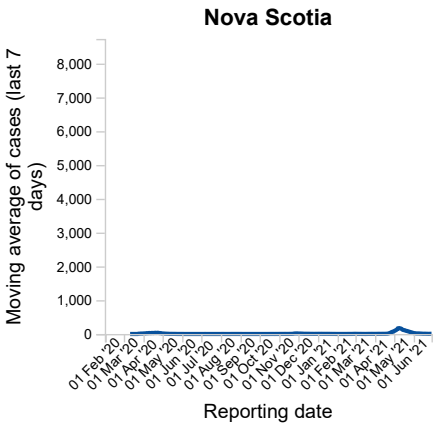


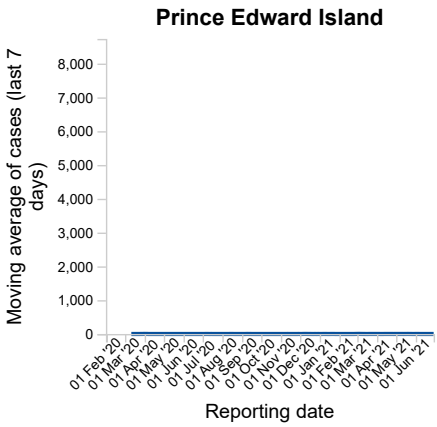


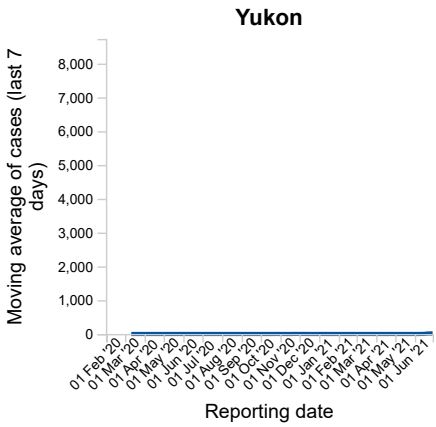


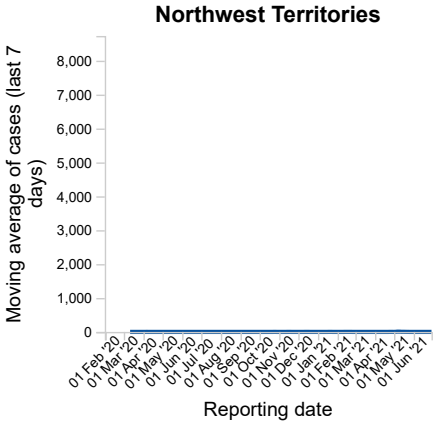


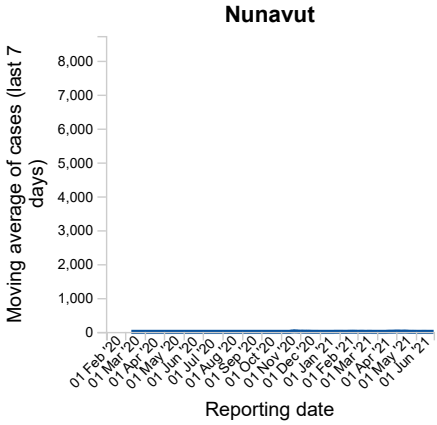












This information is based on data our provincial and territorial partners published on cases, deaths, and testing daily, and are current as of the day they are published. Today's numbers are current as of June 29, 2021. For the most up to date data for any province, territory or city, please visit their website. The number of cases or deaths reported on previous days may differ slightly from those on the provincial and territorial websites as these websites may update historic case and death counts as new information becomes available.

Downloadable data (in .csv format).

Note: Out of the total number of people tested, 76 were repatriated travellers, of which 13 were cases.

National overview

There have been over **36,705,571** COVID-19 tests performed in Canada or **965,803 tests per 1 million people**. Of these, **4.0%** were positive. For information about testing trends, please see the Detailed weekly epidemiological report (PDF).

Table 1. Daily* change in the number of cases, deaths and tests performed, by province or territory, as of June 29, 2021, 7 pm EST

Location	New cases	New deaths	Tests performed
Canada	**602**	**35**	**61,585**
British Columbia	29	0	3,664
Alberta	61	4	22,232
Saskatchewan	52	2	1,425
Manitoba	61	0	1,575
Ontario	299	25	13,071
Quebec	71	4	15,365
Newfoundland and Labrador	0	0	561
New Brunswick	3	0	401
Nova Scotia	1	0	3,077
Prince Edward Island	1	0	138
Yukon	24	0	N/A
Northwest Territories	0	0	13
Nunavut	0	0	63

* The new cases, deaths and tests reflect the difference between a province or territory's current report and their last report. Some provinces and territories do not update daily.

N/A means that no daily update was provided by the province or territory.

Variants of concern (VOC) in Canada

All viruses, including COVID-19, change or mutate over time. Not all mutations are of concern. However, some changes result in variants of concern (VOC). A VOC (Variants of concern) has changes that are significant to public health.

For example, they might:

- spread more easily
- cause more severe illness
- require different treatments, or
- not respond the same to current vaccines

The Public Health Agency of Canada (PHAC) updates VOC (Variants of concern) information from Sunday to Thursday at 7:00 PM EDT, using publicly reported information from the provinces and territories.

Table 2. Cumulative number of cases involving variants of concern (VOC) publicly reported, as of June 29, 2021

Location	B.1.1.7 variant	B.1.351 variant	P.1 variant
Canada	**221,763**	**2,149**	**17,974**
British Columbia	12,054	151	9,709
Alberta	45,508	159	2,752
Saskatchewan	6,634	10	322
Manitoba	6,630	72	205
Ontario	143,381	1,315	4,439
Quebec	6,989	420	511
Newfoundland and Labrador	187	6	1
New Brunswick	180	4	1
Nova Scotia	73	12	1
Prince Edward Island	26	0	0
Yukon	3	0	31
Northwest Territories	77	0	2
Nunavut	21	0	0

Note:

- The table reports publicly available information from the provinces and territories. In case of discrepancies, the provincial or territorial data should be considered current and correct.

- PHAC is in the process of replacing this table with a graphical view that is more representative of the mix of variants present in Canada in the coming weeks. This new graphical view will include all variants of concern including B.1.617 and variants of interest.

There are many variants being tracked internationally and across Canada. Most of these are similar to the original variants that emerged in 2020. VOCs (Variants of concern) now represent a majority of COVID-19 cases in Canada.

Four VOCs (Variants of concern) have been detected in most provinces and territories:

- B.1.1.7
- B.1.351
- P.1
- B.1.617

The **B.1.1.7 variant** continues to account for most VOCs (Variants of concern) classified to date in Canada.

The **B.1.617 variant** has only been recently identified and thus is less understood. Its 3 sub-lineages may have different properties. Early data from the U.K. indicate that the B.1.617.2 sub-lineage may be more transmissible overall, either similar to or perhaps more transmissible than the B.1.1.7 variant. However, laboratory data suggest that currently authorized vaccines are also effective against this sub-lineage. The B.1.617.1 and B.1.617.3 sub-lineages are less well-known, but may be less affected by vaccines. There are many variants being tracked internationally and across Canada, most of which are similar to the original variants that emerged in 2020.

The impact of the B.1.617 variant and its sub-lineages is still being assessed in Canada, where the variant has been identified in all 10 provinces and 1 territory. Genomic surveillance has also identified all 3 sub-lineages (B.1.617.1, B.1.617.2 and B.1.617.3).

Of these 3:

- B.1.617.1 accounted for most of the identified cases in March and April 2021
- B.1.617.2 accounted for most of the identified cases detected at the border
- B.1.617.3 accounts for a very small proportion (1%) of identified cases

Canada is collecting evidence to determine if each of these sub-lineages meets the definition for a variant of concern or a variant of interest.

New variants will continue to appear. It is crucial to remain vigilant and take all available measures to limit spread.

Detailed case information

The tables and figures below reflect detailed case information provided to the Public Health Agency of Canada (PHAC) by health authorities in the provinces and territories. This data is updated every week. It may change as we get more information about cases.

Updated: June 25, 2021, 7 pm EST

Epidemic curve

As of June 25, 2021, 7 pm EST, PHAC has received detailed case report data on 1,410,946 cases. Both exposure and symptom onset date were available for 1,254,652 (88.9%) cases [1].

The shaded area on the far right of Figure 2 represents lag time. This is the period of time (1 to 2 weeks) before the latest cases are reported to PHAC. This delay is a result of the time required to seek health care, get tested and receive results. It also takes time for public health authorities to gather information on cases. We update this information as it becomes available.

Figure 2. COVID-19 cases (n=1,411,021 [1]) in Canada by date of illness onset [2] as of June 25, 2021, 7 pm EST (total cases)

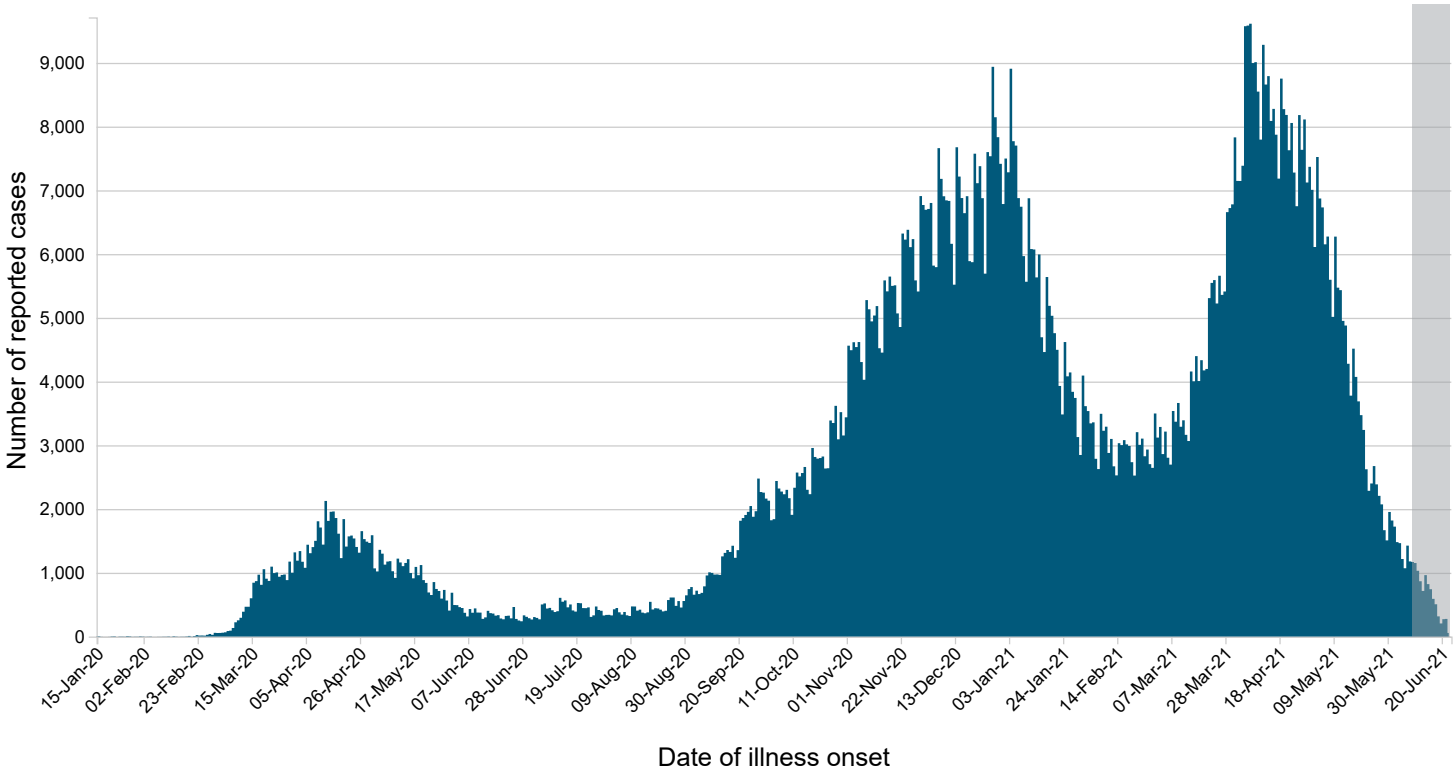


Figure 2. COVID-19 cases (n=1,254,652 [1]) in Canada by date of illness onset [2] as of June 25, 2021, 7 pm EST (by exposure)

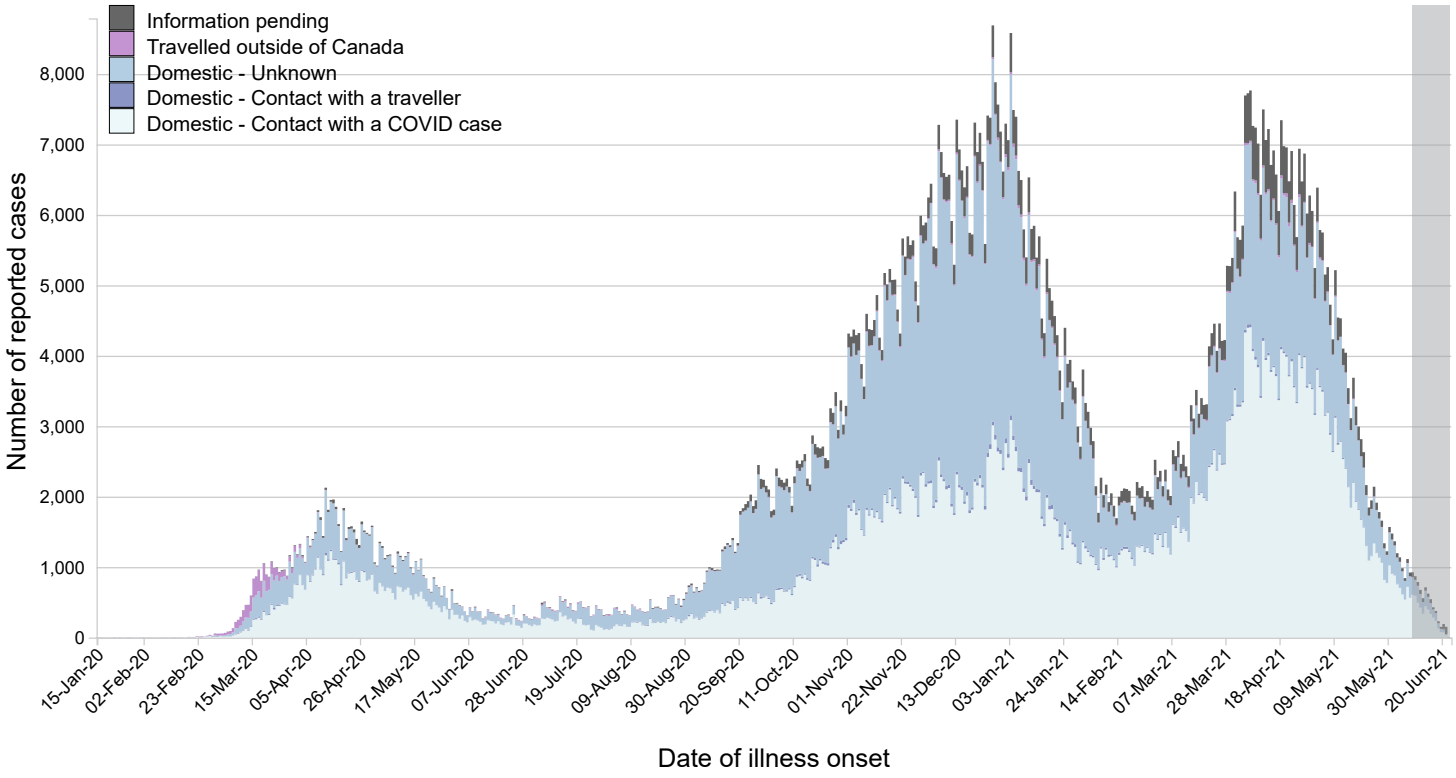


Figure 2. COVID-19 cases (n=1,410,571 [1]) in Canada by date of illness onset [2] as of June 25, 2021, 7 pm EST (by age - 10 year groups)

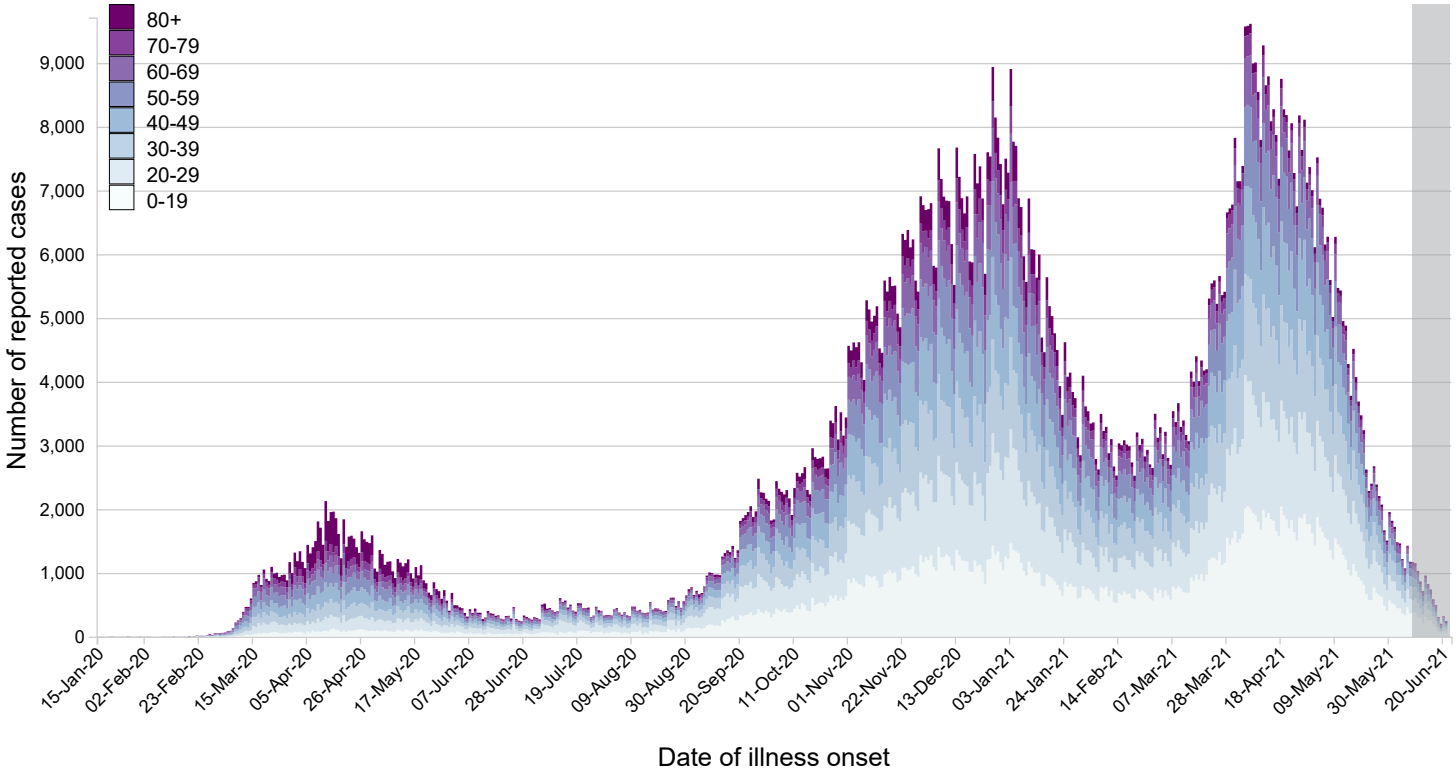
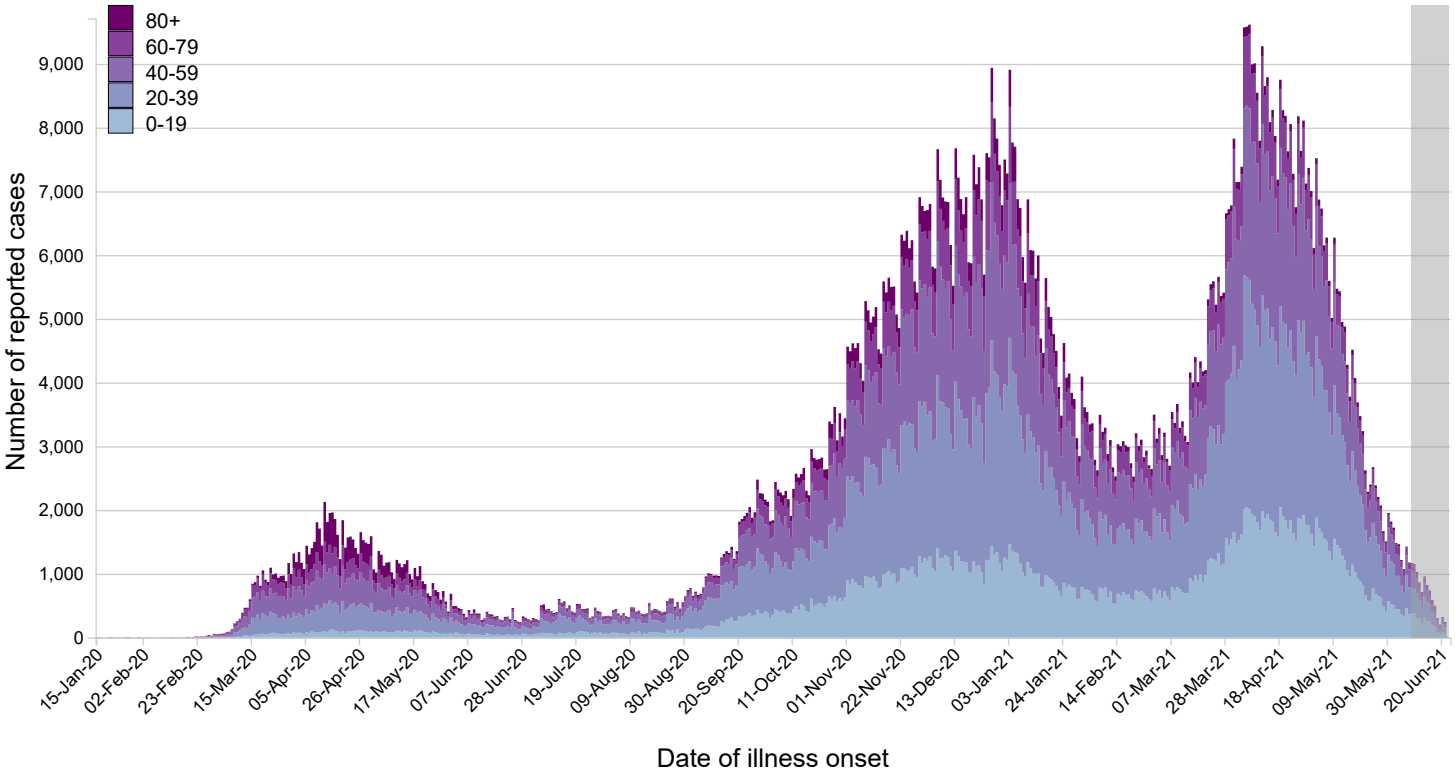


Figure 2. COVID-19 cases (n=1,410,571 [1]) in Canada by date of illness onset [2] as of June 25, 2021, 7 pm EST (by age - 20 year groups)



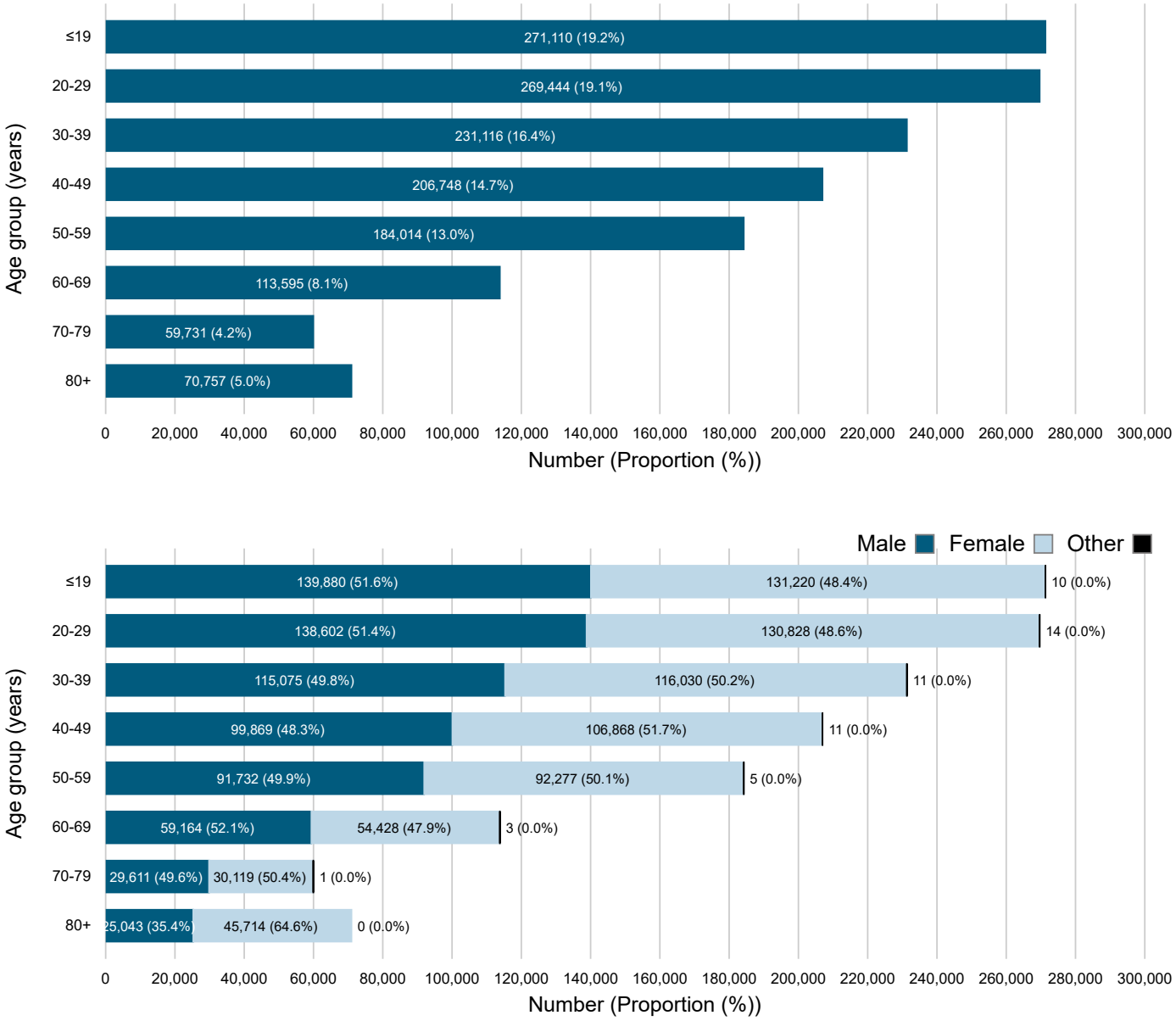
This figure may underestimate the total number of cases among returning travelers. Exposure history is not available for all cases and jurisdictions have not all consistently reported exposure history to PHAC throughout the pandemic.

Demographics

We have detailed case report data from 1,410,946 cases. We know the age of patients in 100.00% of cases, and both age and gender in 99.69% of cases.

Of the cases reported in Canada so far, 50.3% were female and 35.6% were between 20 and 39 years old (Figure 3).

Figure 3. Age distribution of COVID-19 cases (n=1,410,946 [1]) in Canada as of June 25, 2021, 7 pm EST [4]



Age by gender [4] distribution of COVID-19 cases (n=1,410,946 [1]) in Canada, June 25, 2021, 7 pm EST

Age group (years)	Number of cases with case reports (percentage)	Number of male cases (percentage)	Number of female cases (percentage)	Number of other cases (percentage)
≤19	271,110 (19.2%)	139,880 (20.0%)	131,220 (18.5%)	10 (18.2%)
20-29	269,444 (19.1%)	138,602 (19.8%)	130,828 (18.5%)	14 (25.5%)
30-39	231,116 (16.4%)	115,075 (16.5%)	116,030 (16.4%)	11 (20.0%)
40-49	206,748 (14.7%)	99,869 (14.3%)	106,868 (15.1%)	11 (20.0%)
50-59	184,014 (13.0%)	91,732 (13.1%)	92,277 (13.0%)	5 (9.1%)
60-69	113,595 (8.1%)	59,164 (8.5%)	54,428 (7.7%)	3 (5.5%)
70-79	59,731 (4.2%)	29,611 (4.2%)	30,119 (4.3%)	1 (1.8%)
80+	70,757 (5.0%)	25,043 (3.6%)	45,714 (6.5%)	0 (0.0%)
Total	1,406,515 (100%)	698,976 (100%)	707,484 (100%)	55 (100%)

How people were exposed [3]

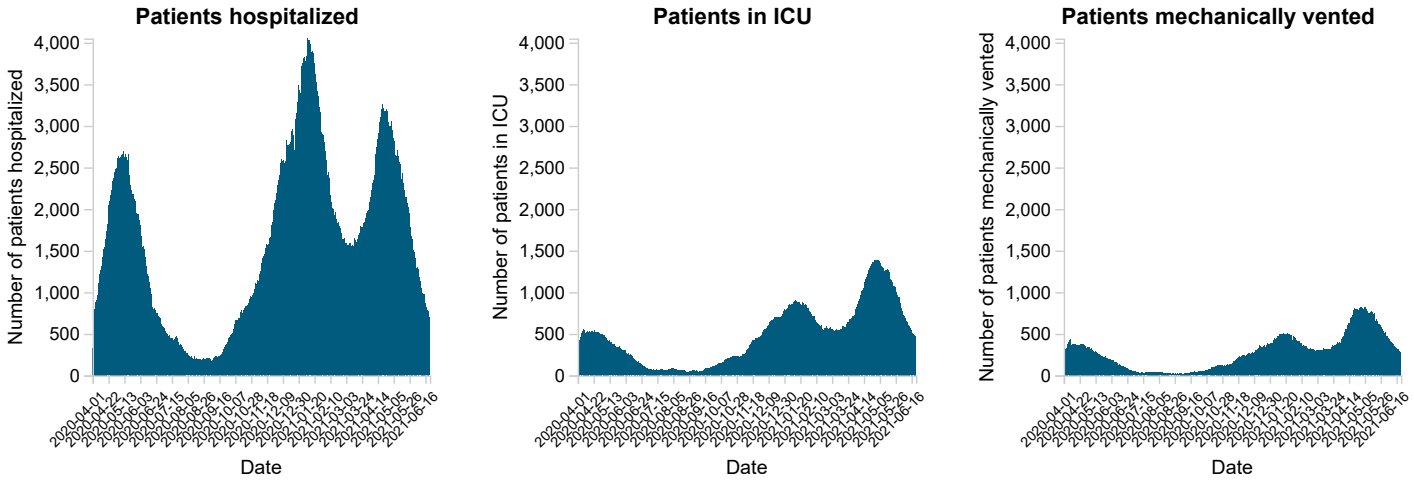
In Canada, detailed case report data were provided for 1,410,946 cases. We have exposure history for 1,254,652 (88.9%) cases. The probable exposure setting of these cases [1] are:

- any exposure that occurred in Canada: **1,167,909 (93.1%)**, including
  - from contact with a known COVID case: **583,505 (46.5%)**
  - from contact with a traveller: **8,451 (0.7%)**
  - from an unknown source: **575,953 (45.9%)**
- currently unknown (information pending): **77,135 (6.1%)**
- travelled outside of Canada: **9,608 (0.8%)**

Severe illness and outcomes

Hospital use

Figure 4. Daily number of hospital beds and ICU beds occupied by COVID-19 patients as of June 21, 2021



Between June 14, 2021 and June 21, 2021:

- the number of **hospital beds** occupied by COVID-19 patients **decreased** from **981** to **696** beds.
- the number of **ICU beds** occupied by COVID-19 patients **decreased** from **563** to **471** beds.
- the number of **COVID-19 patients who were mechanically vented decreased** from **337** to **282**.

Hospitalizations and deaths to date

We have detailed case report data on 1,410,946 cases, and hospitalization status for 988,451 (70.1%) of them:

- **74,044** cases **(7.5%)** were hospitalized, of whom:
  - **13,789 (18.6%)** were admitted to the ICU
  - **1,919 (2.6%)** needed mechanical ventilation

The provinces and territories provided detailed case report forms for **26,172** deaths related to COVID-19.

Figure 5a. Age and gender [4] distribution of COVID-19 cases hospitalized in Canada as of June 25, 2021, 7 pm EST (n=73,902 [1])

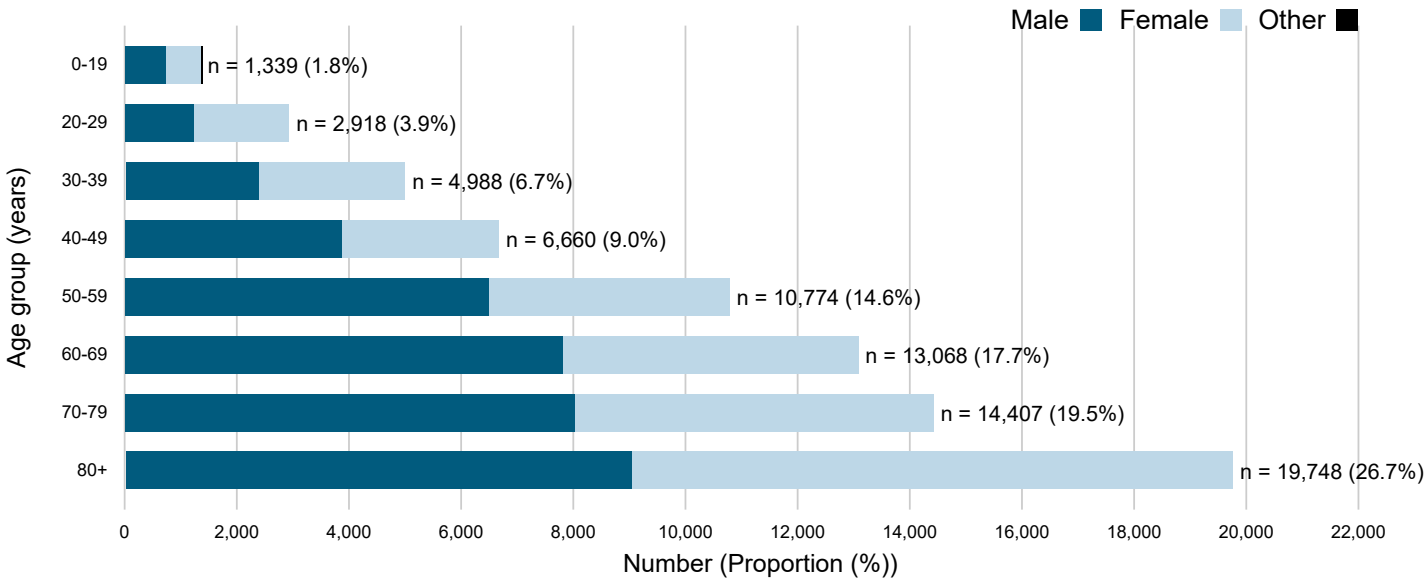


Figure 5b. Age and gender [4] distribution of COVID-19 cases admitted to ICU in Canada as of June 25, 2021, 7 pm EST (n=13,754 [1])

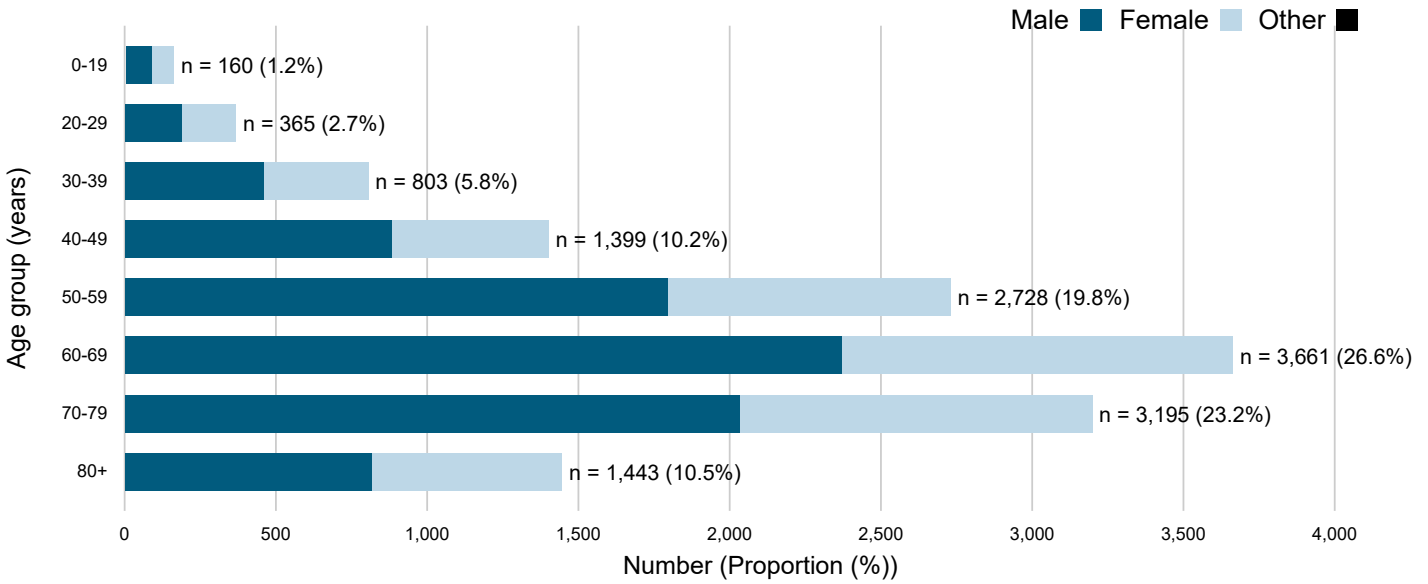
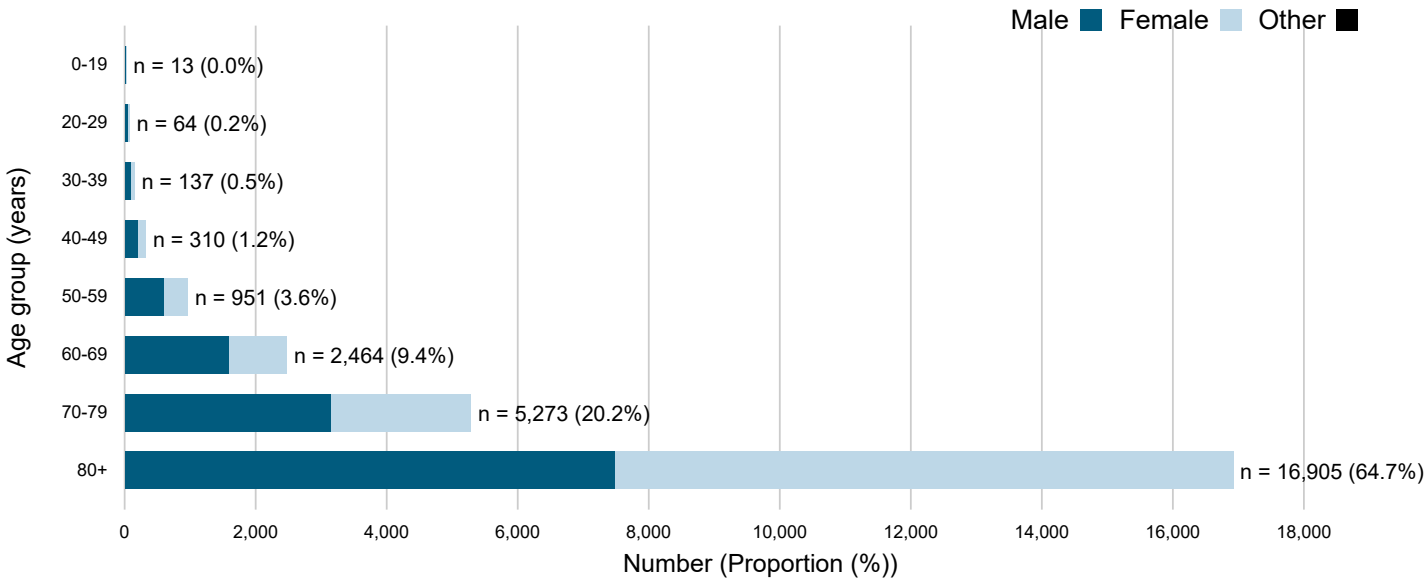


Figure 5c. Age and gender [4] distribution of COVID-19 cases deceased in Canada as of June 25, 2021, 7 pm EST (n=26,117 [1])



Data note: Figure 5 includes COVID-19 cases hospitalized, admitted to ICU, and deceased for which age and gender information were available. Therefore, some COVID-19 hospitalizations, ICU admissions, and deaths may not be included in Figure 5.

Age and gender [4] distribution of COVID-19 cases hospitalized in Canada as of June 25, 2021, 7 pm EST (n=73,902 [1])

Age group (years)	Number of cases with case reports (percentage)	Number of male cases (percentage)	Number of female cases (percentage)	Number of other cases (percentage)
0-19	1,339 (1.8%)	714 (1.0%)	624 (0.8%)	1 (0.0%)
20-29	2,918 (3.9%)	1,231 (1.7%)	1,687 (2.3%)	0 (0.0%)
30-39	4,988 (6.7%)	2,389 (3.2%)	2,599 (3.5%)	0 (0.0%)
40-49	6,660 (9.0%)	3,870 (5.2%)	2,790 (3.8%)	0 (0.0%)
50-59	10,774 (14.6%)	6,486 (8.8%)	4,288 (5.8%)	0 (0.0%)
60-69	13,068 (17.7%)	7,802 (10.6%)	5,266 (7.1%)	0 (0.0%)
70-79	14,407 (19.5%)	8,010 (10.8%)	6,397 (8.7%)	0 (0.0%)
80+	19,748 (26.7%)	9,040 (12.2%)	10,708 (14.5%)	0 (0.0%)

Age and gender [4] distribution of COVID-19 cases admitted to ICU in Canada as of June 25, 2021, 7 pm EST (n=13,754 [1])

Age group (years)	Number of cases with case reports (percentage)	Number of male cases (percentage)	Number of female cases (percentage)	Number of other cases (percentage)
0-19	160 (1.2%)	89 (0.6%)	71 (0.5%)	0 (0.0%)
20-29	365 (2.7%)	189 (1.4%)	176 (1.3%)	0 (0.0%)
30-39	803 (5.8%)	459 (3.3%)	344 (2.5%)	0 (0.0%)
40-49	1,399 (10.2%)	881 (6.4%)	518 (3.8%)	0 (0.0%)
50-59	2,728 (19.8%)	1,795 (13.1%)	933 (6.8%)	0 (0.0%)
60-69	3,661 (26.6%)	2,371 (17.2%)	1,290 (9.4%)	0 (0.0%)
70-79	3,195 (23.2%)	2,031 (14.8%)	1,164 (8.5%)	0 (0.0%)
80+	1,443 (10.5%)	817 (5.9%)	626 (4.6%)	0 (0.0%)

Age and gender [4] distribution of COVID-19 cases deceased in Canada as of June 25, 2021, 7 pm EST (n=26,117 [1])

Age group (years)	Number of cases with case reports (percentage)	Number of male cases (percentage)	Number of female cases (percentage)	Number of other cases (percentage)
0-19	13 (0.0%)	6 (0.0%)	7 (0.0%)	0 (0.0%)
20-29	64 (0.2%)	39 (0.1%)	25 (0.1%)	0 (0.0%)
30-39	137 (0.5%)	87 (0.3%)	50 (0.2%)	0 (0.0%)
40-49	310 (1.2%)	200 (0.8%)	110 (0.4%)	0 (0.0%)
50-59	951 (3.6%)	588 (2.3%)	363 (1.4%)	0 (0.0%)
60-69	2,464 (9.4%)	1,580 (6.0%)	884 (3.4%)	0 (0.0%)
70-79	5,273 (20.2%)	3,148 (12.1%)	2,125 (8.1%)	0 (0.0%)
80+	16,905 (64.7%)	7,470 (28.6%)	9,435 (36.1%)	0 (0)

Provincial, territorial and international reporting

For more information, please refer to provincial or territorial COVID-19 webpages:

- British Columbia
- Alberta
- Saskatchewan
- Manitoba
- Ontario
- Quebec
- Newfoundland and Labrador
- New Brunswick
- Nova Scotia
- Prince Edward Island
- Yukon
- Northwest Territories
- Nunavut
- World Health Organization
- Centers for Disease Control and Prevention
- European Centre for Disease Control and Prevention

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1 This figure is based on cases for which a case report form was received by the Public Health Agency of Canada from provincial or territorial partners.

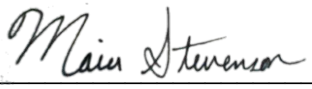
2 The shaded area represents a period of time (lag time) where it is expected that cases have occurred but have not yet been reported nationally. The earliest of the following dates were used as an estimate: Onset date, Specimen Collection Date, Laboratory Testing Date, Date Reported to Province or Territory, or Date Reported to PHAC.

3 Exposure information may not be available for all cases. Some jurisdictions haven't consistently reported to PHAC how people were exposed throughout the pandemic. As a result, this may underestimate the total number of cases by different exposures, especially among returning travelers.

4 Where available, gender data was used; when gender data was unavailable, sex data was used. Reliable data on gender diverse respondents are unavailable due to small counts.

Date modified:
2021-06-29

This is "**Exhibit G**"
to the Affidavit of Matthew Hodge,
affirmed this 2nd day of July, 2021



A Commissioner, etc.

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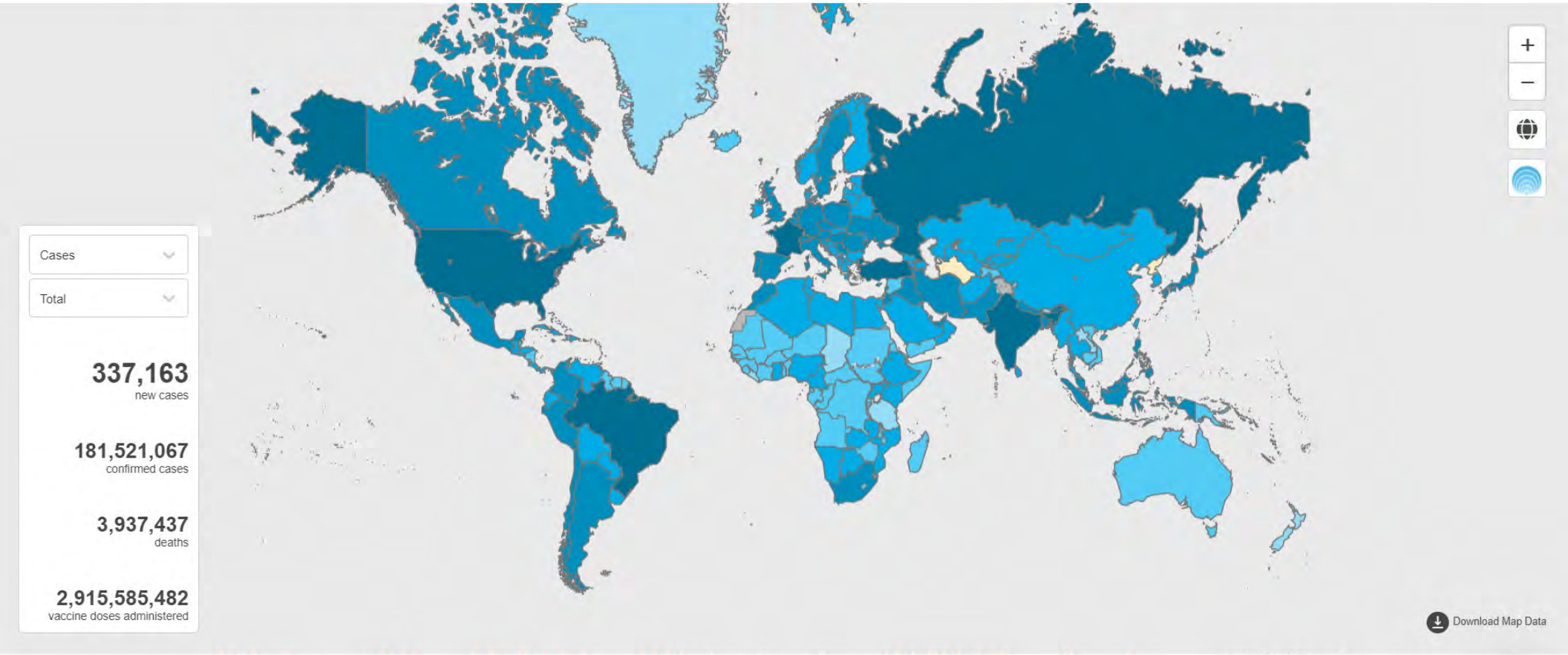


Cases

Total

337,163
new cases

181,521,067
confirmed cases

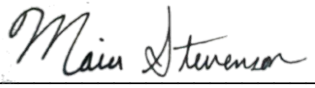
3,937,437
deaths

2,915,585,482
vaccine doses administered

Download Map Data

Globally, as of **6:09pm CEST, 30 June 2021**, there have been **181,521,067 confirmed cases** of COVID-19, including **3,937,437 deaths**, reported to WHO. As of **30 June 2021**, a total of **2,915,585,482 vaccine doses** have been administered.

This is "**Exhibit H**"
to the Affidavit of Matthew Hodge,
affirmed this 2nd day of July, 2021



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SCIENCE BRIEFS

COVID-19 Hospitalizations, ICU Admissions and Deaths Associated with the New Variants of Concern

Ashleigh R. Tuite, David N. Fisman, Ayodele Odutayo, Pavlos Bobos, Vanessa Allen, Isaac I. Bogoch, Adalsteinn D. Brown, Gerald A. Evans, Anna Greenberg, Jessica Hopkins, Antonina Maltsev, Douglas G. Manuel, Allison McGeer, Andrew M. Morris, Samira Mubareka, Laveena Munshi, V. Kumar Murty, Samir N. Patel, Fahad Razak, Robert J. Reid, Beate Sander, Michael Schull, Brian Schwartz, Arthur S. Slutsky, Nathan M. Stall, Peter Jüni on behalf of the Ontario COVID-19 Science Advisory Table

Version 1.0

Published: March 29, 2021

Citation: Tuite AR, Fisman DN, Odutayo A, et al. COVID-19 hospitalizations, ICU admissions and deaths associated with the new variants of concern. *Science Briefs of the Ontario COVID-19 Science Advisory Table*. 2021;1(18). https://doi.org/10.47326/ocsat.2021.02.18.1.0

Author Affiliations: The affiliations of the members of the Ontario COVID-19 Science Advisory Table can be found at https://covid19-sciencetable.ca/.

Declarations of Interest: The declarations of interest of the members of the Ontario COVID-19 Science Advisory Table, its Working Groups, or its partners can be found at https://covid19-sciencetable.ca/.

About Us: The Ontario COVID-19 Science Advisory Table is a group of scientific experts and health system leaders who evaluate and report on emerging evidence relevant to the COVID-19 pandemic, to inform Ontario's response. Our mandate is to provide weekly summaries of relevant scientific evidence for the COVID-19 Health Coordination Table of the Province of Ontario, integrating information from existing scientific tables, Ontario's universities and agencies, and the best global evidence. The Science Table summarizes its findings for the Health Coordination Table and the public in Science Briefs.

Correspondence to: Secretariat of the Ontario COVID-19 Science Advisory Table (info@covid19-sciencetable.ca)

Key Message

New variants of concern (VOCs) now account for 67% of all Ontario SARS-CoV-2 infections. Compared with early variants of SARS-CoV-2, VOCs are associated with a 63% increased risk of hospitalization, a 103% increased risk of intensive care unit (ICU) admission and a 56% increased risk of death due to COVID-19.

VOCs are having a substantial impact on Ontario's healthcare system. On March 28, 2021, the daily number of new SARS-CoV-2 infections in Ontario reached the daily number of cases observed near the height of the second wave, at the start of the province-wide lockdown, on December 26, 2020.

The number of people hospitalized with COVID-19 is now 21% higher than at the start of the province-wide lockdown, while ICU occupancy is 28% higher (Figure 1). The percentage of COVID-19 patients in ICUs who are younger than 60 years is about 50% higher now than it was prior to the start of the province-wide lockdown.

Because the increased risk of COVID-19 hospitalization, ICU admission and death with VOCs is most pronounced 14 to 28 days after diagnosis, there will be significant delays until the full burden to the health care system becomes apparent.

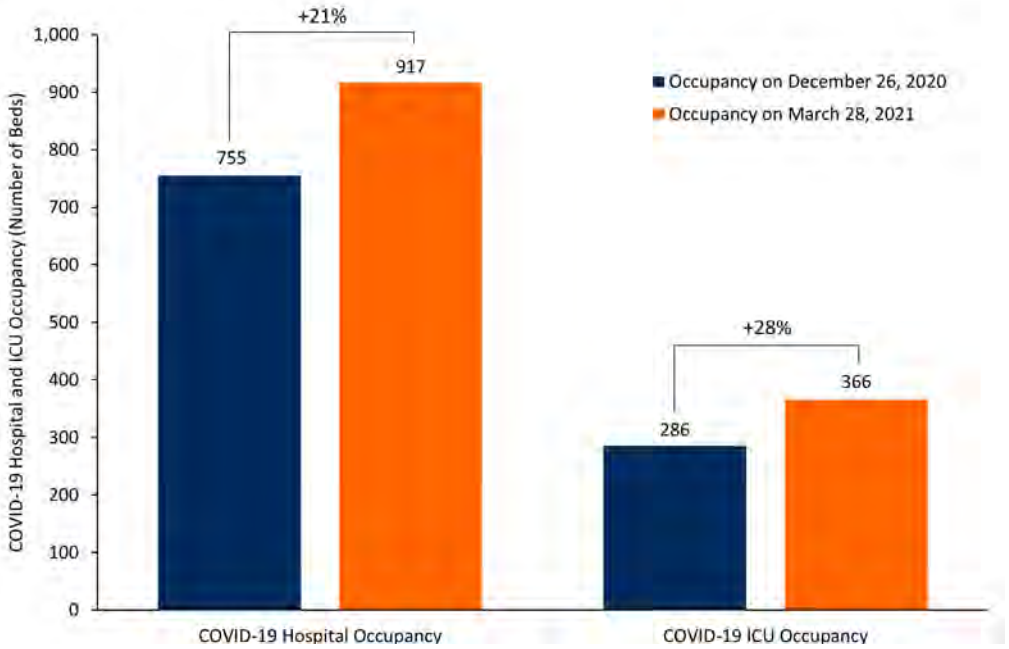

Figure 1. COVID-19 Hospital and ICU Occupancy on March 28, 2021 Compared with December 26, 2020
Bar graphs showing the COVID-19 hospital and ICU occupancy in Ontario. The relative increase between March 28,

2021 and December 26, 2020 is indicated above the corresponding bars for hospital and ICU occupancy. ICU, intensive care unit.

Summary

Background

As of March 28, 2021 new variants of concern (VOCs) account for 67% of all Ontario SARS-CoV-2 infections. The B.1.1.7 variant originally detected in Kent, United Kingdom accounts for more than 90% of all VOCs in Ontario, with emerging evidence that it is both more transmissible and virulent.

Questions

What are the risks of COVID-19 hospitalization, ICU admission and death caused by VOCs as compared with the early variants of SARS-CoV-2?

What is the early impact of new VOCs on Ontario's healthcare system?

Findings

A retrospective cohort study of 26,314 people in Ontario testing positive for SARS-CoV-2 between February 7 and March 11, 2021, showed that 9,395 people (35.7%) infected with VOCs had a 62% relative increase in COVID-19 hospitalizations (odds ratio [OR] 1.62, 95% confidence interval [CI] 1.41 to 1.87), a 114% relative increase in ICU admissions (OR 2.14, 95% CI 1.52 to 3.02), and a 40% relative increase in COVID-19 deaths (OR 1.40, 95% CI 1.01 to 1.94), after adjusting for age, sex and comorbidities.

A meta-analysis including the Ontario cohort study and additional cohort studies in the United Kingdom and Denmark showed that people infected with VOCs had a 63% higher risk of hospitalization (RR 1.63, 95% CI 1.44 to 1.83), a doubling of the risk of ICU admission (RR 2.03, 95% CI 1.69 to 2.45), and a 56% higher risk of all-cause death (RR 1.56, 95% CI 1.30 to 1.87). Estimates observed in different studies and regions were completely consistent, and the B.1.1.7 variant was dominant in all three jurisdictions over the study periods.

The number of people hospitalized with COVID-19 on March 28, 2021, is 21% higher than at the start of the province-wide lockdown during the second wave on December 26, 2020, while ICU occupancy is 28% higher.

Between December 14 to 20, 2020, there were 149 new admissions to ICU; people aged 59 years and younger accounted for 30% of admissions. Between March 15, 2021 and March 21, 2021, there were 157 new admissions to ICU; people aged 59 years and younger accounted for 46% of admissions.

Interpretation

The new VOCs will result in a considerably higher burden to Ontario's health care system during the third wave compared to the impact of early SARS-CoV-2 variants during Ontario's second wave.

Since the start of the third wave on March 1, 2021, the number of new cases of SARS-CoV-2 infection, and the COVID-19 hospital and ICU occupancies have surpassed prior thresholds at the start of the province-wide lockdown on December 26, 2020.

Background

Around March 1, 2021, Ontario entered the third wave of the COVID-19 pandemic, with the slope of the epidemic curve driven by the increasing number of VOCs since March 3, 2021 (Figure 2).[1] As of March 28, 2021, there were an estimated total of

107.1 new SARS-CoV-2 infections per 100,000 persons per week, with 35.7 new SARS-CoV-2 infections per 100,000 Ontarians per week caused by early variants of SARS-CoV-2 (non-VOCs), and 71.4 new SARS-CoV-2 infections per 100,000 Ontarians per week caused by new VOCs. The VOCs accounted for an estimated 67% of new cases of SARS-CoV-2 infections.[1] VOCs are now the dominant source of SARS-CoV-2 infection in Ontario.

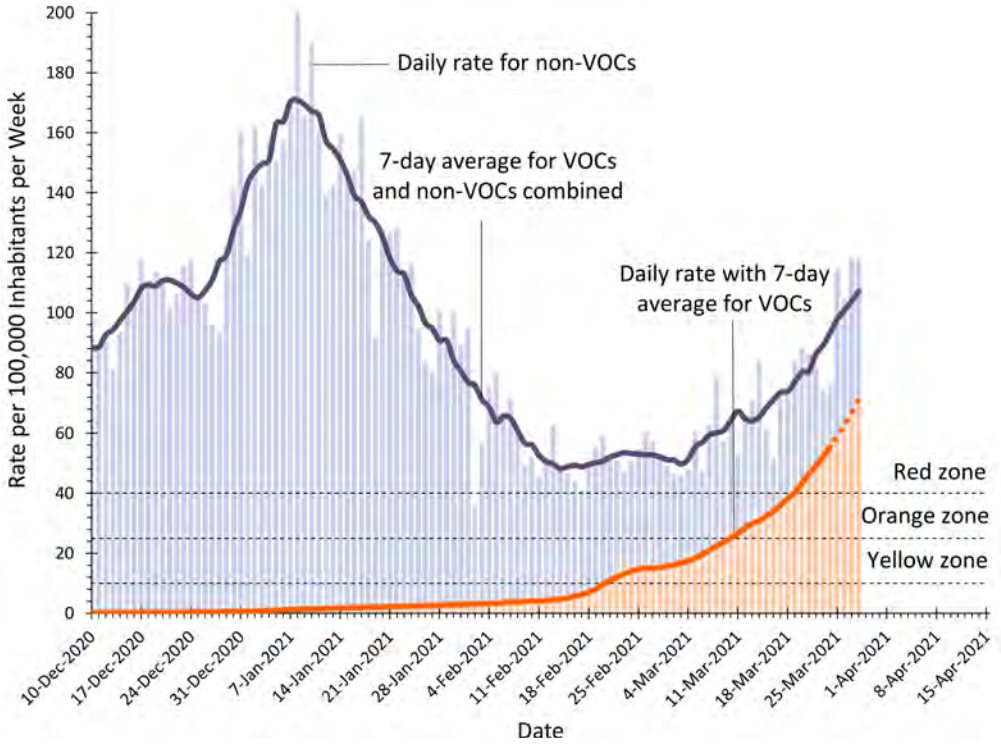

Figure 2. Rate of New SARS-CoV-2 Infections in Ontario

Seven-day moving averages of confirmed new SARS-CoV-2 infections overall in Ontario per 100,000 inhabitants per week (purple line), and infections caused by new VOCs in Ontario per 100,000 inhabitants per week (orange line). The daily rate per 100,000 inhabitants per week is represented by blue and orange bars. The incidence of new infections related to VOCs from March 24th 2021 and onwards is predicted (dashed orange line). The color-coded zones are the zones of public health measures established by Ontario's COVID-19 response framework: grey/red zone = weekly SARS-CoV-2 incidence of ≥40 per 100,000; orange zone = weekly incidence 25 to 39.9 per 100,000; and yellow zone = weekly incidence of 10 to 24.9 per 100,000. VOC, variant of concern. Graph adapted from Ontario COVID-19 Science Advisory Table.[1]

The B.1.1.7 variant, which was originally detected in Kent, United Kingdom, currently accounts for more than 90% of all VOCs in Ontario. The B.1.351 and P.1 variants originally detected in South Africa and Brazil, respectively, account for the remaining VOCs.[2] The B.1.1.7 variant which is dominant in Ontario, is at least 40% more transmissible than early variants of SARS-CoV-2,[3] and emerging evidence suggests it may be more virulent.[4]

Questions

What are the risks of COVID-19 hospitalization, ICU admission and death caused by VOCs as compared with the early variants of SARS-CoV-2?

What is the early impact of new VOCs on Ontario's healthcare system?

Findings

Table 1 presents the results of a retrospective cohort study of 26,314 people in Ontario who were PCR-positive for SARS-CoV-2 between February 7 and March 11, 2021, with 9,395 people (35.7%) having an infection caused by a VOC. After adjusting for age, sex and comorbidities, infections due to VOCs were associated

with a 62% relative increase in COVID-19 hospitalizations (odds ratio [OR] 1.62, 95% confidence interval [CI] 1.41 to 1.87), a 114% relative increase in ICU admissions (OR 2.14, 95% CI 1.52 to 3.02), and a 40% relative increase in COVID-19 deaths (OR 1.40, 95% CI 1.01 to 1.94). These risk elevations for COVID-19 hospitalization, ICU admission and death were consistent across all age groups.

	Adjusted odds ratio (95% CI)
COVID-19 Hospitalizations	1.62 (1.41 to 1.87)
COVID-19 ICU admissions	2.14 (1.52 to 3.02)
COVID-19 Deaths	1.40 (1.01 to 1.94)

Table 1. Risk of COVID-19 Hospitalization, Intensive Care Unit Admission and Death Associated with VOCs Compared to Early Variants in Ontario, Canada

Adjusted odds ratios and 95% confidence intervals for the risk of COVID-19 hospitalizations, intensive care unit admissions and deaths associated with new VOCs compared to early variants. VOC, variant of concern; CI, confidence interval; ICU, intensive care unit.

Figure 3 presents the results a meta-analysis of cohort studies in Ontario (Table 1, above), the United Kingdom[5,6] and Denmark[7] comparing new VOCs with early variants, again with the dominant VOC being B.1.1.7 in all three jurisdictions over the study periods.[3] Pooling adjusted estimates of relative risks (RRs), people infected with VOCs had a 63% higher risk of hospitalization (RR 1.63, 95% CI 1.44 to 1.83), a doubling of the risk of ICU admission (RR 2.03, 95% CI 1.69 to 2.45), and a 56% higher risk of all-cause death (RR 1.56, 95% CI 1.30 to 1.87). Estimates observed in different studies and regions were completely consistent.

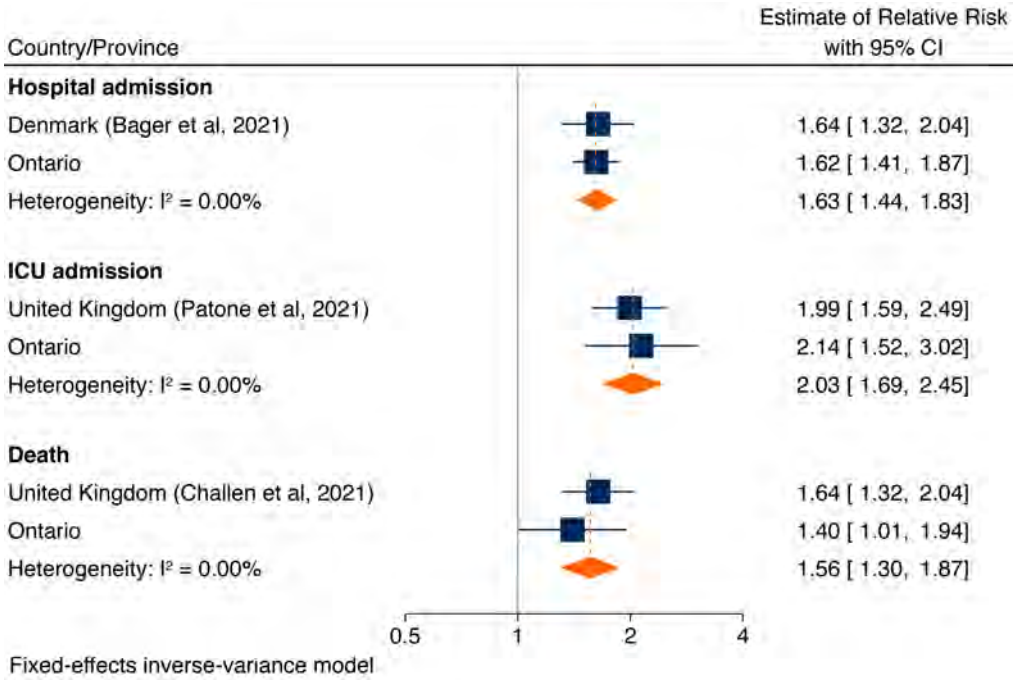

Figure 3. Meta-Analysis of the Risk of COVID-19 Hospitalization, Intensive Care Unit Admission and Death Associated with new VOCs Compared to Early Variants

Each square presents the results of an individual cohort study, with the size of the square being proportional to the weights used in the meta-analysis and the horizontal lines indicating the 95% confidence intervals. The solid vertical line at 1 indicates that there is no difference in prognosis between new VOCs and early variants. The diamond indicates the pooled estimate of the relative risk combining individual studies from different regions. Estimates for Ontario and Denmark are odds ratios; estimates for the United Kingdom are hazard ratios. The retrospective cohort study in Ontario included 26,314 participants in Ontario with PCR confirmed SARS-CoV-2 infection between February 7 and March 11, 2021, of whom 9,395 were infected with new VOCs. The retrospective cohort study by Bager et al. included 18,449 participants in Denmark with PCR confirmed SARS-CoV-2 infection between January 1 and February 9, 2021 with 2,155 infected with new VOCs.[7] Estimates were adjusted for age, sex, calendar period, region, and number of comorbidities during the past 5 years. The retrospective cohort study by Patone et al. included 198,420 individuals in the United Kingdom with PCR confirmed SARS-CoV-2 infection between November 1, 2020 and January 27, 2021, of whom 80,494 were infected with new VOCs. Relative risk estimates were adjusted for age, sex, region, socio-demographic factors and comorbidities, including asthma, chronic obstructive pulmonary disease, diabetes

and hypertension.[5] The retrospective cohort study by Challen et al. included 109,812 individuals in the United Kingdom with PCR confirmed SARS-CoV-2 infection between October 1, 2020 and January 29, 2021, with 54,906 participants with new VOCs matched to 54,906 participants with early variants.[6] Participants were matched on age, sex, date of specimen collection, ethnicity, geographical location, and index of multiple deprivation, which is a marker for socioeconomic status; estimates were subsequently adjusted for age. VOC, variant of concern; CI, confidence interval; ICU, intensive care unit.

Figure 4 shows the time to death observed in a retrospective cohort study by Challen et al. in the United Kingdom involving 109,812 participants with positive PCR tests for SARS-CoV-2 between October 1, 2020, to January 29, 2021, with 54,906 participants infected with new VOCs matched to 54,906 participants infected with the early variant.[6] The curves overlap until day 12 after diagnosis, at which point the curves start to separate, with a higher risk of death among participants infected with new VOCs compared with participants infected with early variants.

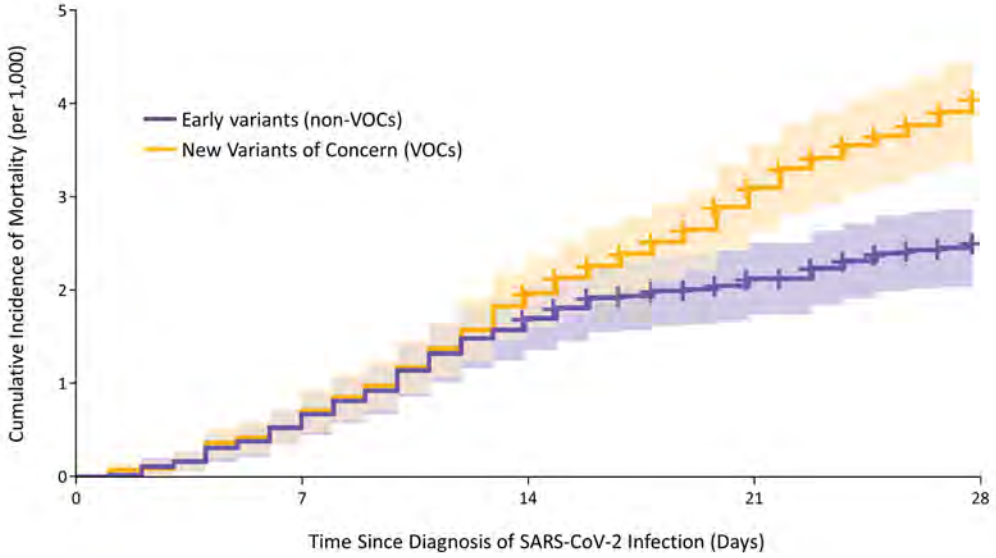

Figure 4. Time to Death Following SARS-CoV-2 Infection with New VOCs Compared with Early Variants
Curves describing the time to death from first PCR confirmation of SARS-CoV-2 infection among individuals in the United Kingdom infected with new VOCs versus early SARS-CoV-2 variants. Participants were matched on age, sex, date of specimen collection, ethnicity, geographical location, and index of multiple deprivation, which is a marker for socioeconomic status, and estimates were subsequently adjusted for age. Data from Challen et al.[6] VOC, variant of concern.

Figure 5 shows the risk of death associated with new VOCs compared with early SARS-CoV-2 variants from days 0 to 14 and days 15 to 28 after diagnosis of SARS-CoV-2 infection. Results are adapted from the aforementioned retrospective cohort study of people with PCR confirmed SARS-CoV-2 infection in the United Kingdom by Challen et al.[6] Between days 0 and 14 after diagnosis, there was only a minimal difference in the risk of death (RR 1.23, 95% CI 0.92 to 1.64) associated with the new VOCs compared with early variants. However, between days 15 and 28, the risk of death was more than doubled (RR 2.40, 95% CI 1.66 to 3.47).

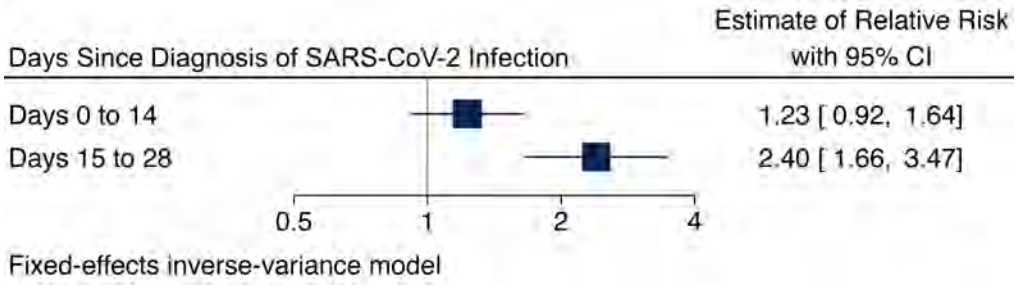

Figure 5. Risk of COVID-19 Death Associated with new VOCs Compared with Early Variants by Time Since Diagnosis of SARS-CoV-2 Infection
Adapted from a retrospective cohort study by Challen et al. which included 109,812 individuals in the United Kingdom with PCR-confirmed SARS-CoV-2 infection between October 2020 to 29 January 2021, with 54,906 individuals with new VOCs matched to 54,906 individuals with the early variant.[6] Individuals were matched on age, sex, date of specimen

collection, ethnicity, geographical location, and index of multiple deprivation, which is a marker for socioeconomic status. Each square presents the relative risk for death with the new VOCs versus early variants. The horizontal lines indicate the 95% confidence intervals. The solid vertical line at 1 indicates that there is no difference in prognosis between new VOCs and early SARS-CoV-2 variants. VOC, variant of concern; CI, confidence interval.

Figure 6 shows the risk of ICU admission associated with new VOCs versus early SARS-CoV-2 variants at days 1, 5, 10 and 15 after diagnosis of SARS-CoV-2 infection in a retrospective cohort study by Patone et al. The study involved 198,420 individuals in the United Kingdom with PCR-confirmed SARS-CoV-2 infection, of whom 80,494 were infected with new VOCs.[5] On day 1, there was a minimal difference in the risk of ICU admission between people infected with new VOCs and those infected with early variants (RR 1.20, 95% CI 0.58 to 2.48). Subsequently, there was a progressive, lagged increase in the risk of ICU admission associated with new VOCs, with a 58% increase at day 5 and a near fourfold increase at day 10.

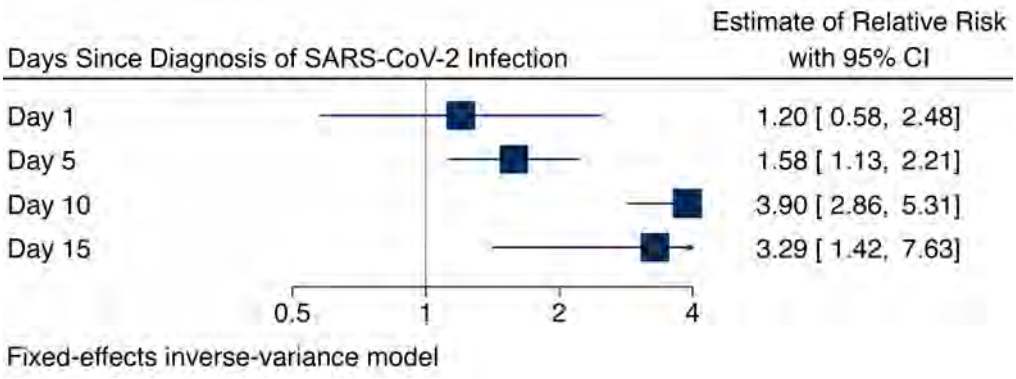

Figure 6. Risk of COVID-19 ICU Admission Associated with New VOCs Compared with Early Variants by Time Since Diagnosis of SARS-CoV-2 Infection

Adapted from a retrospective cohort study by Patone et al.[5] The study involved 198,420 individuals in the United Kingdom with PCR-confirmed SARS-CoV-2 infection, of whom 80,494 were infected with new VOCs. Relative risk estimated were adjusted for age, sex, region, socio-demographic factors and comorbidities including asthma, chronic obstructive pulmonary disease, diabetes and hypertension. Each square represents the relative risk for ICU admission with the new VOCs versus early variants. The horizontal lines indicate the 95% confidence intervals. The solid vertical line at 1 indicates that there is no difference in prognosis between new VOCs and early variants. VOC, variant of concern; CI, confidence interval.

Figure 7 shows the 7-day moving average of daily SARS-CoV-2 infections, and daily COVID-19 hospital and ICU occupancy in Ontario. At the time of the province-wide lockdown near the height of Ontario's second wave on December 26, 2020, there were 2,236 new infections per day, 755 people were hospitalized due to COVID-19, and 286 in ICU due to COVID-19.

Since the start of the third wave around March 1, 2021, the number of new cases, as well as hospital and ICU occupancy have surpassed prior thresholds seen at the start of the province-wide lockdown on December 26, 2020. The threshold of 286 COVID-19 cases in ICUs at the time of the lockdown on December 26, 2020, was reached on March 9, 2021. Likewise, COVID-19 hospital occupancy of 755 people was reached on March 16, 2021. Finally, the threshold of 2,236 new SARS-CoV-2 infections per day was reached on March 28, 2021.

We project a 2 to 4 week time lag between daily SARS-CoV-2 cases and COVID-19 hospitalizations and ICU admissions, with lagging risk increases due to the new VOCs (see Figures 3 to 5). Therefore, hospital and ICU occupancies due to COVID-19 will continue to increase considerably over time, and would so even if SARS-CoV-2 case numbers were to remain at the current level seen on March 28, 2021.

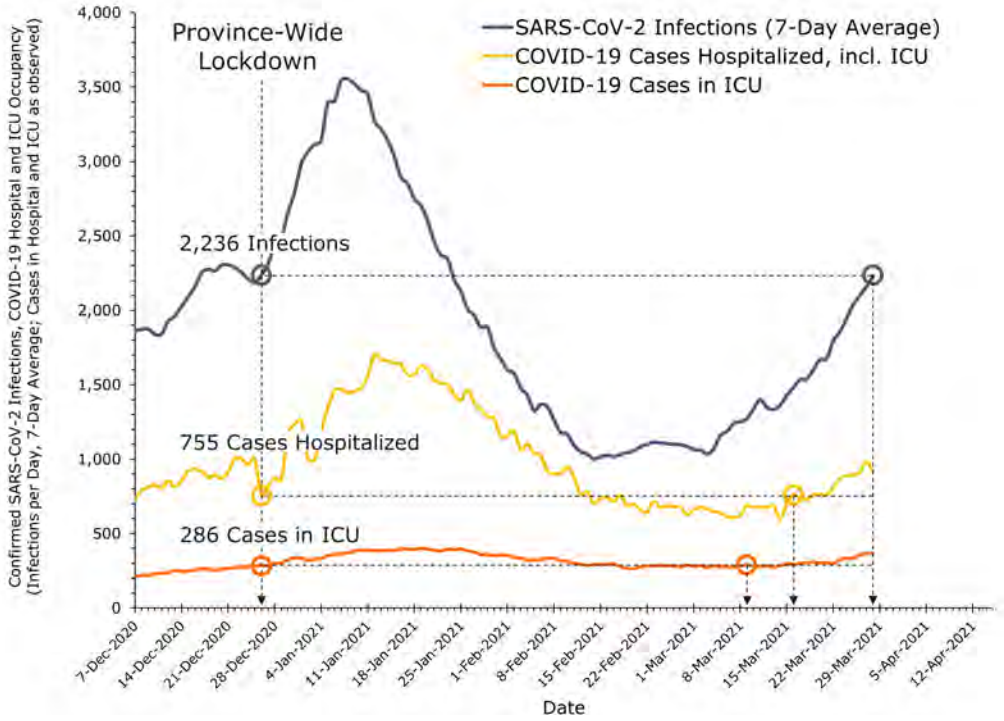

Figure 7. Number of New SARS-CoV-2 Infections, COVID-19 Hospital, and ICU Occupancy in Ontario
7-day moving averages of confirmed new SARS-CoV-2 infections in Ontario per week, number of people hospitalized with COVID-19, and number of ICU beds in Ontario occupied by COVID-19 patients. VOC, variant of concern; ICU, intensive care unit.

Table 2 presents a comparison of the number of new SARS-CoV-2 infections and COVID-19 hospital and ICU occupancy for key dates during the third wave compared with the start of the province-wide lockdown on December 26, 2020 during the second wave. As of March 28, 2021, the predicted 7-day average of SARS-CoV-2 infections during the third wave reached the 7-day midpoint average seen at the start of the province-wide lockdown on December 26, 2020.

Key	Date	SARS-CoV-2 Infections	Hospital Occupancy	ICU Occupancy
A	26-Dec-20	**2,236**	**755**	**286**
B	9-Mar-21	1,269	689	**290**
C	16-Mar-21	1,480	**761**	292
D	28-Mar-21	**2,236**	917	366

Table 2. Comparison of Key Dates During the Third Wave in Ontario with the Start of the Province-Wide Lockdown During the Second Wave on December 26, 2020
A, December 26, 2020, was the start date of the province-wide lockdown during the second wave; B, March 9, 2021 is the date when the COVID-19 ICU occupancy during the third wave reached COVID-19 ICU occupancy seen on December 26, 2020; C, March 16, 2021 is the date when COVID-19 hospital occupancy during the third wave reached COVID-19 hospital occupancy seen on December 26, 2020; D, March 28, 2021 is the date when the predicted 7-day average of SARS-CoV-2 infections during the third wave reached the 7-day midpoint average seen on December 26, 2020. ICU, intensive care unit. Second wave, September 1, 2020 to February 28, 2021. Third wave, March 1, 2020 to ongoing.

Figure 1 above presents a comparison of COVID-19 hospital occupancy and ICU occupancy in Ontario on March 28, 2021, compared with the start of the province-wide lockdown on December 26, 2020. The number of people hospitalized with COVID-19 on March 28, 2021, is 21% higher than on December 26, 2020, while ICU occupancy is 28% higher.

Figure 8 presents the percentage of COVID-19 ICU admissions in Ontario by age group in the week prior to the lockdown during the second wave (December 14 to 20, 2020) with the last available week of ICU admission data during the third wave (March 15 to 21, 2021). Between December 14 to 20, 2020, there were 149 new admissions to ICU; people aged 59 years and younger accounted for 30% of admissions. Between March 15, 2021 and March 21, 2021, there were 157 new admissions to ICU; people aged 59 years and younger accounted for 46% of admissions.

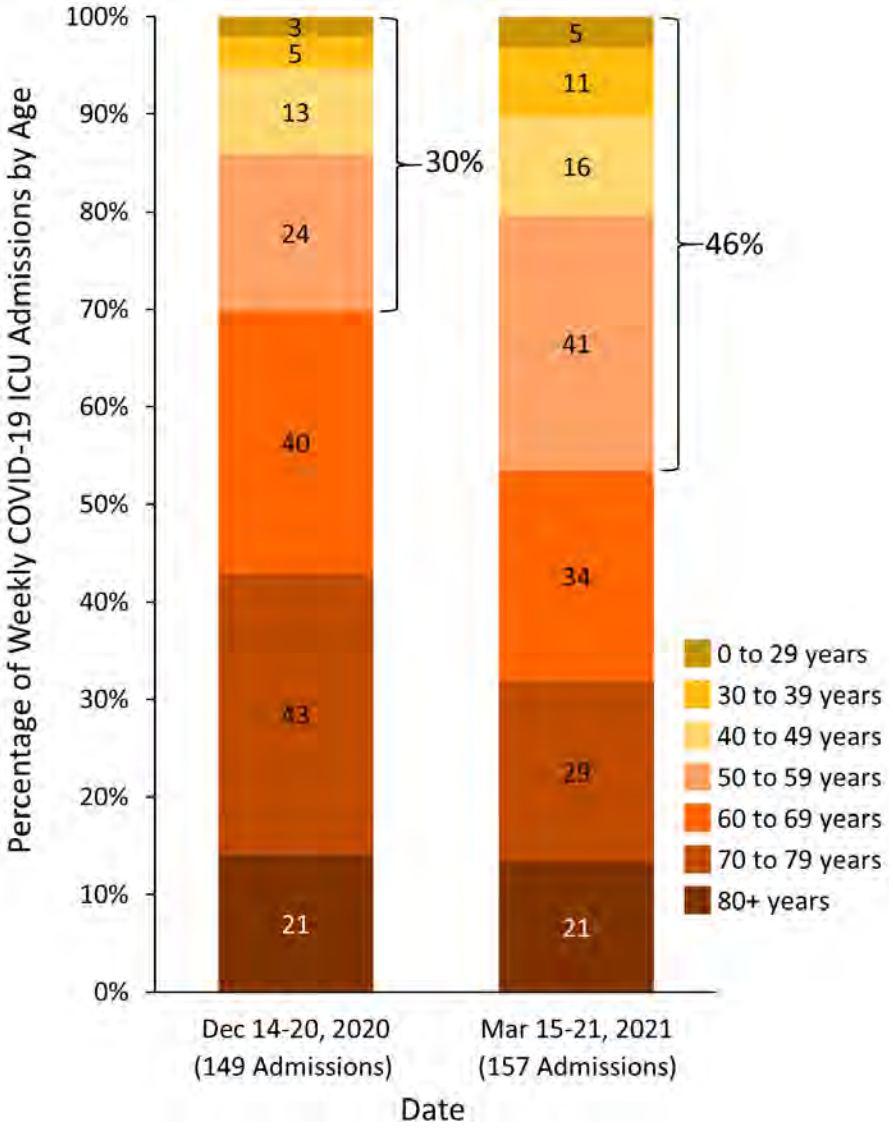

Figure 8. Weekly COVID-19 ICU Admissions in Ontario by Age
December 14 to 20, 2020 corresponds to the week prior to lockdown during the second wave, March 15 to 21, 2021 corresponds to the last available week of ICU admission data during the third wave. Data sourced from the Critical Care Information System (CCIS).

Interpretation

Compared with early variants of SARS-CoV-2, new VOCs are associated with a 103% increase in the risk of hospitalization, a 63% increase in the risk of ICU admission and a 56% increase in the risk of death due to COVID-19, which will result in a considerably higher burden to the health care system than observed with early variants during the second wave. The risk increase is particularly pronounced 14 to 28 days after a diagnosis of SARS-CoV-2 infection, which in turn will result in delays until the full burden to the health care system becomes apparent.

Since the start of the third wave around March 1, 2021, the number of new cases of SARS-CoV-2 infection, and the COVID-19 hospital and ICU occupancies have surpassed prior thresholds at the start of the province-wide lockdown on December 26, 2020. As of March 28, 2020, hospital occupancy was 21% higher and ICU occupancy 28% higher than at the start of the province-wide lockdown.

Currently, patients aged 59 years and younger make up 46% of new COVID-19 admissions to ICUs, compared with 30% in the week prior to the start of the province-wide lockdown on December 26, 2020.

Methods Used for This Science Brief

We conducted a retrospective cohort study using cases of SARS-CoV-2 infection reported in CCM/iPHIS with a case report date between Feb 7 and March 11, 2021. We restricted the analysis to cases that were tested for variants of concern. As Ontario's long-term care population was highly vaccinated with SARS-CoV-2 vaccines as of February 2021, and were unlikely to become critically ill and require intensive care, long term care residents were excluded from the analysis. A total of 26,314 individuals were included in the analysis, of whom 9,395 had a detected SARS-CoV-2 infection with a VOC. Associations between VOC SARS-CoV-2 infection and COVID-19 outcomes were evaluated by constructing logistic regression models with the following prespecified covariates: age (by 10-year age categories), sex, obesity, and any of the following medical comorbidities: asthma, immunocompromise, COPD, hematological disease, renal disease, neurological condition, diabetes, or liver disease. Time (date of case report) was included as a linear trend term. To account for geographic variability in the fraction of infections caused by VOCs, public health units were included as indicator variables. The analysis of the age distribution in Figure 8 is based on all cases, without exclusion of long-term care residents.

We searched PubMed, Google Scholar, the COVID-19 Rapid Evidence Reviews, the Joanna Briggs Institute's COVID-19 Special Collection, LitCovid in PubMed, the Oxford COVID-19 Evidence Service, the World Health Organization's Global Literature on Coronavirus Disease, and other COVID-19 specific resources listed by the Guidelines International Network and the McMaster Health Forum for studies on the prognosis associated with new VOCs compared with early variants. In addition, we retrieved reports citing relevant articles through Google Scholar and reviewed references from identified articles for additional studies. The search was last updated on March 26, 2021. For the United Kingdom, the analysis by Challen et al[6] was selected for extraction of mortality data rather than the analysis by Davies et al[4] since Challen et al.'s analysis was considered to have a lower risk of confounding.

We used an inverse-variance fixed-effects meta-analysis to combine adjusted estimates from individual studies. Analyses were done in R (R Foundation, Vienna, Austria) and STATA (StataCorp LLC, College Station, TX).

Author Contributions

PJ conceived the Science Brief. ART, AO and PJ wrote the first draft. ART, DNF, PB and PJ performed analyses. All authors revised the Science Brief critically for important intellectual content and approved the final version.

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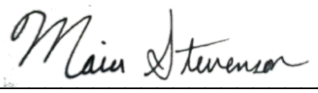
This is "**Exhibit I**"
to the Affidavit of Matthew Hodge,
affirmed this 2nd day of July, 2021



A Commissioner, etc.

Public Health Ontario | Santé publique Ontario

WEEKLY EPIDEMIOLOGICAL SUMMARY

SARS-CoV-2 Whole Genome Sequencing in Ontario, June 23, 2021

This report summarizes the results of SARS-CoV-2 whole genome sequencing completed by Public Health Ontario (PHO) as of June 17, 2021 and partner laboratories in the Ontario COVID-19 Genomics Network as of June 16, 2021. Not all data from the network laboratories were available to be included in this report. Results included in this report represent the number of samples tested and not the number of cases. More than one sample may be sequenced per person.

Background

The continued monitoring of global SARS-CoV-2 genomic data has identified changes in the genome as it spreads through populations. These random changes or mutations arise as a virus evolves over time. The accumulation of these mutations can result in a new lineage of the virus, which is a common occurrence. These new lineages will differ slightly in genome sequence and are termed variants. Although many variants will have no difference in the ability to spread or cause disease, some variants have mutations which may enhance virulence, transmissibility, and/or allow the virus to escape natural or vaccine-induced immunity.

The identification of variants and mutations occurs through whole genome sequencing (WGS) of select samples. Through global surveillance of SARS-CoV-2 genomes, a number of variants have been identified with evidence of clinical and/or public health significance, termed variants of concern (VOC). Current VOCs include B.1.1.7 (Alpha), B.1.351 (Beta), P.1 (Gamma) and B.1.617.2 (Delta). WGS has also identified a number of variants of interest (VOI), which may share one or more mutations in common with a VOC, but do not have sufficient evidence at this time to be categorized as a VOC (i.e. evidence of increased transmissibility, disease severity, or immune escape). These variants are also characterized and monitored through genomic surveillance. A VOI may be re-classified as a VOC where there is sufficient scientific evidence to support this designation. Full definitions of VOC/VOI can be found on the Public Health Agency of Canada's SARS-CoV-2 Variants webpage.[1]

The Ontario COVID-19 Genomics Network performs WGS on select samples received for SARS-CoV-2 diagnostic testing or VOC PCR testing. Sequences are processed using bioinformatics analysis and assigned a Pango lineage[2] using the pangolin tool[3], allowing for the identification of VOC, VOI and other lineages.

Highlights

- From May 9 to June 5, 2021, there were 2,342 samples sequenced by the Ontario COVID-19 Genomics Network for representative surveillance. The majority were Pango lineage B.1.1.7 (Alpha; 71.6%), followed by B.1.617.2 (Delta; 17.1%), and P.1 (Gamma; 4.0%).
- The proportion that were B.1.617.2 (Delta) increased from 14.1% (May 23 to 29) to 22.2% (May 30 to June 5).
- The public health units with the highest proportion of B.1.617.2 (Delta) from May 30 to June 5, 2021 were: Peel Public Health (38.2%), Region of Waterloo Public Health and Emergency Services (34.9%), Porcupine Health Unit (29.4%), and Halton Region Public Health (26.7%); excluding public health units with fewer than 25 samples sequenced.
- From January 1 to June 5, 2021, the most commonly identified VOI was B.1.1.318, with a total of 1,513 samples.

The data in this report should be interpreted with caution. For representative surveillance, PHO began sequencing eligible samples prior to other laboratories. For cumulative whole genome sequencing (WGS) results, the selection of samples for WGS historically has been influenced by laboratory testing algorithms. This has created a sampling bias reflected in the distribution of lineage results.

The Ontario COVID-19 Genomics Network is in the process of implementing a representative surveillance strategy. This will allow for provincial estimates of the prevalence of VOC, VOI, and other lineages. On June 14, the network moved to sequencing 100% of eligible samples.

Representative Surveillance

Table 1. Number and percentage of samples by VOC/VOI Pango lineage and week, representative surveillance, Ontario, May 9, 2021 to June 5, 2021

Pango lineage (WHO label)	Week 19 (May 9-15)	Week 20 (May 16-22)	Week 21 (May 23-29)	Week 22 (May 30-June 5)	Total (May 9-June 5)
Variant of concern (VOC)					
B.1.1.7 (Alpha)	337 (77.3%)	252 (68.9%)	483 (75.6%)	605 (67.1%)	1,677 (71.6%)
B.1.351 (Beta)	1 (0.2%)	3 (0.8%)	4 (0.6%)	5 (0.6%)	13 (0.6%)
P.1 (Gamma)	25 (5.7%)	14 (3.8%)	18 (2.8%)	36 (4.0%)	93 (4.0%)
B.1.617.2 (Delta)	47 (10.8%)	64 (17.5%)	90 (14.1%)	200 (22.2%)	401 (17.1%)
Variant of interest (VOI)					
A.23.1	0 (0.0%)	1 (0.3%)	0 (0.0%)	0 (0.0%)	1 (0.0%)
B.1.1.318	10 (2.3%)	8 (2.2%)	21 (3.3%)	19 (2.1%)	58 (2.5%)
B.1.427/B.1.429 (Epsilon)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.525 (Eta)	3 (0.7%)	4 (1.1%)	4 (0.6%)	14 (1.6%)	25 (1.1%)
B.1.526 (Iota)	0 (0.0%)	0 (0.0%)	1 (0.2%)	0 (0.0%)	1 (0.0%)
B.1.526.1	0 (0.0%)	1 (0.3%)	3 (0.5%)	1 (0.1%)	5 (0.2%)
B.1.526.2	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.0%)
B.1.526.3	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.616	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.617.1 (Kappa)	1 (0.2%)	0 (0.0%)	1 (0.2%)	0 (0.0%)	2 (0.1%)
B.1.617.3	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
P.2 (Zeta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
P.3 (Theta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Non-VOC/VOI	12 (2.8%)	19 (5.2%)	14 (2.2%)	20 (2.2%)	65 (2.8%)
Total sequenced	**436 (100%)**	**366 (100%)**	**639 (100%)**	**901 (100%)**	**2,342 (100%)**

Note: Results may not be representative of Ontario overall. PHO began sequencing 10% of eligible samples on May 2 and 50% on May 30. Other VOC PCR testing laboratories were asked to submit 10% of eligible samples to the Ontario COVID-19 Genomics Network (OCGN) on May 26 and 50% on June 2. Results are included for four (of five) OCGN laboratories. Week was assigned based on earliest date available for the sample. Results for recent weeks are incomplete as not all sequencing and bioinformatics analysis were complete at the time of data extraction and will be included in subsequent reports.
Data source: PHO, The Hospital for Sick Children, Kingston Health Sciences Centre, Shared Hospital Laboratory

Table 2. Percentage of B.1.617.2 (Delta) samples identified (number identified/total sequenced) by public health unit (PHU), region, and week, representative surveillance, Ontario, May 9, 2021 to June 5, 2021

Public Health Unit	Week 19 (May 9-15)	Week 20 (May 16-22)	Week 21 (May 23-29)	Week 22 (May 30-June 5)	Total (May 9- June 5)
Northwestern Health Unit	0.0% (0/2)	0.0% (0/1)	0.0% (0/0)	0.0% (0/0)	0.0% (0/3)
Thunder Bay District Health Unit	0.0% (0/3)	0.0% (0/0)	0.0% (0/12)	0.0% (0/4)	0.0% (0/19)
TOTAL NORTH WEST	**0.0% (0/5)**	**0.0% (0/1)**	**0.0% (0/12)**	**0.0% (0/4)**	**0.0% (0/22)**
Algoma Public Health	50.0% (1/2)	0.0% (0/5)	0.0% (0/0)	0.0% (0/1)	12.5% (1/8)
North Bay Parry Sound District Health Unit	0.0% (0/3)	0.0% (0/0)	0.0% (0/1)	33.3% (1/3)	14.3% (1/7)
Porcupine Health Unit	0.0% (0/3)	12.5% (2/16)	7.1% (2/28)	29.4% (15/51)	19.4% (19/98)
Public Health Sudbury & Districts	0.0% (0/0)	0.0% (0/0)	33.3% (1/3)	0.0% (0/1)	25.0% (1/4)
Timiskaming Health Unit	0.0% (0/0)	0.0% (0/0)	0.0% (0/0)	0.0% (0/0)	0.0% (0/0)
TOTAL NORTH EAST	**12.5% (1/8)**	**9.5% (2/21)**	**9.4% (3/32)**	**28.6% (16/56)**	**18.8% (22/117)**
Ottawa Public Health	25.0% (1/4)	0.0% (0/3)	0.0% (0/27)	0.0% (0/13)	2.1% (1/47)
Eastern Ontario Health Unit	0.0% (0/3)	0.0% (0/1)	0.0% (0/2)	0.0% (0/0)	0.0% (0/6)
Hastings Prince Edward Public Health	100.0% (1/1)	0.0% (0/2)	0.0% (0/0)	0.0% (0/0)	33.3% (1/3)
Kingston, Frontenac and Lennox & Addington Public Health	0.0% (0/6)	0.0% (0/3)	0.0% (0/1)	0.0% (0/5)	0.0% (0/15)
Leeds, Grenville & Lanark District Health Unit	0.0% (0/0)	0.0% (0/0)	0.0% (0/0)	0.0% (0/0)	0.0% (0/0)
Renfrew County and District Health Unit	0.0% (0/0)	100.0% (1/1)	0.0% (0/1)	0.0% (0/0)	50.0% (1/2)
TOTAL EASTERN	**14.3% (2/14)**	**10.0% (1/10)**	**0.0% (0/31)**	**0.0% (0/18)**	**4.1% (3/73)**
Durham Region Health Department	0.0% (0/4)	0.0% (0/6)	0.0% (0/22)	12.0% (6/50)	7.3% (6/82)
Haliburton, Kawartha, Pine Ridge District Health Unit	0.0% (0/5)	0.0% (0/10)	0.0% (0/9)	60.0% (3/5)	10.3% (3/29)
Peel Public Health	13.9% (28/201)	21.2% (33/156)	19.0% (33/174)	38.2% (47/123)	21.6% (141/654)
Peterborough Public Health	0.0% (0/4)	0.0% (0/5)	0.0% (0/4)	50.0% (3/6)	15.8% (3/19)
Simcoe Muskoka District Health Unit	0.0% (0/1)	0.0% (0/1)	20.0% (4/20)	5.9% (2/34)	10.7% (6/56)
York Region Public Health	0.0% (0/6)	0.0% (0/6)	3.8% (1/26)	20.7% (12/58)	13.5% (13/96)
TOTAL CENTRAL EAST	**12.7% (28/221)**	**17.9% (33/184)**	**14.9% (38/255)**	**26.4% (73/276)**	**18.4% (172/936)**
Toronto Public Health	5.1% (5/98)	17.8% (13/73)	15.6% (27/173)	21.9% (78/356)	17.6% (123/700)
TOTAL TORONTO	**5.1% (5/98)**	**17.8% (13/73)**	**15.6% (27/173)**	**21.9% (78/356)**	**17.6% (123/700)**
Chatham-Kent Public Health	0.0% (0/1)	0.0% (0/0)	0.0% (0/0)	0.0% (0/3)	0.0% (0/4)
Grey Bruce Health Unit	0.0% (0/1)	0.0% (0/1)	0.0% (0/0)	100.0% (1/1)	33.3% (1/3)
Huron Perth Public Health	0.0% (0/0)	75.0% (3/4)	33.3% (1/3)	0.0% (0/2)	44.4% (4/9)

Public Health Unit	Week 19 (May 9-15)	Week 20 (May 16-22)	Week 21 (May 23-29)	Week 22 (May 30-June 5)	Total (May 9- June 5)
Lambton Public Health	0.0% (0/0)	0.0% (0/0)	0.0% (0/1)	0.0% (0/3)	0.0% (0/4)
Middlesex-London Health Unit	0.0% (0/4)	0.0% (0/0)	7.7% (1/13)	4.0% (1/25)	4.8% (2/42)
Southwestern Public Health	100.0% (1/1)	0.0% (0/0)	0.0% (0/3)	0.0% (0/4)	12.5% (1/8)
Windsor-Essex County Health Unit	0.0% (0/17)	0.0% (0/11)	0.0% (0/24)	0.0% (0/22)	0.0% (0/74)
TOTAL SOUTH WEST	**4.2% (1/24)**	**18.8% (3/16)**	**4.5% (2/44)**	**3.3% (2/60)**	**5.6% (8/144)**
Brant County Health Unit	0.0.0% (0/0)	0.0% (0/2)	0.0% (0/6)	0.0% (0/19)	0.0% (0/27)
City of Hamilton Public Health Services	0.0% (0/4)	0.0% (0/2)	100.0% (2/2)	50.0% (1/2)	30.0% (3/10)
Haldimand-Norfolk Health Unit	33.3% (1/3)	0.0% (0/2)	50.0% (2/4)	25.0% (1/4)	30.8% (4/13)
Halton Region Public Health	12.5% (1/8)	33.3% (2/6)	20.0% (3/15)	26.7% (8/30)	23.7% (14/59)
Niagara Region Public Health	0.0% (0/2)	0.0% (0/1)	0.0% (0/2)	0.0% (0/8)	0.0% (0/13)
Region of Waterloo Public Health and Emergency Services	10.8% (4/37)	12.9% (4/31)	26.7% (12/45)	34.9% (15/43)	22.4% (35/156)
Wellington-Dufferin-Guelph Public Health	33.3% (4/12)	35.3% (6/17)	6.7% (1/15)	23.8% (5/21)	24.6% (16/65)
TOTAL CENTRAL WEST	**15.2% (10/66)**	**19.7% (12/61)**	**22.5% (20/89)**	**23.6% (30/127)**	**21.0% (72/343)**
UNKNOWN	0.0% (0/0)	0.0% (0/0)	0.0% (0/3)	25.0% (1/4)	14.3% (1/7)
TOTAL ONTARIO	**10.8% (47/436)**	**17.5% (64/366)**	**14.1% (90/639)**	**22.2% (200/901)**	**17.1% (401/2,342)**

Note: Results may not be representative of public health units overall. PHO began sequencing 10% of eligible samples on May 2 and 50% on May 30. Other VOC PCR testing laboratories were asked to submit 10% of eligible samples to the Ontario COVID-19 Genomics Network (OCGN) on May 26 and 50% on June 2. Results are included for four (of five) OCGN laboratories. Week was assigned based on earliest date available for the sample. Results for recent weeks are incomplete as not all sequencing and bioinformatics analysis were complete at the time of data extraction and will be included in subsequent reports. Public health unit was assigned based on patient postal code. If unavailable, ordering provider postal code was used (13.8% of samples).
Data source: PHO, The Hospital for Sick Children, Kingston Health Sciences Centre, Shared Hospital Laboratory

Table 3a. Number and percentage of samples by VOC/VOI Pango lineage and public health unit (PHU), representative surveillance, North West Region, May 9, 2021 to June 5, 2021

Pango lineage (WHO label)	Northwestern Health Unit	Thunder Bay District Health Unit	Total
Variant of concern			
B.1.1.7 (Alpha)	0 (0.0%)	15 (78.9%)	15 (68.2%)
B.1.351 (Beta)	0 (0.0%)	0 (0.0%)	0 (0.0%)
P.1 (Gamma)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.617.2 (Delta)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Variant of interest			
A.23.1	1 (33.3%)	0 (0.0%)	1 (4.5%)
B.1.1.318	0 (0.0%)	4 (21.1%)	4 (18.2%)
B.1.427/B.1.429 (Epsilon)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.525 (Eta)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526 (Iota)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526.1	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526.2	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526.3	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.616	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.617.1 (Kappa)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.617.3	0 (0.0%)	0 (0.0%)	0 (0.0%)
P.2 (Zeta)	0 (0.0%)	0 (0.0%)	0 (0.0%)
P.3 (Theta)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Non-VOC/VOI	2 (66.7%)	0 (0.0%)	2 (9.1%)
Total sequenced	**3 (100%)**	**19 (100%)**	**22 (100%)**

Note: Results may not be representative of public health units overall. PHO began sequencing 10% of eligible samples on May 2 and 50% on May 30. Other VOC PCR testing laboratories were asked to submit 10% of eligible samples to the Ontario COVID-19 Genomics Network (OCGN) on May 26 and 50% on June 2. Results are included for four (of five) OCGN laboratories. Sample date is the earliest date available for the sample. Results for recent weeks are incomplete as not all sequencing and bioinformatics analysis were complete at the time of data extraction and will be included in subsequent reports. Public health unit was assigned based on patient postal code. If unavailable, ordering provider postal code was used.
Data source: PHO, The Hospital for Sick Children, Kingston Health Sciences Centre, Shared Hospital Laboratory

Table 3b. Number and percentage of samples by VOC/VOI Pango lineage and public health unit (PHU), representative surveillance, North East Region, May 9, 2021 to June 5, 2021

Pango lineage (WHO label)	Algoma Public Health	North Bay Parry Sound District Health Unit	Porcupine Health Unit	Public Health Sudbury & Districts	Timiskaming Health Unit	Total
Variant of concern						
B.1.1.7 (Alpha)	4 (50%)	6 (85.7%)	79 (80.6%)	3 (75.0%)	0 (0.0%)	92 (78.6%)
B.1.351 (Beta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
P.1 (Gamma)	2 (25.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (1.7%)
B.1.617.2 (Delta)	1 (12.5%)	1 (14.3%)	19 (19.4%)	1 (25.0%)	0 (0.0%)	22 (18.8%)
Variant of interest						
A.23.1	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.1.318	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.427/B.1.429 (Epsilon)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.525 (Eta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526 (Iota)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526.1	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526.2	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526.3	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.616	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.617.1 (Kappa)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.617.3	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
P.2 (Zeta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
P.3 (Theta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Non-VOC/VOI	1 (12.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.9%)
Total sequenced	**8 (100%)**	**7 (100%)**	**98 (100%)**	**4 (100%)**	**0 (0.0%)**	**117 (100%)**

Note: Results may not be representative of public health units overall. PHO began sequencing 10% of eligible samples on May 2 and 50% on May 30. Other VOC PCR testing laboratories were asked to submit 10% of eligible samples to the Ontario COVID-19 Genomics Network (OCGN) on May 26 and 50% on June 2. Results are included for four (of five) OCGN laboratories. Sample date is the earliest date available for the sample. Results for recent weeks are incomplete as not all sequencing and bioinformatics analysis were complete at the time of data extraction and will be included in subsequent reports. Public health unit was assigned based on patient postal code. If unavailable, ordering provider postal code was used.

Data source: PHO, The Hospital for Sick Children, Kingston Health Sciences Centre, Shared Hospital Laboratory

Table 3c. Number and percentage of samples by VOC/VOI Pango lineage and public health unit (PHU), representative surveillance, Eastern Region, May 9, 2021 to June 5, 2021

Pango lineage (WHO label)	Eastern Ontario Health Unit	Hastings Prince Edward Public Health	Kingston, Frontenac and Lennox & Addington Public Health	Leeds, Grenville & Lanark District Health Unit	Ottawa Public Health	Renfrew County and District Health Unit	Total
Variant of concern							
B.1.1.7 (Alpha)	6 (100%)	2 (66.7%)	14 (93.3%)	0 (0.0%)	42 (89.4%)	1 (50.0%)	65 (89.0%)
B.1.351 (Beta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
P.1 (Gamma)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.1%)	0 (0.0%)	1 (1.4%)
B.1.617.2 (Delta)	0 (0.0%)	1 (33.3%)	0 (0.0%)	0 (0.0%)	1 (2.1%)	1 (50.0%)	3 (4.1%)
Variant of interest							
A.23.1	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.1.318	0 (0.0%)	0 (0.0%)	1 (6.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.4%)
B.1.427/B.1.429 (Epsilon)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.525 (Eta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526 (Iota)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526.1	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526.2	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526.3	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.616	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.617.1 (Kappa)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.617.3	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
P.2 (Zeta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
P.3 (Theta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Non-VOC/VOI	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (6.4%)	0 (0.0%)	3 (4.1%)
Total sequenced	**6 (100%)**	**3 (100%)**	**15 (100%)**	**0 (0.0%)**	**47 (100%)**	**2 (100%)**	**73 (100%)**

Note: Results may not be representative of public health units overall. PHO began sequencing 10% of eligible samples on May 2 and 50% on May 30. Other VOC PCR testing laboratories were asked to submit 10% of eligible samples to the Ontario COVID-19 Genomics Network (OCGN) on May 26 and 50% on June 2. Results are included for four (of five) OCGN laboratories. Sample date is the earliest date available for the sample. Results for recent weeks are incomplete as not all sequencing and bioinformatics analysis were complete at the time of data extraction and will be included in subsequent reports. Public health unit was assigned based on patient postal code. If unavailable, ordering provider postal code was used.

Data source: PHO, The Hospital for Sick Children, Kingston Health Sciences Centre, Shared Hospital Laboratory

Table 3d. Number and percentage of samples by VOC/VOI Pango lineage and public health unit (PHU), representative surveillance, Central East Region, May 9, 2021 to June 5, 2021

Pango lineage (WHO label)	Durham Region Health Department	Haliburton, Kawartha, Pine Ridge District Health Unit	Peel Public Health	Peterborough Public Health	Simcoe Muskoka District Health Unit	York Region Public Health	Total
Variant of concern							
B.1.1.7 (Alpha)	54 (65.9%)	14 (48.3%)	440 (67.3%)	15 (78.9%)	46 (82.1%)	65 (67.7%)	634 (67.7%)
B.1.351 (Beta)	0 (0.0%)	0 (0.0%)	2 (0.3%)	0 (0.0%)	0 (0.0%)	1 (1.0%)	3 (0.3%)
P.1 (Gamma)	2 (2.4%)	0 (0.0%)	27 (4.1%)	0 (0.0%)	3 (5.4%)	12 (12.5%)	44 (4.7%)
B.1.617.2 (Delta)	6 (7.3%)	3 (10.3%)	141 (21.6%)	3 (15.8%)	6 (10.7%)	13 (13.5%)	172 (18.4%)
Variant of interest							
A.23.1	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.1.318	4 (4.9%)	0 (0.0%)	17 (2.6%)	0 (0.0%)	1 (1.8%)	5 (5.2%)	27 (2.9%)
B.1.427/B.1.429 (Epsilon)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.525 (Eta)	16 (19.5%)	0 (0.0%)	2 (0.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	18 (1.9%)
B.1.526 (Iota)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526.1	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526.2	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526.3	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.616	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.617.1 (Kappa)	0 (0.0%)	0 (0.0%)	1 (0.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)
B.1.617.3	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
P.2 (Zeta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
P.3 (Theta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Non-VOC/VOI	0 (0.0%)	12 (41.4%)	24 (3.7%)	1 (5.3%)	0 (0.0%)	0 (0.0%)	37 (4.0%)
Total sequenced	**82 (100%)**	**29 (100%)**	**654 (100%)**	**19 (100%)**	**56 (100%)**	**96 (100%)**	**936 (100%)**

Note: Results may not be representative of public health units overall. PHO began sequencing 10% of eligible samples on May 2 and 50% on May 30. Other VOC PCR testing laboratories were asked to submit 10% of eligible samples to the Ontario COVID-19 Genomics Network (OCGN) on May 26 and 50% on June 2. Results are included for four (of five) OCGN laboratories. Sample date is the earliest date available for the sample. Results for recent weeks are incomplete as not all sequencing and bioinformatics analysis were complete at the time of data extraction and will be included in subsequent reports. Public health unit was assigned based on patient postal code. If unavailable, ordering provider postal code was used.

Data source: PHO, The Hospital for Sick Children, Kingston Health Sciences Centre, Shared Hospital Laboratory

Table 3e. Number and percentage of samples by VOC/VOI Pango lineage and public health unit (PHU), representative surveillance, Toronto Region, May 9, 2021 to June 5, 2021

Pango lineage (WHO label)	Toronto Public Health	Total
Variant of concern		
B.1.1.7 (Alpha)	503 (71.9%)	503 (71.9%)
B.1.351 (Beta)	4 (0.6%)	4 (0.6%)
P.1 (Gamma)	29 (4.1%)	29 (4.1%)
B.1.617.2 (Delta)	123 (17.6%)	123 (17.6%)
Variant of interest		
A.23.1	0 (0.0%)	0 (0.0%)
B.1.1.318	17 (2.4%)	17 (2.4%)
B.1.427/B.1.429 (Epsilon)	0 (0.0%)	0 (0.0%)
B.1.525 (Eta)	7 (1.0%)	7 (1.0%)
B.1.526 (Iota)	0 (0.0%)	0 (0.0%)
B.1.526.1	0 (0.0%)	0 (0.0%)
B.1.526.2	1 (0.1%)	1 (0.1%)
B.1.526.3	0 (0.0%)	0 (0.0%)
B.1.616	0 (0.0%)	0 (0.0%)
B.1.617.1 (Kappa)	0 (0.0%)	0 (0.0%)
B.1.617.3	0 (0.0%)	0 (0.0%)
P.2 (Zeta)	0 (0.0%)	0 (0.0%)
P.3 (Theta)	0 (0.0%)	0 (0.0%)
Non-VOC/VOI	16 (2.3%)	16 (2.3%)
Total sequenced	**700 (100%)**	**700 (100%)**

Note: Results may not be representative of public health units overall. PHO began sequencing 10% of eligible samples on May 2 and 50% on May 30. Other VOC PCR testing laboratories were asked to submit 10% of eligible samples to the Ontario COVID-19 Genomics Network (OCGN) on May 26 and 50% on June 2. Results are included for four (of five) OCGN laboratories. Sample date is the earliest date available for the sample. Results for recent weeks are incomplete as not all sequencing and bioinformatics analysis were complete at the time of data extraction and will be included in subsequent reports. Public health unit was assigned based on patient postal code. If unavailable, ordering provider postal code was used.
Data source: PHO, The Hospital for Sick Children, Kingston Health Sciences Centre, Shared Hospital Laboratory

Table 3f. Number and percentage of samples by VOC/VOI Pango lineage and public health unit (PHU), representative surveillance, South West Region, May 9, 2021 to June 5, 2021

Pango lineage (WHO label)	Chatham-Kent Public Health	Grey Bruce Health Unit	Huron Perth Public Health	Lambton Public Health	Middlesex-London Health Unit	Southwestern Public Health	Windsor-Essex County Health Unit	Total
Variant of concern								
B.1.1.7 (Alpha)	4 (100%)	1 (33.3%)	1 (11.1%)	4 (100%)	37 (88.1%)	6 (75.0%)	68 (91.9%)	121 (84.0%)
B.1.351 (Beta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (12.5%)	0 (0.0%)	1 (0.7%)
P.1 (Gamma)	0 (0.0%)	0 (0.0%)	4 (44.4%)	0 (0.0%)	2 (4.8%)	0 (0.0%)	0 (0.0%)	6 (4.2%)
B.1.617.2 (Delta)	0 (0.0%)	1 (33.3%)	4 (44.4%)	0 (0.0%)	2 (4.8%)	1 (12.5%)	0 (0.0%)	8 (5.6%)
Variant of interest								
A.23.1	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.1.318	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.427/B.1.429 (Epsilon)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.525 (Eta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526 (Iota)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.4%)	0 (0.0%)	0 (0.0%)	1 (0.7%)
B.1.526.1	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (6.8%)	5 (3.5%)
B.1.526.2	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526.3	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.616	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.617.1 (Kappa)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.617.3	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
P.2 (Zeta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
P.3 (Theta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Non-VOC/VOI	0 (0.0%)	1 (33.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.4%)	2 (1.4%)
Total sequenced	**4 (100%)**	**3 (100%)**	**9 (100%)**	**4 (100%)**	**42 (100%)**	**8 (100%)**	**74 (100%)**	**144 (100%)**

Note: Results may not be representative of public health units overall. PHO began sequencing 10% of eligible samples on May 2 and 50% on May 30. Other VOC PCR testing laboratories were asked to submit 10% of eligible samples to the Ontario COVID-19 Genomics Network (OCGN) on May 26 and 50% on June 2. Results are included for four (of five) OCGN laboratories. Sample date is the earliest date available for the sample. Results for recent weeks are incomplete as not all sequencing and bioinformatics analysis were complete at the time of data extraction and will be included in subsequent reports. Public health unit was assigned based on patient postal code. If unavailable, ordering provider postal code was used.
Data source: PHO, The Hospital for Sick Children, Kingston Health Sciences Centre, Shared Hospital Laboratory

Table 3g. Number and percentage of samples by VOC/VOI Pango lineage and public health unit (PHU), representative surveillance, Central West Region, May 9, 2021 to June 5, 2021

Pango lineage (WHO label)	Brant County Health Unit	City of Hamilton Public Health Services	Haldimand -Norfolk Health Unit	Halton Region Public Health	Niagara Region Public Health	Region of Waterloo Public Health and Emergency Services	Wellington-Dufferin-Guelph Public Health	Total
Variant of concern								
B.1.1.7 (Alpha)	20 (74.1%)	6 (60.0%)	8 (61.5%)	39 (66.1%)	11 (84.6%)	110 (70.5%)	47 (72.3%)	241 (70.3%)
B.1.351 (Beta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (3.2%)	0 (0.0%)	5 (1.5%)
P.1 (Gamma)	5 (18.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (7.7%)	5 (3.2%)	0 (0.0%)	11 (3.2%)
B.1.617.2 (Delta)	0 (0.0%)	3 (30.0%)	4 (30.8%)	14 (23.7%)	0 (0.0%)	35 (22.4%)	16 (24.6%)	72 (21.0%)
Variant of interest								
A.23.1	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.1.318	2 (7.4%)	1 (10.0%)	1 (7.7%)	5 (8.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	9 (2.6%)
B.1.427/B.1.429 (Epsilon)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.525 (Eta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526 (Iota)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526.1	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526.2	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.526.3	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.616	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
B.1.617.1 (Kappa)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.6%)	0 (0.0%)	1 (0.3%)
B.1.617.3	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
P.2 (Zeta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
P.3 (Theta)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Non-VOC/VOI	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.7%)	1 (7.7%)	0 (0.0%)	2 (3.1%)	4 (1.2%)
Total sequenced	**27 (100%)**	**10 (100%)**	**13 (100%)**	**59 (100%)**	**13 (100%)**	**156 (100%)**	**65 (100%)**	**343 (100%)**

Note: Results may not be representative of public health units overall. PHO began sequencing 10% of eligible samples on May 2 and 50% on May 30. Other VOC PCR testing laboratories were asked to submit 10% of eligible samples to the Ontario COVID-19 Genomics Network (OCGN) on May 26 and 50% on June 2. Results are included for four (of five) OCGN laboratories. Sample date is the earliest date available for the sample. Results for recent weeks are incomplete as not all sequencing and bioinformatics analysis were complete at the time of data extraction and will be included in subsequent reports. Public health unit was assigned based on patient postal code. If unavailable, ordering provider postal code was used.
Data source: PHO, The Hospital for Sick Children, Kingston Health Sciences Centre, Shared Hospital Laboratory

Cumulative Whole Genome Sequencing Results

Table 4. Number of samples by VOC/VOI Pango lineage, cumulative counts, Ontario, January 1, 2021 to June 5, 2021

Pango lineage (WHO label)	January 1 - May 8	May 9 - June 5	Total
Variant of concern (VOC)			
B.1.1.7 (Alpha)	6,767	2,107	8,874
B.1.351 (Beta)	1,093	39	1,132
P.1 (Gamma)	3,324	365	3,689
B.1.617.2 (Delta)	269	684	953
Variant of interest (VOI)			
A.23.1	83	1	84
B.1.1.318	1,187	326	1,513
B.1.427/B.1.429 (Epsilon)	16	0	16
B.1.525 (Eta)	306	50	356
B.1.526 (Iota)	95	3	98
B.1.526.1	2	5	7
B.1.526.2	4	1	5
B.1.526.3	7	0	7
B.1.616	0	0	0
B.1.617.1 (Kappa)	72	5	77
B.1.617.3	2	0	2
P.2 (Zeta)	46	0	46
P.3 (Theta)	1	0	1
Non-VOC/VOI	3,390	126	3,516
Total sequenced	**16,664**	**3,712**	**20,376**

Note: Includes results from PHO since January 1, 2021, The Hospital for Sick Children since April 21, 2021, Kingston Health Sciences Centre since January 1, 2021, Shared Hospital Laboratory since March 26, 2021, and Hamilton Regional Laboratory Medicine Program since April 11, 2021. Past testing algorithms have led to preferential sequencing of samples with N501Y and/or E484K mutations detected by PCR, which has biased the results toward lineages with these mutations. Results should be interpreted with caution as frequencies do not reflect prevalence. Sample date is the earliest date available for the sample.
Data source: PHO, The Hospital for Sick Children, Kingston Health Sciences Centre, Shared Hospital Laboratory, Hamilton Regional Laboratory Medicine Program

Technical Notes

Data Sources

- Public Health Ontario (PHO)
    - Data were extracted from the PHO Laboratory Information Management System on June 17 at approximately 5:00 a.m.
    - Data were extracted from the PHO SARS-CoV-2 Whole Genome Sequencing Database on June 17 at approximately 9:00 a.m.
- The Hospital for Sick Children (HSC)
    - Data were received by PHO on June 16, 2021 at approximately 11:45 a.m.
- Kingston Health Sciences Centre (KHSC)
    - Data were received by PHO on June 16, 2021 at approximately 4:00 p.m.
- Shared Hospital Laboratory (SHL)
    - Data were received by PHO on June 16, 2021 at approximately 5:45 p.m.
- Hamilton Regional Laboratory Medicine Program (HRLMP)
    - Data were received by PHO on June 17, 2021 at approximately 6:45 a.m.

Ontario SARS-CoV-2 Whole Genome Sequencing Strategy

- At the beginning of 2021, Ontario's whole genome sequencing strategy was to sequence samples with specific mutations identified from VOC PCR testing to confirm they were variants of concern. From February 3, 2021 this included sequencing samples with the N501Y mutation detected (initially associated with the B.1.1.7 [Alpha] lineage) and from March 22, 2021, samples with the E484K mutation detected (initially associated with the P.1 [Gamma] and B.1.351 [Beta] lineages).
- Ontario's strategy has recently shifted to representative surveillance with VOC PCR testing laboratories being asked to send 10% of eligible samples (Ct ≤ 30 and sufficient volume remaining) to Ontario COVID-19 Genomics Network (OCGN) sequencing laboratories. PHO began sequencing a 10% systematic sample of eligible samples on May 2; 50% on May 30; and 100% on June 14. Other VOC PCR testing laboratories were asked to begin submitting a 10% systematic or random sample of eligible samples to OCGN laboratories on May 26; 50% on June 2; and 100% on June 14.

Data Caveats and Methods

- Whole genome sequencing sample logistics are complex and require samples to be transferred across a large network of laboratories. Samples are initially sent to one of 73 diagnostic testing laboratories. If the diagnostic PCR cycle threshold is ≤ 35 and there is sufficient volume remaining, samples are submitted for testing at one of 11 VOC PCR testing laboratories. If the VOC PCR cycle threshold is ≤ 30 and there is sufficient volume remaining, VOC PCR testing laboratories have been asked to submit a proportion of their eligible samples to one of five OCGN laboratories for sequencing according to the surveillance strategy.

- Results included in this report are sample-based and not person-based. As such, it is possible that more than one sample was sequenced per individual.

- The dates associated with samples submitted by network laboratories vary due to sample logistics and different laboratory information systems. Dates associated with WGS samples were assigned based on a hierarchy: sample collection date > SARS-CoV-2 diagnostic received date > SARS-CoV-2 diagnostic reported date > VOC PCR received date > VOC PCR reported date > WGS received date > WGS reported date. Weeks were created to align with surveillance weeks used by the Public Health Agency of Canada for influenza reporting.

- Lineage nomenclature is dynamic. Pango lineage naming and assignment may change as more samples are sequenced and analyzed globally. Similarly, VOC and VOI classifications may change.

Data Caveats and Methods: Representative Surveillance

- Results may not be representative of Ontario overall. Samples selected include a proportion of eligible samples received by OCGN laboratories according to the whole genome sequencing strategy. Individual VOC PCR laboratories may have implemented the strategy and/or increased the proportion of samples selected from 10% to 50% on different dates.

- PHO is unable to confirm whether VOC PCR testing laboratories have submitted eligible samples.

- Results for recent weeks are incomplete as not all sequencing and bioinformatics analysis were complete at the time of data extraction.

- Public health unit was assigned based on patient postal code. If unavailable, ordering provider postal code was used (13.8% of samples).

Data Caveats and Methods: Whole Genome Sequencing Results

- The data included do not reflect all whole genome sequencing conducted in Ontario. Data from the OCGN laboratories cover different time periods: PHO since January 1, 2021, HSC since April 21, 2021, KHSC since January 1, 2021, SHL since March 26, 2021, and HRLMP since April 11, 2021.

- Past testing algorithms have led to preferential sequencing of samples with N501Y and/or E484K mutations detected by VOC PCR. This has created a sampling bias reflected in the distribution of lineage results. Data submitted to PHO from other laboratories in the OCGN have not been independently verified.

References

1. Public Health Agency of Canada. SARS-CoV-2 variants: national definitions, classifications and public health actions [Internet]. Ottawa, ON: Government of Canada; 2021 [modified 2021 May 14; cited 2021 May 29]. Available from: https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/health-professionals/testing-diagnosing-case-reporting/sars-cov-2-variants-national-definitions-classifications-public-health-actions.html
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3. cov-lineages. pangolin [Internet]. 2020 [cited 2021 May 29]. GitHub. Available from: https://github.com/cov-lineages/pangolin

Citation

Ontario Agency for Health Protection and Promotion (Public Health Ontario). Epidemiologic summary: SARS-CoV-2 whole genome sequencing in Ontario, June 23, 2021. Toronto, ON: Queen's Printer for Ontario; 2021.

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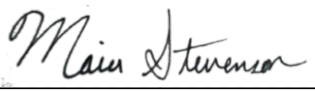
Ontario

This is "**Exhibit J**"
to the Affidavit of Matthew Hodge,
affirmed this 2nd day of July, 2021



A Commissioner, etc.

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SYNTHESIS

20/05/21

COVID-19 Transmission Through Large Respiratory Droplets and Aerosols… What We Know So Far

Introduction

Public Health Ontario (PHO) is actively monitoring, reviewing and assessing relevant information related to Coronavirus Disease 2019 (COVID-19). "What We Know So Far" documents provide a rapid review of the evidence on a specific aspect or emerging issue related to COVID-19. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is transmitted in different ways; however, this document will focus on transmission by respiratory droplets and aerosols.

Key Findings

- The historical dichotomy of droplet versus airborne transmission, while useful in implementing infection prevention and control (IPAC) strategies, does not accurately recognize the complexity of viral respiratory transmission, including for SARS-CoV-2.
- SARS-CoV-2 is transmitted most frequently and easily at short range through exposure to respiratory particles that range in size from large droplets which fall quickly to the ground to smaller droplets, known as aerosols, which can remain suspended in the air.
- There is evidence to suggest long-range transmission can occur under the right set of favourable conditions, implicating aerosols in transmission.
- The relative role of large respiratory droplets versus smaller droplet particles in short-range transmission is challenging to quantify. Their contributions to a specific case-contact interaction vary based on contextual factors including source/receptor characteristics (e.g., forceful expulsions such as singing, coughing, sneezing; viral load) and pathway characteristics (e.g., duration of exposure; environmental conditions such as ventilation, temperature, humidity, ultraviolet light; source control; and use of personal protective equipment).
- Translation of this summary into control measures needs to take into consideration other information, such as evidence around the effectiveness of control measures to date. Several control measures applied together in a layered approach are likely to be effective irrespective of the relative contribution of droplets or aerosols, including achieving high vaccination coverage and avoiding the "3 C's" (closed spaces, crowded places and close contact).

Background

The diameter of microorganism-containing respiratory particles relevant for respiratory infections ranges from approximately 0.01 micrometres (µm) to greater than 100 µm.[1] Particles larger than about 100 µm play a role in respiratory infection transmission by impacting on mucosal surfaces, such as the nostrils, mouth and eyes. Particles smaller than 100 µm can be inhaled or impact on mucosal surfaces. Some particles are small enough that they can be suspended in the air for various periods of time (known as aerosols).[2] Environmental factors such as local air currents and humidity affect these particles, e.g., how they move, evaporate, and how long they remain in air.[3] Therefore, the mode of transmission is influenced by three key elements: the source, the pathway, and the receptor. Depending on the unique characteristics of each element, certain modes may be more likely than others.

Traditionally, respiratory particles >5 or 10 µm have been termed droplets and were thought to impact directly on mucous membranes, while smaller particles were thought to be inhaled. This dichotomy of transmission routes has been applied to infection prevention controls within health care settings worldwide. However, these transmission routes are not mutually exclusive as droplets well over 5 µm are capable of remaining suspended in air for some time and can be inhaled. At short range within about 2 metres (m), infection can occur from inhaled aerosols as well as droplets landing on mucous membranes (short-range transmission). Herein, we refer to what was traditionally called airborne transmission via inhalation of aerosols that have remained suspended over long distances and periods of time[4,5] as long-range transmission.

We describe transmission through epidemiological studies, experimental or simulation of transmission studies, and statistical or mathematical modelling. Modelling shows what is possible, experimental studies what is plausible, and epidemiologic studies observe what is actually occurring, and each type of evidence is subject to limitations. However, exact routes of SARS-CoV-2 transmission in real-life scenarios can only be inferred based on the available data.

The purpose of this rapid review is to outline the evidence for droplets and aerosols in SARS-CoV-2 transmission. We have summarized the evidence as either short-range transmission from large respiratory droplets and small droplets or aerosols, or long-range transmission from aerosols.

Methods and Scope

In considering feasibility, scope and timelines, we undertook a rapid review to update our summary of SARS-CoV-2 transmission from large respiratory droplets and aerosols. A rapid review is a knowledge synthesis where certain steps of the systematic review process are omitted in order to be timely (e.g., duplicate screening).[6]

We conducted literature searches in MEDLINE (April 22, 2021) and National Institutes of Health COVID-19 Portfolio (Preprints) (April 27, 2021), search strategies are available upon request. We searched PubMed and Google Scholar on April 28, 2021 for additional articles of interest.

English-language peer-reviewed and non-peer-reviewed records that described large respiratory droplet and aerosol routes of transmission of COVID-19 were included. We restricted the search to articles published after January 1, 2020. This rapid review concentrated on evidence from systematic reviews and meta-analyses, supplemented by primary literature where appropriate. We reviewed citations from included articles to identify additional research.

Prior to publishing, PHO subject-matter experts review all What We Know So Far documents. As the scientific evidence is expanding rapidly, the information provided in this document is only current as of the date of respective literature searches.

Out-of-scope for this document was a review of IPAC practices appropriate for individual transmission scenarios and settings. Application of a hierarchy of control measures for non-health care settings is briefly discussed in the conclusions. For additional information related to IPAC in health care settings, please see PHO's technical briefing *IPAC Recommendations for Use of Personal Protective Equipment for Care of Individuals with Suspect or Confirmed COVID-19* and *Interim Guidance for Infection Prevention and Control of SARS-CoV-2 Variants of Concern for Health Care Settings*.[7,8] Please note that the *Ministry of Health's Directive 1* is the provincial baseline standard for provision of personal protective equipment for hospitals, long-term care homes and retirement homes and that the *Ministry of Health's Directive 5* provides agency to health care workers to make professional decisions regarding the appropriate personal protective equipment when dealing with suspected, probable or confirmed COVID-19 patients or residents.[9,10] Evidence for contact/fomite transmission, and virus and host (source/receptor) factors were not reviewed in this document, but are acknowledged as contributors to short- and long-range transmission. Other routes of transmission are reviewed in PHO's synthesis *COVID-19 Routes of Transmission – What We Know So Far*.[11]

Short-range Transmission

Main Findings

SARS-CoV-2 is transmitted most frequently and easily at short range. Short-range transmission generally occurs within 2 m of an infectious individual (e.g., during a conversation with inadequate distancing, no barriers, no personal protective equipment). Theoretically, short-range transmission may occur due to droplets or aerosols, but the relative contribution of either is specific to each case-contact interaction which varies based on contextual factors including source/receptor and pathway characteristics.

Environmental Factors Affecting Short-range Droplets and Aerosols

In addition to virus and host factors, environmental factors are associated with short-range viral transmission. The distance travelled by large respiratory droplets is generally <2 m, although it can reach up to 8 m in certain circumstances. In a study by Guo et al. (2020), SARS-CoV-2 virus was detected on the floor up to 4 m away from a patient.[12] In a systematic review of studies assessing the horizontal distance travelled by respiratory droplets, Bahl et al. (2020) reported that droplets could travel up to 8 m.[13] In a mathematical model, Chen et al. (2021) reported that respiratory droplets >100 µm in diameter are only important in transmission at a distance of less than 0.2 m when the infector is talking, or within 0.5 m when the infector is coughing.[14] Modelling by Wang et al. (2021) (preprint) suggested droplets >100 µm would most often not travel past 1.75 m (most droplets >100 µm diameter settle before 1.25 m).[15]

In a review of respiratory virus transmission, Leung (2021) reported that environmental factors affecting transmission include temperature, relative humidity, ventilation, airflow and ultraviolet (UV) light.[16] Ventilation, airflow and forceful expulsion (sneezing or coughing) can make respiratory particles travel further than 2 m through momentum.[14,17] High temperature and low humidity contributes to shrinking of droplets such that they may remain suspended in air for longer periods of time.[18]

Even at short-range distances, ventilation may affect transmission. De Oliveira et al. (2021) modelled infection risk in ventilated (10 air changes per hour [ACH]) and unventilated spaces without respiratory protection during a 1-hour exposure at 2-m distance.[19] The impact of decreasing concentration of virus in the air through ventilation was notable. Estimates of infection risk were reduced by at least three times based on the parameters and assumptions of their model. The authors also commented that the direction of airflow can have a significant impact – upward air streams can maintain aerosols at face height significantly increasing infectious risk.

Indoor settings are a predominant risk factor for transmission. In a systematic review of 5 studies, Bulfone et al. (2020) reported that the odds of indoor transmission were 18.7 times (95% confidence interval [CI]: 6.0–57.9) higher than outdoor settings, and less than 10% of infections occurred outdoors.[20] Very few superspreading events have been described from exclusively outdoor exposures. The explanation for this observation is likely multifactorial which includes important differences in ventilation, UV light, humidity, as well as possible differences in behaviour.

Epidemiological and Modelling Studies Describing Short-range Transmission

The following section reviews the epidemiologic and modelling evidence supporting short-range transmission of COVID-19. It reviews the reproductive number and summarizes the epidemiological and modelling studies by setting, including transportation, health care and sports.

The reproductive number (R_0) of SARS-CoV-2 is less suggestive of long-range transmission commonly occurring, as viruses where long-range transmission commonly occurs tend to have a higher R_0.[16] For example, in a systematic review by Guerra et al. (2017), the R_0 for the measles virus in the pre-vaccine era was 6.1–27.0,[21] compared to the median range of R_0 (2.7–3.3) reported for SARS-CoV-2.[22] It is important to note that R_0 is not a direct measure or indication of transmission route, as R_0 can be setting and population-specific, and be impacted by factors such human behaviours. The R_0 for SARS-CoV-2 also displays overdispersion, where the overall R_0 is lower than pathogens that commonly transmit through aerosols at long-range, but a small proportion of cases are associated with reproductive numbers in the range typical of viruses that commonly transmit through aerosols at long-range (i.e., superspreader events).[23] Such cases illustrate the potential variability in COVID-19 transmission, depending on differences in source/receptor characteristics and environment.

Short-range transmission was favoured in a retrospective cohort study of 18 short-to-medium haul flights (median flight time 115 minutes) to England from the beginning of the pandemic.[24] The attack rate was 0.2% (95% confidence interval [CI]: 0.1–0.5) for all aircraft-acquired cases, and was higher at 3.8% (95% CI: 1.3–10.6) if a subgroup analysis was performed only on contacts within a two-seat radius. It was assumed that no masks were worn given that it was early in the pandemic.

Family gatherings for meals are high-risk scenarios for transmission. Lo Menzo et al. (2021) reported transmission of lineage B.1.1.7 variant of concern to 8 of 9 family members during a dinner gathering.[25] The only uninfected family member was presumed to have immunity acquired from a previous infection (high antibody titres and polymerase chain reaction (PCR) negative result). Contact and fomite transmission cannot be excluded from this type of event.

In a case-control study of 154 patients 18 years and older in the United States (US), Fisher et al. (2020) reported that close contact with a person with COVID-19 was reported more often among cases (42.2%) than controls (14.5%) ($p<0.01$).[26]

Short-range transmission has been documented in school settings. Four student-to-student and one student-to-teacher transmission events were reported in Salt Lake County, Utah.[27] For four transmission events, unprotected, short-range exposures were noted. There was a lack of transmission to other students that were a median of 1 m away during class, but adhered to control measures implemented in the school. However, when household transmission associated with the secondary cases was evaluated, transmission was high for 3 of the 5 households of secondary patients. In these three households, 6 of 8 household members were also infected and may be related to challenges with physical distancing, masking, and shared surfaces in the household.

Using whole genome sequencing of SARS-CoV-2 clinical samples (n=50) in Dublin, Ireland, Lucey et al. (2020) investigated cases of hospital-acquired COVID-19 and reported that the majority of infections were among patients who required extensive and prolonged care by health care providers.[28] The authors concluded that the likely mode of transmission from health care workers to patients was through short-range transmission and close contact, rather than long-range transmission. Notably, the use of masks by health care providers was not universal and patients were not wearing masks either.

Three short-range health care-associated transmission events have been reported where large respiratory droplet transmission was less likely because masks were worn by either the source or the contact and in two of three events, the contact was also wearing eye protection.[29] In case 1, an asymptomatic, unmasked patient transmitted infection to two health care workers who wore medical masks and face shields, following multiple hours of exposure in a room with 6 ACH. A second case occurred where a presymptomatic masked health care worker transmitted infection to an unmasked patient in a room with 6 ACH. A third case involved a presymptomatic masked patient transmitting infection to a health care worker who was wearing a mask and goggles during a 45 minute face-to-face discussion at 1 m. Notably in the third case, the patient's mask was removed temporarily for oropharynx inspection. While each case was verified by whole genome sequencing, there was a lack of detail about the specific encounters (e.g., distance, duration, if direct contact occurred, if doffing errors occurred), and no airflow studies were conducted.

An analysis of SARS-CoV-2 infections in an outdoor rugby league, including video evaluation of close contact due to tackling inherent in the game, indicated that no cases among players in the league could be linked to close-contact during the outdoor rugby games.[30] Instead, transmissions were linked to other indoor short-range transmission events. While this study demonstrates examples where outdoor close-contact transmission did not occur, there were not enough close-contacts documented to provide evidence that close-contact transmission could not have occurred in the context of outdoor rugby.

In a modelling study, Zhang and Wang (2020) reported that the median infection risk via long-range aerosol transmission (10^{-6}–10^{-4}) was significantly lower than the risk via close contact (10^{-1}).[31] The model was based on a 1-hour exposure in a room with an area of 10–400 m^2, with one infected individual and a ventilation rate of 0.1–2.0 ACH. In a modelling study by Hu et al. (2020), the transmission risk from epidemiological data among train passengers as 0%–10.3% (95% CI: 5.3%–19.0%).[32] Travellers directly adjacent to the index patient had a much higher infection risk (relative risk [RR]: 18.0; 95% CI: 13.9–23.4), and the attack rate decreased with increasing distance.

Household and Non-Household Secondary Attack Rates

The consensus among systematic reviews is that household settings, where physical distancing, consistent source control mask-wearing, and disinfection of shared surfaces are potentially not feasible, are associated with a higher risk of infection compared to casual-contact settings (17%–27% compared

to 0%–7%). However, the secondary household attack rates are not as high as would be expected if SARS-CoV-2 easily spread through long-range transmission (e.g., >90% in measles).[16,33]

In a systematic review and meta-analysis of 54 studies and 77,758 patients, Madewell et al. (2020) reported that the household secondary attack rate was 16.6% (95% CI: 14.0–19.3).[34] In a systematic review and meta-analysis of 45 studies, Thompson et al. (2021) estimated the household secondary attack rate as 21.1% (95% CI: 17.4–24.8; 29 studies).[35] Non-household settings had lower secondary attack rates: 1) social settings with family and friends (5.9%; 95% CI: 0.3–9.8; 7 studies); 2) travel (5.0%; 95% CI: 0.3–9.8; 5 studies); 3) health care facilities (3.6%; 95% CI: 1.0–6.9; 10 studies); workplaces (1.9%; 95% CI: 0.0–3.9; 7 studies); and casual social contacts with strangers (1.2%; 95% CI: 0.3–2.1; 7 studies). Koh et al. (2020), in a meta-analysis of 43 studies, reported that the household secondary attack rate was 18.1% (95% CI: 15.7–20.6; 43 studies), much higher than the secondary attack rate in health care settings (0.7%; 95% CI: 0.4–1.0; 18 studies).[36] In a systematic review and meta-analysis of 24 studies, Lei et al. (2020) reported that the secondary attack rate in households was 27% (95% CI: 21−32); the risk of secondary infection was 10 times higher in households compared to non-household settings (odds ratio [OR]: 10.7; 95% CI: 5.7–20.2; p<0.001).[37] Tian and Huo (2020), in a meta-analysis of 18 studies, reported that the household secondary attack rate was 20% (95% CI: 15–28; 15 studies; n=3,861 patients), followed by social gatherings at 6% (95% CI: 3–10; 5 studies; n=2,154 patients) and health care settings at 1% (95% CI: 1–2; 4 studies; n=1,320 patients).[38]

Long-range Transmission

Main Findings

Transmission of SARS-CoV-2 over longer distances (generally >2 m) and time occurs through inhalation of aerosols under favourable circumstances, such as prolonged exposure in an inadequately ventilated space. Current evidence supports long-range transmission of SARS-CoV-2 occurring “opportunistically”, in that long-range transmission can occur under some circumstances, but inconsistently, and is not the predominant situation in which transmission occurs. Epidemiological and modelling studies support that long-range transmission via aerosols occurs. All of these examples include combinations of favourable source/receptor and pathway conditions such as inadequate ventilation, prolonged exposure time, high viral load, with certain activities (singing, exercising, yelling, etc.), and lack of masking for source control by the index case.

Environmental Factors Affecting Long-range Aerosols

In experimental models, researchers have demonstrated the potential for long-range transmission. In a series of experiments, simulations and modelling, Wang et al. (2021) (preprint) reported that aerosols could remain suspended for a longer period than historically predicted.[15] In general, viral copies/millilitre (ml) or concentration decreased as distance from source increased. The work showed that the evaporation time for large respiratory droplets is longer than predicted, especially at higher relative humidity (90%). In a sneeze plume, the largest respiratory droplets (>100 µm) are centrally located within the plume, with smaller respiratory droplets and aerosols at the periphery. The largest droplets contain more virus copies but are less abundant as they settle quickly to the ground, while smaller droplets carry fewer virus copies but are more abundant and remain in the air. The authors conclude that while aerosol transmission is important past 1 m from the source, aerosol transmission is likely even more important at shorter ranges.

Modelling studies have also highlighted the potential for aerosol transmission at varying distances. Xu et al. (2021) analysed the data of 197 symptomatic COVID-19 cases in the Diamond Princess cruise ship outbreak and concluded that long-range transmission did not occur between cabins based on the random distribution of symptomatic cases on all decks and the lack of spatial clusters of close contact (within cabin) infection.[39] The authors inferred that most transmission had occurred in public areas before the quarantine, possibly due to crowding and insufficient ventilation in those spaces. The authors also inferred that there was no transmission between passenger rooms during the quarantine period, and suggested that the ship's central heating, ventilation, and air conditioning (HVAC) system did not play a role in SARS-CoV-2 transmission. However, the authors noted that the lack of data on 109 of the 306 symptomatic individuals and on the 328 asymptomatic individuals may alter their estimation. In addition, their estimation did not take into consideration possible transmission between crew and passengers. Another model of the same outbreak estimated that the contribution of short-range transmission (from large droplets or aerosols) accounted for a median of 36% (mean: 35%) of transmission events, fomite (median: 21%; mean: 30%) and long-range (median: 41%; mean: 35%) contributing to the remainder.[40]

A study of aerosol particles (<5 μm diameter) by Dobramysl et al. (2021) (preprint) reported that time to infection increases approximately linearly as distance from source increases, the most important parameter for time to infection.[41] Exposure to a person breathing normally (simulating an asymptomatic individual) at a distance of 1 m led to infection after 90 minutes; however, coughing every 5 minutes led to infection in 15 minutes. Mask use and even minimal ventilation increased time to infection at a given distance. The importance of ventilation is also described in a modelling study by Jones (2020) which suggested that exposure to inhalable particles mostly (80%) occurs within close proximity to the patient.[42] In still air, aerosols will rise above head-level; however, turbulent air can change the trajectory of virus-laden aerosols, bringing aerosols closer to the head.[43-45] A modelling study by Sen (2021) found that when the ceiling-mounted elevator fan was off, about 11% of the droplets expelled by coughing fell to the ground while 89% evaporated and became smaller.[46] After travelling downward in cough-induced turbulence for approximately 6 seconds, droplets about 50 μm tended to move up and spread in the upper part of the elevator. If the cough happened at 30° to another rider, up to 40% of the droplets may fall on the face of another elevator rider. However, when the fan is operating, up to 50% of the droplets were dragged down to the floor in less than 3 seconds.

The basement of a large wholesale market was investigated as the source of a major outbreak in Beijing, China.[47] Many factors contributed to spread across multiple possible modes of transmission including long-range transmission. A field study of the area using fluorescent powders and microspheres as tracers allowed authors to conclude that while air was circulated, the air was unfiltered and there was very little fresh air, there was high humidity, low temperature, inadequate hand sanitization supplies in washrooms, and significant contamination of surfaces possibly due in part to resuspension of droplets from wet floors.

Given that persistence of aerosols over time is a factor in long-range transmission, the viability of SARS-CoV-2 in aerosols is important to consider. The half-life of SARS-CoV-2 in aerosols is approximately 1 hour.[48,49] Humidity seems to have less of an effect on SARS-CoV-2 viability in aerosols compared to the effect of sunlight or temperature.[50,51] Increasing temperature is associated with a reduction in the half-life of SARS-CoV-2 in aerosols.[52-54] Using a rotating drum experiment similar to other studies for viability of SARS-CoV-2, simulated sunlight (UVA/UVB) was applied to aerosolized virus through a window on the drum.[51] Results indicated 90% inactivation of virus within 20 minutes.

Inadequate ventilation can contribute to spread of aerosols, where the buildup of infectious aerosols is inversely proportional to the number of air exchanges.[55-57] In a modelling study, Schijven et al. (2021) assessed the risk of aerosol transmission of SARS-CoV-2 at a distance beyond 1.5 m from continuous breathing, speaking, or singing, or from one cough or one sneeze, in an indoor environment of 100 m^3.[58] Where there was no ventilation, the mean risk of transmission (derived from dose-response data for human coronavirus 229E) after 20 minutes of exposure to a person with 10^7 RNA copies/ml of mucous was estimated at 0.1%, except for sneezing with high aerosol volume (40,000 picolitres/sneeze). The mean risk of transmission increased to above 30% for sneezing with high aerosol volume and above 10% for singing after an exposure of 2 hours to a person with mucous RNA concentration above 10^8 copies/ml. Ventilation at 1 ACH reduced the risk by approximately half and at 6 ACH, the risk of transmission was reduced by a factor of 8–13 for sneezing and coughing, and by a factor of 4–9 for singing, speaking and breathing.

Estimates for minimum infectious dose, amount of viable virus in aerosols and quantified exposure rates are lacking. One preprint study assessed superspreading events related to long-range transmission in order to determine a minimum infectious dose for transmission.[59] The model used rate of aerosolized virion shedding based on data from other coronaviruses and a destabilization rate measured for SARS-CoV-2. They reported a critical exposure threshold for aerosol transmission of 50 virions. A computational characterization of inhaled droplets by Basu (2021) reported an estimated inhaled infectious dose around 300 virions, which was similar to estimates of 500 virions for ferrets.[60] The author acknowledged that this estimate could vary widely depending on environmental and individual biological factors.

Epidemiological and Modelling Studies Describing Long-range Transmission

Epidemiological case studies have reported long-range transmission of SARS-CoV-2, exclusively in indoor settings (e.g., bus, church, restaurant, concert halls, apartment building, office building).[61-67] In most of these case studies, long-range transmission was inferred as the dominant route of transmission, given that infectees were usually further than 2 m away from index cases. In addition, in these case studies, susceptible people were exposed to index cases for prolonged periods (>50 minutes) in indoor environments with inadequate ventilation and, in some instances, with increased respirations (e.g., singing, yelling, or exercising) and/or no face mask use (by case and/or contact). As with most epidemiological studies on transmission events, it was difficult to exclude other contributing routes of transmission. We summarize a few of these case studies, highlighting settings and contributing contextual factors to long-range transmission.

Stagnant indoor conditions can contribute to aerosol transmission. One example is a series of transmissions linked to an individual who developed symptoms around the time they were playing squash in an unventilated squash court.[68] Players who arrived hours after the index case and played in the same squash court were later identified as positive cases, though the role of other potential routes (e.g. unidentified staff contacts, shared surfaces) may have contributed as well and the source of transmission could not be confirmed. In contrast, a post-operative analysis of susceptible patients (no previous SARS-CoV-2 infection or vaccination) in a surgical suite within 48 hours following the use of the suite by SARS-CoV-2 positive patients indicated that there were no transmission events. The event rate was lower than the number of events in a control group (0% vs. 1.9%).[69] Ventilation was likely a significant factor that prevented transmission in the surgical suite.

In a study of six indoor singing events (five with transmission) in the Netherlands, Shah et al. (2021) (preprint) reported that long-range transmission was the likely route of transmission (short-range transmission possibly contributing to transmission at three of these events and indirect contact transmission possibly contributing to transmission at one of the events).[62] The authors assigned transmission likelihood as either less likely or possible; however, the authors do not state how these were defined. Attack rates at these events ranged from 25%–74% (9–21 people aged 20–79 years attended the events) and authors hypothesize that singing led to transmission. The authors note that they cannot quantify the contribution of each route of transmission. Genomic sequencing was not performed to help rule out other sources of SARS-CoV-2.

In a choir group (Washington, US), 53 of 60 individuals (excluding the index patient) were confirmed or strongly suspected to have been infected during a 2.5 hour rehearsal in a main hall.[64] Individuals who moved to another area of the building from the index case to practice for 45 minutes were less likely to become infected than those who remained in the main hall for the full duration of the rehearsal.

Twelve secondary cases of SARS-CoV-2 were linked to an index case, an 18-year-old chorister with high viral load who sang at four 1-hour services.[70] The index case was seated at a piano raised approximately 3 m from the ground floor and facing away from the secondary cases. Secondary cases sat between 1–15 m (horizontal distance) from the index case. Use of masks was not in place and there was minimal ventilation during the service (ventilation system was off, fans were off and doors and windows were largely closed). Interestingly, no new cases were linked to exposure that occurred the day of respiratory symptom-onset, and no explanation could be provided for why only a certain section near the chorister was affected and other sections (including those directly in front of the index case) were not.

In a case study by Shen et al. (2020), passengers who were not wearing masks were exposed to a presymptomatic index patient for 100 minutes while on a bus in eastern China.[61] Twenty-four of 67 passengers became infected, including several passengers seated beyond 2 m distance. The bus containing the index patient was heated and air was recirculated without filtration. Infections occurred in individuals at either end of the bus and the index case was located roughly in the middle. Risk of infection was only moderately higher for individuals sitting closer to the index patient. In contrast, seven of 172 other people attending the same religious event were positive for SARS-CoV-2. Some of the cases became positive after 14 days from exposure; thus, transmission likely did not occur on the bus for these case. The authors of this study postulate that the poor ventilation in the bus supports aerosol transmission in this cluster; however, other routes of transmission such as close contact from movement within the bus or fomites could not be excluded.

Vehicles are also potential environments for short-range and long-range transmission. A patient transport van was implicated in long-range aerosol transmission despite physical distancing observed by the infected drivers in two distinct transmission events.[71] One driver did not wear a mask, but all passengers wore a single-layer mask. The passengers were exposed for 2 hours during both events. Transmission was confirmed by whole genome sequencing. Fans were on medium speed and windows were closed. Airflow experiments were conducted with different size aerosols demonstrating plausibility of spread from the driver.

An epidemiological investigation of a chain of transmissions was reported beginning with a flight from India to New Zealand, a bus ride to a quarantine facility, a stay at a quarantine facility, a bus ride to the airport, and subsequent household transmissions.[72] Based on positivity test dates, genome sequencing, flight positions and hotel room placement the transmission events were ascribed to both short-range and long-range transmission on flights, within the quarantine facility, and within households. Masks

were required on flights and bus rides. One of the transmission events occurred between two adjacent hotel rooms in the quarantine facility. The authors used recorded video and observed >20 hours between any shared items and no direct contact. The authors concluded that fomite transmission was unlikely and attributed transmission to aerosols in the corridor outside of the hotel rooms wherein the space was enclosed and unventilated. Notably, the hotel rooms themselves, based on a review of the ventilation system, exerted positive pressure relative to the corridor.

An investigation by Lin et al. (2021) into an outbreak of nine COVID-19 cases from three families living in vertically-aligned units of an apartment building in Wuhan, China supported the possibility of long-range transmission.[66] Phylogenetic analysis of respiratory samples showed that all cases were infected by the same strain of SARS-CoV-2. Epidemiological investigation revealed that 4/5 cases of the index family in apartment 15-b had a travelling history to Wuhan, while the other four cases in apartments 25-b and 27-b had neither a travelling history to Wuhan nor close contact with any COVID-19 cases prior to their infection. Transmission through close contact in the elevators was considered unlikely as video records in the elevator did not show any close contact between the index family and the cases from units 25-b and 27-b. However, there was an incident where one unmasked occupant of unit 27-b took the elevator 8 minutes after two unmasked occupants from the index family had left the elevator. Epidemiologically, the infection rate for residents in units b was significantly higher ($p<0.05$) than that in units a and c. Testing of wind speed at the bathtub drain and floor drain found that the airflow produced by toilet flushing on one storey can influence the entire building as the drain pipes for toilets and the sewage pipes connected with floor drains were connected with the exhaust pipe. An experiment with a tracer gas indicated that gas could spread from one storey to another via the drainage and vent systems, especially as the seals in U-shaped traps in the floor drains were dried out in some units and the use of exhaust fans could create a negative pressure in the pipeline system. A similar situation was reported involving air ducts in a naturally ventilated apartment complex in Seoul, South Korea.[67] There were no valves blocking air from entering the bathrooms from the shared natural ventilation shafts (not for building or apartment unit ventilation). Limitations of this outbreak investigation included no genome sequencing or air sampling. Direct applicability to Canadian contexts may be limited by different building construction standards and practices.

Independent of ventilation, movement of air from an infected individual to others nearby can be an important factor in long-range transmission. Direct airflow was deemed responsible for a long-range transmission event in a restaurant in Korea.[73] The suspected index case sat 4.8 m and 6.5 m away and directly upwind of the airflow from two secondary cases at different tables. Nine other visitors in the restaurant did not test positive for SARS-CoV-2 even though at least two were closer to the index case for longer but not in the direct path of airflow originating from the index case. Notably the transmission in one case was suspected to have occurred from an exposure as short as five minutes, and three patrons sitting with the secondary cases but facing away from the index cases were not infected.

An investigation by Lu et al. (2020) into a COVID-19 outbreak in a restaurant in Guangzhou, China involving three families sitting at three tables in close proximity for about 1 hour concluded that the air conditioning (AC) system likely contributed to transmission.[63] In this scenario, a presymptomatic index case and secondary cases were present in the same area for 53–73 minutes. The location of a consistently running AC unit was in the airflow path of the secondary cases and was in an enclosed environment. No secondary cases occurred in staff or at adjacent tables that were outside of the likely "air column". The furthest distance between index and secondary cases was approximately 3 m. Additional investigation indicated that the exhaust fans had been closed due to cold outside temperatures.[74] The airflow assessment indicated that air was recirculating in a defined area, which exposed the three families.

A report involving group exercise at three facilities in Hawaii, US calculated attack rates of 25%–100%.[75] There was no fresh air ventilation and exposure occurred over a duration of 1 hour. Extended close contact and lack of masks in some cases were concluded as contributing to the transmission.

An outbreak in a multi-bed hospital room occurred wherein three patients and six health care workers became infected despite the use of masks and presence of ventilation of 3–4 ACH.[76] The presymptomatic index case was a parent located in a chair beside their child's bed who constantly wore a surgical mask, near the entrance to the room. Notably the air conditioning unit appeared to be located on the ceiling and no details were given about how it operated (e.g., constant versus timed/triggered) and what amount of fresh air circulation it provided. There were no exhaust vents indicated on the room diagram. Exposures for health care workers were in the range of 10–15 minutes, most at distances further than 2 m from the index patient. The report noted that masks were worn as personal protective equipment by health care workers. Transmission was based on the epidemiology of the outbreak without corroboration by genomic analysis of infections.

Detection of SARS-CoV-2 in Air Samples

Air sampling for virus refers to the process of collecting volumes of air by a device to determine if aerosols may contain virus. Collection can vary by aerodynamic size captured, duration of collection, volume per second collected, and media on which samples deposit. Air samples can then be tested by molecular methods such as reverse transcription PCR (RT-PCR) to amplify viral nucleic acids and/or viral culture. RT-PCR cannot determine whether the microorganisms detected are viable. Viral culture is used to determine whether a sample containing the virus is capable of replication. While there are several factors that contribute to the probability of infection, replication is a surrogate measure for inducing infection. To detect viability, researchers apply a sample to a susceptible cell culture and incubate up to a few weeks to detect morphological changes.

Detection of SARS-CoV-2 RNA in air samples has been inconsistent.[77] Multiple air sampling studies performed in proximity to confirmed COVID-19 cases were unable to detect any virus by RT-PCR.[78-86] Kenarkoohi et al. detected SARS-CoV-2 RNA by RT-PCR in 1/5 samples from a ward containing intubated, severely ill patients, but did not find any positive air samples in other areas of the hospital such as wards with suspected, confirmed and mild patients (culturing of virus was not attempted in this study).[87] Chia et al. (2020), in an extended study of Ong et al. (2020), detected SARS-CoV-2 RNA by RT-PCR in air samples collected within 1 m of patients in two of three airborne infection isolation rooms (AIIRs) (no culture of virus attempted).[88] Lei et al. (2020) reported limited detection of SARS-CoV-2 RNA virus by air sampling in open wards, private isolation rooms and bathrooms.[85] One PCR-positive air sample was obtained during an endotracheal intubation within 10 cm of the patient's head in a naturally ventilated room (window open with fan attached), eleven other air samples near patients and 17 samples outside patient rooms and at nursing stations were PCR-negative.[89] The stage of infection and level of infectiousness of the patient populations sampled were not reported.

In a study of SARS-CoV-2 RNA in air samples collected from a variety of settings, Liu et al. (2020) reported that the highest concentration of viral RNA was reported from patient and staff areas of hospitals, compared to public areas.[90] Gharehchahi et al. (2021) (preprint) found SARS-CoV-2 RNA in 7/17 (41.2%) of air samples in a hospital for COVID-19 patients, including a mechanically-ventilated temporary waste storage area, two naturally-ventilated offices (one in the admission and discharge area, the other in an administrative department), and within 2 m of patients' beds in two intensive care units (ICUs), a negative pressure room, and an accident and emergency ward that are mechanically-ventilated with or without natural ventilation.[91] SARS-CoV-2 RNA was not detected from the four

samples at nursing stations 2–5 m from patients' beds. The authors speculated that the detection of RNA in non-clinical areas could be due to inadequate ventilation and the occasional presence of infected health care workers.

Stern et al. (2021) sampled air in locations outside of patient care areas in an acute care hospital and found 8/90 (9%) of the samples positive for SARS-CoV-2 RNA, with concentrations ranging from 5–51 copies/m^3.[92] The size of the RNA-positive samples ranged from ≤2.5 to ≥10 μm. Locations adjacent to negative-pressured wards designated for COVID-19 patients did not appear to increase the likelihood of detecting viral RNA, having higher viral concentration, or finding particles of specific sizes in air samples. However, a significant positive association was observed between the average number of COVID-19 patients staying in the hospital during each sampling period, and the likelihood of an air sample testing positive for SARS-CoV-2 RNA. Furthermore, areas where staff congregated during times of high community rates of COVID-19 were associated with positive air samples. Of note, one RNA-positive air sample was taken when the unit was closed for cleaning and not under negative pressure, and the unit doors were left open for cleaning staff who had to pass by the air sampler to access the area for cleaning.

When air samples were RT-PCR-positive, culturing attempts were infrequently successful. In a systematic review and meta-analysis of 24 studies, Birgand et al. (2020) reported that 17.4% (82/471) of air samples from patient environments were RNA-positive (there was no difference in positivity at ≤1 m [2.5%] or 1–5 m [5.5%]; p=0.22), while culturing produced viable virus in 8.6% (7/81; 2 out of 5 studies) of samples.[93] A study by Guo et al. (2020) detected SARS-CoV-2 by RT-PCR in 35% (14/40) of air samples in an ICU and 12.5% (2/16) of air samples in the general ward that managed patients with COVID-19. Fifteen of 16 RT-PCR-positive air samples were from within 2 m of patients, with 1/8 samples positive at 4 m away.[12] Ben-Shmuel et al. (2020) conducted limited sampling (generally one air sample per area) in rooms with ventilated and non-ventilated patients, at a nursing station, and in private and public areas of a quarantine hotel.[94] RT-PCR-positive air samples were detected in a room with a ventilated patient (distance from patient was not reported) (n=1/1), at a nursing station (n=1/1), and in a quarantine hotel room (n=1/1). However, there were no positive air samples in rooms of non-ventilated patients (n=0/3), a doffing area (n=0/1), and a public area of a quarantine hotel (n=0/1). The authors attempted viral culturing; however, no samples were positive.

At this time, only three studies, two from the same research group and one preprint from July 2020, have successfully cultured viable virus from the air. The preprint and one published study were already referred to above in the summary of Birgand et al. (2020). Sampling techniques and equipment may have caused the lack of culture viability despite RT-PCR detection in other studies. Future studies should aim to replicate the use of equipment and culture methods as these studies.

Lednicky et al. (2021) used a prototype and commercial version of an air sampler and custom RT-PCR probes for detection of SARS-CoV-2 in a patient room with two patients. One patient was discharged soon after sampling periods began and after receiving a negative RT-PCR test.[95] The remaining patient began experiencing respiratory illness two days prior to admission to the room. The study detected RT-PCR-positive air samples following 3 hours of sampling as well as positive viral cultures. Researchers positioned samplers 2–4.8 m from the recently symptomatic patient's head. The ventilation unit provided 6 ACH, filtering air and treating air with UV irradiation before recycling the air. Estimates of virus per volume of air ranged from 6–74 tissue culture infective dose $(TCID)_{50}$ units/L of air. Recently, a second study by Lednicky et al. was performed to detect viable SARS-CoV-2 virus from the front passenger seat area of a car driven by a SARS-CoV-2-positive patient without cough symptoms.[96] This study involved a sampler affixed to the sun visor in the passenger seat collecting particles sizes in ranges

of <0.25 µm, 0.25–0.50 µm, 0.50–1.0 µm, 1.0–2.5 µm and >2.5 µm. The patient drove for 15 minutes with the windows up and air conditioner on. The sampler was turned off 2 hour after the patient completed the 15 minute drive. Viable virus was cultured only from the 0.25–0.5 µm fraction, which also had the highest quantity of detectable copies of viral RNA.

Further research is needed to reconcile differences in viral RNA detection and virus viability in air samples, despite RT-PCR-positive samples found on the surfaces of ventilation units.[97] Differences may be due to several factors, including: 1) air sampling devices are potentially not capable of maintaining viability of captured virus; 2) timing of air sampling varies by time since onset of symptoms, severity of disease or viral load; and 3) the conditions of ventilation (engineering controls) reducing concentrations of viral aerosols to undetectable levels. Even in rooms with high air exchanges, Tang et al.'s review of SARS-CoV-2 aerosols indicates that viral RNA copies can still be detected in air samples from patient rooms (1.8–3.4 viral RNA copies/m^3), toilet rooms (19 copies/m^3), and personal protective equipment doffing rooms (18–42 copies/m^3).[98] In a series of distinct room types (two AIIR with 15+ ACH, an isolation room without negative pressure and a shared cohort room) for patients admitted within 7 days of symptom-onset, Kim et al. reported that 32 air samples were negative and 20 air samples from anterooms were also negative.[86] Culturing viruses is technically challenging; therefore, the lack of positive cultures does not necessarily indicate an absence of infectious virus. On the other hand, the detection of SARS-CoV-2 viral RNA on surfaces that are rarely touched suggests that the virus may be transported through the air to those no-touch surfaces.[99]

Conclusions

Respiratory virus transmission occurs on a spectrum, from larger droplets that spread at short range, to aerosols that are present at short ranges but may also contribute to long-range transmission. As a result, categorizing SARS-CoV-2 transmission as either droplet or airborne does not accurately reflect this spectrum. Other respiratory viruses, like influenza, have similarly been described to demonstrate a spectrum of droplet sizes contributing to transmission.[100,101]

The highest risk of SARS-CoV-2 transmission likely occurs via close (<2 m), unprotected exposure (lacking multiple prevention measures) to an infectious individual. While there is a lower risk of transmission at longer distances with unprotected exposure, this kind of transmission has only been documented to occur under certain conditions, usually involving inadequate ventilation or with recirculation of unfiltered or untreated air in combination with activities involving increased exhalation/expulsion (e.g., shouting, singing, exercising), and often with a lack of source control masking.[102] Defining measures or cutoffs for inadequate ventilation was not possible based on the available descriptions of the contexts in which inadequate ventilation was reported to contribute to transmission. However, they included situations where air is circulated without filtration or exchange with fresh air, where there is no ventilation (e.g., windowless rooms without a ventilation system), and where the size of the room and ventilation rate relative to the quantity of infectious aerosols generated exceeds an unknown threshold of risk for infection. VOCs may be more effectively transmitted across all modes of transmission; however, there is no evidence that any VOCs transmit by fundamentally different routes.[103-105]

The delineation of relative contributions of short-range large respiratory droplets and aerosols and long-range aerosols to overall transmission patterns is complicated by the variable confluence of dynamic source/receptor factors and pathway factors. For example, each infector/infectee interaction is affected by source activities and amount of source viral load (e.g., forceful expulsion of droplets during coughing or singing, and timing in the course of illness), source/receptor adherence to preventative measures in place (e.g., hand hygiene, physical distancing, surface disinfection, mask-wearing and ventilation), and

pathway factors that include airflow, UV, temperature, and humidity in indoor or outdoor environments.[16] It is likely that the relative contribution of respiratory particle size to transmission will depend on these combination of factors.

A large body of evidence is emerging related to SARS-CoV-2. Studies related to identification of a specific mode of transmission are generally low quality. Moreover, data from different fields (e.g., epidemiology versus modelling) can be at odds with respect to conclusions drawn about the role of different sized droplets in short-range transmission and relative importance of long-range transmission events. Ongoing study is needed for further evidence regarding the quantity of viral particles required to cause infection. Additional assessment of SARS-CoV-2 viability in aerosols is needed. Lastly, elucidation of setting-specific risk factors for transmission (e.g., differences between source/receptor and pathway factors in health care settings, residential buildings, schools, warehouses, transportation) may provide further insight into mechanisms for transmission.

The COVID-19 pandemic has identified the importance of interdisciplinary collaboration towards understanding and having a common lexicon for describing virus transmission. When the analysis and interpretation of data is challenged by variable terminology used between and within public health, clinicians, aerosol scientists and the public, this can limit progress towards identification and application of appropriate mitigation measures.[106]

Implications for Practice

This document summarizes the evolving evidence on transmission through respiratory particles and acknowledges the role for both larger droplets and aerosols in transmission. While our understanding of how transmission occurs has evolved and the relative contribution of droplets and aerosols continues to be studied, this may not necessitate a change in infection control measures, but highlights the importance of incorporating multiple infection control layers to mitigate transmission. Translation of this information into recommendations for control measures also needs to take into consideration evidence not reviewed in this document on the overall effectiveness of control measures to date: 1) effectiveness of measures in isolation and in combination as layered mitigation; 2) effectiveness in the community vs. health care settings; and 3) effectiveness and the impact of implementation fidelity.

A detailed assessment of the evidence for infection prevention and control measures was out of scope for this document and thus limits discussion of recommendations for specific measures in different contexts. Of note, vaccination against SARS-CoV-2 is a relatively recent measure that is very effective at reducing transmission regardless of the mode of transmission and should be the priority control measure both in health care and community settings.[107]

In health care settings, recommendations for IPAC measures are described in *IPAC Recommendations for Use of Personal Protective Equipment for Care of Individuals with Suspect or Confirmed COVID-19* and *Interim Guidance for Infection Prevention and Control of SARS-CoV-2 Variants of Concern for Health Care Settings*.[7,8] These documents integrate the existing evidence around droplet, aerosol and contact transmission with jurisdictional experience with control measures and outbreak management to date, and recommends the use of the hierarchy of hazard controls to reduce the risk of transmission.

The bulk of disease transmission occurs in the community and in workplaces, not in health care settings. As SARS-CoV-2 transmits early in the course of infection, most commonly in the asymptomatic or presymptomatic period[108-111] and within the first two days of symptom-onset, cases may not seek health care during their most transmissible phase. In all settings it is necessary to utilize multiple control

measures to mitigate the dynamic transmission factors and address potential routes of transmission. Infection prevention controls should also be context-dependent and take into account vaccination status/coverage, the ability to physically distance and avoid crowding, the feasibility of proper wearing of appropriate personal protective and source control equipment, training and education on the appropriate use of personal protective equipment, hand hygiene, surface disinfection, indoor ventilation, and early identification and isolation of infectious persons. Finally, application of measures should also be in the context of overall rates of community transmission and risk of exposure.

Several resources exist for community guidance (e.g., non-health care workplaces, public and private spaces) on how to reduce the risk of SARS-CoV-2 transmission through a layered approach of multiple public health measures designed to mitigate short-range and long-range transmission.[112-114] In general these involve avoiding the "3 C's": closed spaces, crowded places, and close contact. The degree to which various mitigation layers are necessary or possible will depend on the setting and risk context. Transmission can be mitigated through:

- Getting vaccinated[115,116] (higher vaccine coverage in the population can reduce risk for individuals unable to receive a vaccine)
- Staying home when sick[117,118] (e.g., active and passive screening prior to entry into public settings)
- Limiting the number and duration of contacts with individuals outside your household
- Physical distancing[114] and avoiding crowded spaces
- Consistently and appropriately using a well-fitted, well-constructed (2-3-layer) mask for source control and personal protective equipment.[119-122]
- Ensuring that ventilation systems[123] are well-maintained and optimized with the support of professionals according to relevant recommendations (e.g., from American Society of Heating, Refrigerating and Air-Conditioning Engineers) and/or using outdoor environments whenever possible.
- Performing hand hygiene, respiratory etiquette, and environmental cleaning[124]

The above measures are effective means of reducing risk of transmission irrespective of the relative contribution of larger droplets or aerosols to transmission. Some controls will be more effective than others and it is the combination and consistent application of these controls that is most effective for reducing disease spread.

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Citation

Ontario Agency for Health Protection and Promotion (Public health Ontario). COVID-19 transmission through large respiratory droplets and aerosols…what we know so far. Toronto, ON: Queen's Printer for Ontario; 2021.

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Ontario

This is "**Exhibit K**"
to the Affidavit of Matthew Hodge,
affirmed this 2nd day of July, 2021

A Commissioner, etc.

World Health Organization

< Go back to all Coronavirus disease 2019 Q&As

Coronavirus disease (COVID-19): How is it transmitted?

13 December 2020 | Q&A

The English version was updated on 30 April 2021.

How does COVID-19 spread between people?

We know that the disease is caused by the SARS-CoV-2 virus, which spreads between people in several different ways.

The virus can spread from an infected person's mouth or nose in small liquid particles when they cough, sneeze, speak, sing or breathe. These particles range from larger respiratory droplets to smaller aerosols.

- **Current evidence suggests that the virus spreads mainly between people who are in close contact with each other, typically within 1 metre (short-range). A person can be infected when aerosols or droplets containing the virus are inhaled or come directly into contact with the eyes, nose, or mouth.**
- **The virus can also spread in poorly ventilated and/or crowded indoor settings, where people tend to spend longer periods of time. This is because aerosols remain suspended in the air or travel farther than 1 metre (long-range).**

People may also become infected by touching surfaces that have been contaminated by the virus when touching their eyes, nose or mouth without cleaning their hands.

Further research is ongoing to better understand the spread of the virus and which settings are most risky and why. Research is also under way to study virus variants that are emerging and why some are more transmissible. For updated information on SARS-CoV-2 variants, please read the weekly epidemiologic updates.

When do infected people transmit the virus?

What is the difference between people who are asymptomatic or pre-symptomatic? Don't they both mean someone without symptoms?

Are there certain settings where COVID-19 can spread more easily?

How can I reduce my risk of getting COVID-19?

العربية | 中文 | Français | Русский | Español

WHO TEAM WHO Headquarters (HQ)

Related

Transmission of SARS-CoV-2: implications for infection prevention precautions

World Health Organization

< Go back to all Coronavirus disease 2019 Q&As

Coronavirus disease (COVID-19): How is it transmitted?

13 December 2020 | Q&A

The English version was updated on 30 April 2021.

How does COVID-19 spread between people?

When do infected people transmit the virus?

Whether or not they have symptoms, infected people can be contagious and the virus can spread from them to other people.

Laboratory data suggests that infected people appear to be most infectious just before they develop symptoms (namely 2 days before they develop symptoms) and early in their illness. People who develop severe disease can be infectious for longer.

While someone who never develops symptoms can pass the virus to others, it is still not clear how frequently this occurs and more research is needed in this area.

What is the difference between people who are asymptomatic or pre-symptomatic? Don't they both

What is the difference between people who are asymptomatic or pre-symptomatic? Don't they both mean someone without symptoms?

Are there certain settings where COVID-19 can spread more easily?

How can I reduce my risk of getting COVID-19?

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Related

Transmission of SARS-CoV-2: implications for infection prevention precautions

Access the publication

This is "**Exhibit L**"
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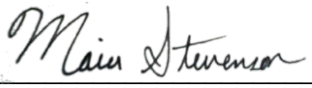


A Commissioner, etc.

Avoid the Three Cs

World Health Organization
Western Pacific Region

Be aware of different levels of risk in different settings.

There are certain places where COVID-19 spreads more easily:

1

Crowded places

with many people nearby

2

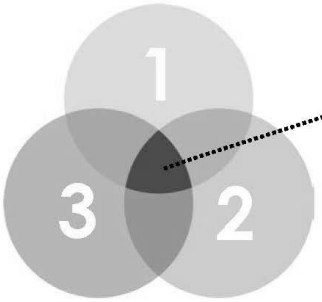
Close-contact settings

Especially where people have close-range conversations

3

Confined and enclosed spaces

with poor ventilation

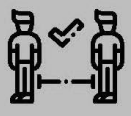


The risk is higher in places where these factors overlap.

Even as restrictions are lifted, consider where you are going and #StaySafe by avoiding the Three Cs.

WHAT SHOULD YOU DO?

Avoid crowded places and limit time in enclosed spaces



Maintain at least 1m distance from others

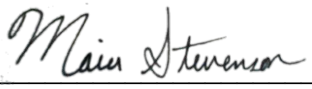
When possible, open windows and doors for ventilation

Keep hands clean and cover coughs and sneezes

Wear a mask if requested or if physical distancing is not possible

If you are unwell, stay home unless to seek urgent medical care.

This is "**Exhibit M**"
to the Affidavit of Matthew Hodge,
affirmed this 2nd day of July, 2021



A Commissioner, etc.

The airborne lifetime of small speech droplets and their potential importance in SARS-CoV-2 transmission

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Edited by Axel T. Brunger, Stanford University, Stanford, CA, and approved May 4, 2020 (received for review April 10, 2020)

Speech droplets generated by asymptomatic carriers of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) are increasingly considered to be a likely mode of disease transmission. Highly sensitive laser light scattering observations have revealed that loud speech can emit thousands of oral fluid droplets per second. In a closed, stagnant air environment, they disappear from the window of view with time constants in the range of 8 to 14 min, which corresponds to droplet nuclei of *ca.* 4 μm diameter, or 12- to 21-μm droplets prior to dehydration. These observations confirm that there is a substantial probability that normal speaking causes airborne virus transmission in confined environments.

COVID-19 | speech droplet | independent action hypothesis | respiratory disease | disease transmission

It has long been recognized that respiratory viruses can be transmitted via droplets that are generated by coughing or sneezing. It is less widely known that normal speaking also produces thousands of oral fluid droplets with a broad size distribution (*ca.* 1 μm to 500 μm) (1, 2). Droplets can harbor a variety of respiratory pathogens, including measles (3) and influenza virus (4) as well as *Mycobacterium tuberculosis* (5). High viral loads of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) have been detected in oral fluids of coronavirus disease 2019 (COVID-19)–positive patients (6), including asymptomatic ones (7). However, the possible role of small speech droplet nuclei with diameters of less than 30 μm, which potentially could remain airborne for extended periods of time (1, 2, 8, 9), has not been widely appreciated.

In a recent report (10), we used an intense sheet of laser light to visualize bursts of speech droplets produced during repeated spoken phrases. This method revealed average droplet emission rates of *ca.* 1,000 s^{-1} with peak emission rates as high as 10,000 s^{-1}, with a total integrated volume far higher than in previous reports (1, 2, 8, 9). The high sensitivity of the light scattering method in observing medium-sized (10 μm to 100 μm) droplets, a fraction of which remain airborne for at least 30 s, likely accounts for the large increase in the number of observed droplets. Here, we derive quantitative estimates for both the number and size of the droplets that remain airborne. Larger droplets, which are also abundant but associated with close-proximity direct virus transfer or fomite transmission (11), or which can become resuspended in air at a later point in time (12), are not considered here.

According to Stokes' law, the terminal velocity of a falling droplet scales as the square of its diameter. Once airborne, speech-generated droplets rapidly dehydrate due to evaporation, thereby decreasing in size (13) and slowing their fall. The probability that a droplet contains one or more virions scales with its initial hydrated volume, that is, as the cube of its diameter, d. Therefore, the probability that speech droplets pass on an infection when emitted by a virus carrier must take into account how long droplet nuclei remain airborne (proportional to d^{-2}) and the probability that droplets encapsulate at least one virion (proportional to d^3), the product of which is proportional to d.

The amount by which a droplet shrinks upon dehydration depends on the fraction of nonvolatile matter in the oral fluid, which includes electrolytes, sugars, enzymes, DNA, and remnants of dehydrated epithelial and white blood cells. Whereas pure saliva contains 99.5% water when exiting the salivary glands, the weight fraction of nonvolatile matter in oral fluid falls in the 1 to 5% range. Presumably, this wide range results from differential degrees of dehydration of the oral cavity during normal breathing and speaking and from decreased salivary gland activity with age. Given a nonvolatile weight fraction in the 1 to 5% range and an assumed density of 1.3 $g{\cdot}mL^{-1}$ for that fraction, dehydration causes the diameter of an emitted droplet to shrink to about 20 to 34% of its original size, thereby slowing down the speed at which it falls (1, 13). For example, if a droplet with an initial diameter of 50 μm shrinks to 10 μm, the speed at which it falls decreases from 6.8 $cm{\cdot}s^{-1}$ to about 0.35 $cm{\cdot}s^{-1}$. The distance over which droplets travel laterally from the speaker's mouth during their downward trajectory is dominated by the total volume and flow velocity of exhaled air (8). The flow velocity varies with phonation (14), while the total volume and droplet count increase with loudness (9). Therefore, in an environment of stagnant air, droplet nuclei generated by speaking will persist as a slowly descending cloud emanating from the speaker's mouth, with the rate of descent determined by the diameter of the dehydrated speech droplet nuclei.

The independent action hypothesis (IAH) states that each virion has an equal, nonzero probability of causing an infection. Validity of IAH was demonstrated for infection of insect larvae by baculovirus (15), and of plants by Tobacco etch virus variants that carried green fluorescent protein markers (16). IAH applies to systems where the host is highly susceptible, but the extent to which IAH is valid for humans and SARS-CoV-2 has not yet been firmly established. For COVID-19, with an oral fluid average virus RNA load of 7×10^6 copies per milliliter (maximum of 2.35×10^9 copies per milliliter) (7), the probability that a 50-μm-diameter droplet, prior to dehydration, contains at least one virion is ∼37%. For a 10-μm droplet, this probability drops to 0.37%, and the probability that it contains more than one virion, if generated from a homogeneous distribution of oral fluid, is negligible. Therefore, airborne droplets pose a significant risk only if IAH applies to human virus transmission. Considering that frequent person-to-person transmission has been reported in community and health care settings, it appears likely that IAH

Author contributions: C.E.B., A.B., and P.A. designed research; V.S., A.B., and P.A. performed research; V.S. analyzed data; and C.E.B., A.B., and P.A. wrote the paper.

The authors declare no competing interest.

Data deposition: Movies that show the experimental setup and the full 85-minute observation of speech droplet nuclei have been deposited at Zenodo and can be accessed at https://doi.org/10.5281/zenodo.3770559.

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First published May 13, 2020.

applies to COVID-19 and other highly contagious airborne respiratory diseases, such as influenza and measles.

Results and Discussion

The output from a green (532 nm) Coherent Verdi laser operating at 4-W optical power was transformed with spherical and cylindrical optics into a light sheet that is ∼1 mm thick and 150 mm tall. This light sheet passed through slits centered on opposite sides of a cubic 226-L enclosure. When activated, a 40-mm, 12-V muffin fan inside the enclosure spatially homogenizes the distribution of particles in the enclosure. A movie showing the arrangement is available (17). Movie clips of speech droplet nuclei were recorded at a frame rate of 24 Hz with high-definition resolution (1,920 × 1,080 pixels). The camera lens provided a horizontal field of view of ∼20 cm. Therefore, the volume intercepted by the light sheet and viewed by the camera is ∼30 cm^3. The total number of particles in the enclosure can be approximated by multiplying the average number of particles detected in a single movie frame by the volume ratio of the enclosure to the visualized sheet, which is ∼7,300. Slow convection currents, at speeds of a few centimeters per second, remained for the duration of the recording. These convection currents are attributed to a 0.5 °C temperature gradient in the enclosure (bottom to top) that presumably is due to heat dissipated by the iPhone11 camera, which was attached to the front side of the enclosure. Since the net air flux across any horizontal plane of the enclosure is zero, this convection does not impact the average rate at which droplet nuclei fall to the bottom of the enclosure.

With the internal circulation fan turned on, the enclosure was purged with HEPA-filtered air for several minutes. Then, the purge shutter was closed, the movie clip was started, the speaker port was opened, and the enclosure was "filled" with speech droplets by someone repeating the phrase "stay healthy" for 25 s. This phrase was chosen because the "th" phonation in the word "healthy" was found to be an efficient generator of oral fluid speech droplets. The internal fan was turned off 10 s after speech was terminated, and the camera continued recording for 80 min. The movie clip was analyzed frame by frame to determine the number of spots/streaks whose maximum single-pixel intensity exceeded a threshold value of 30. Fig. 1 charts the time-dependent decrease in the number of scattering particles detected. We are not yet able to quantitatively link the observed scattered light intensity to the size of the scattering particle because the light intensity varies across the sheet. However, the brightest 25% were found to decay more quickly than the dimmer fraction, with the two curves reasonably well described by exponential decay times of 8 and 14 min, respectively (Fig. 1*A*). These fits indicate that, near time 0, there were, on average, approximately nine droplet nuclei in the 30-cm^3 observation window, with the larger and brighter nuclei (on average) falling to the bottom of the enclosure at faster speeds than the smaller and dimmer ones.

With the assumption that the contents of the box are homogenized by the muffin fan at time 0, the average number of droplets found in a single frame near time 0 corresponds to *ca.* 66,000 small droplets emitted into the 226-L enclosure, or *ca.* 2,600 small droplet nuclei per second of speaking. If the particle size distribution were a delta function and the particles were uniformly distributed in the enclosure, the particle count would be expected to remain constant until particles from the top of the enclosure descend to the top of the light sheet, after which the particle count would decay linearly to background level. The observation that the decay profiles are approximately exponential points to a substantial heterogeneity in particle sizes, even after binning them into two separate groups.

The weighted average decay rate (0.085 min^{-1}) of the bright and dim fractions of particles (Fig. 1*A*) translates into a half-life in the enclosure of *ca.* 8 min. Assuming this half-life corresponds to the time required for a particle to fall 30 cm (half the height of the box), its terminal velocity is only 0.06 $cm{\cdot}s^{-1}$, which corresponds to a droplet nucleus diameter of ∼4 μm. At the relative humidity (27%) and temperature (23 °C) of our experiment, we expect the droplets to dehydrate within a few seconds. A dehydrated particle of 4 μm corresponds to a hydrated droplet of *ca.* 12- to 21-μm diameter, or a total hydrated volume of ∼60 nL to 320 nL for 25 s of loud speaking. At an average viral load of 7×10^6 per milliliter (7), we estimate that 1 min of loud speaking generates at least 1,000 virion-containing droplet nuclei that remain airborne for more than 8 min. These therefore could be inhaled by others and, according to IAH, trigger a new SARS-CoV-2 infection.

The longest decay constant observed by us corresponds to droplets with a hydrated diameter of ≥12 μm when exiting the mouth. The existence of even smaller droplets has been

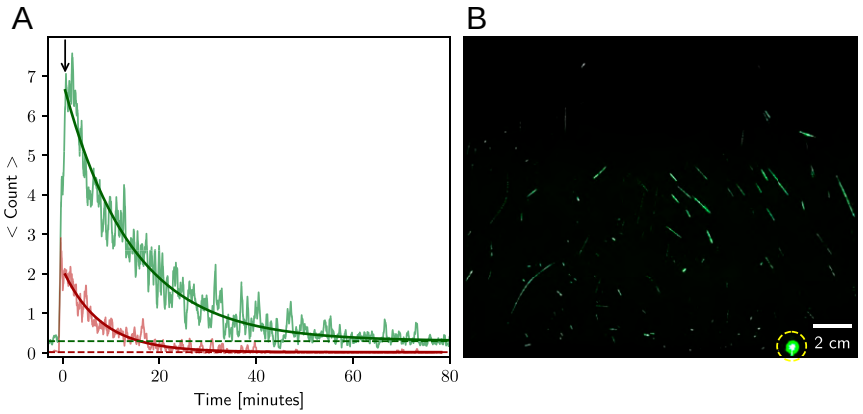

Fig. 1. Light scattering observation of airborne speech droplet nuclei, generated by a 25-s burst of repeatedly speaking the phrase "stay healthy" in a loud voice (maximum 85 dB_B at a distance of 30 cm; average 59 dB_B). (*A*) Chart of particle count per frame versus time (smoothed with a 24-s moving average), with the red curve representing the top 25% in scattering brightness and the green curve representing the rest. The bright fraction (red) decays with a time constant of 8 min, and the dimmer fraction (green) decays with a time constant of 14 min. Both exponential decay curves return to their respective background level of *ca.* 0 (red horizontal dashed line) and 0.4 (green dashed line) counts per frame. Time "0" corresponds to the time the stirring fan was turned off. The 25-s burst of speaking started 36 s before time 0. The black arrow (at 0.5 min) marks the start of the exponential fits. (*B*) Image of the sum of 144 consecutive frames (spanning 6 s) extracted shortly after the end of the 25-s burst of speaking. The dashed circle marks the needle tip used for focusing the camera. The full movie recording is available in ref. 17, with time "0" in the graph at time point 3:38 in the movie.

established by aerodynamic particle sizer (APS) measurements (2). APS is widely used for detecting aerosol particulates and is best suited for particles in the 0.5- to 5-μm range. Morawska et al. (2) detected as many as 330 particles per second in the 0.8- to 5.5-μm range upon sustained "aah" vocalization. Considering the short travel time (0.7 s) between exiting the mouth and the APS detector, and the high relative humidity (59%) used in that study, droplet dehydration may have been incomplete. If it were 75% dehydrated at the detector, an observed 5.5-μm particle would have started as an 8.7-μm droplet when exiting the mouth, well outside the 12- to 21-μm range observed above by light scattering. This result suggests that APS and light scattering measurements form a perfect complement. However, we also note that, even while the smallest droplet nuclei effectively remain airborne indefinitely and have half-lives that are dominated by the ventilation rate, at a saliva viral load of 7×10^6 copies per milliliter, the probability that a 1-μm droplet nucleus (scaled back to its originally hydrated 3-μm size) contains a virion is only 0.01%.

Our current setup does not detect every small particle in each frame of the movie, and our reported values are therefore conservative lower limit estimates. We also note that the saliva viral load shows large patient-to-patient variation. Some patients have viral titers that exceed the average titer of Wölfel et al. by more than two orders of magnitude (7, 18), thereby increasing the number of virions in the emitted droplets to well over 100,000 per minute of speaking. The droplet nuclei observed in our present study and previously by APS (2, 9) are sufficiently small to reach the lower respiratory tract, which is associated with an increased adverse disease outcome (19, 20).

Our laser light scattering method not only provides real-time visual evidence for speech droplet emission, but also assesses their airborne lifetime. This direct visualization demonstrates how normal speech generates airborne droplets that can remain suspended for tens of minutes or longer and are eminently capable of transmitting disease in confined spaces.

Data Availability Statement. All raw data used for analysis are available in ref. 17.

ACKNOWLEDGMENTS. We thank Bernhard Howder for technical support, Clemens Wendtner, William A. Eaton, Roland Netz, and Steven Chu for insightful comments. This work was supported by the Intramural Research Program of the National Institute of Diabetes and Digestive and Kidney Diseases.

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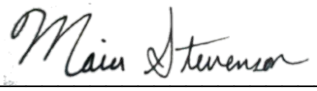
This is "**Exhibit N**"
to the Affidavit of Matthew Hodge,
affirmed this 2nd day of July, 2021



A Commissioner, etc.

Title: Increased household secondary attacks rates with Variant of Concern SARS-CoV-2 index cases

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Abstract

IMPORTANCE: Higher secondary attack rates related to variant of concern (VOC) index cases have been reported, but have not been explored within households, which continue to be an important source of coronavirus disease 2019 (COVID-19) transmission

OBJECTIVE: To compare secondary attack rates in households with VOC versus non-VOC index cases.

DESIGN: A retrospective cohort study of household index cases reported from February 7 – 27, 2021. A propensity-score matched cohort was derived to calculate adjusted estimates.

SETTING: Ontario, Canada.

PARTICIPANTS: A population-based cohort of all private households with index cases. We excluded cases in congregate settings, as well as households with one individual or with >1 case with the same earliest symptom onset date.

EXPOSURE: VOC status, defined as either individuals confirmed as B.1.1.7 using whole genome sequencing or those that screened positive for the N501Y mutation using real-time PCR.

MAIN OUTCOME AND MEASURE: Household secondary attack rate, defined as the number of household secondary cases that occurred 1-14 days after the index case divided by the total number of household secondary contacts.

RESULTS: We included 1,259 index VOC and non-VOC cases in the propensity score-matched analysis. The secondary attack rate for VOC index cases in this matched cohort was 1.31 times higher than non-VOC index cases (RR=1.31, 95%CI 1.14-1.49), similar to the unadjusted estimate. In stratified analyses, the higher secondary attack rate for VOC compared to non-VOC index cases was accentuated for asymptomatic index cases (RR=1.91, 95% CI 0.96-3.80) and presymptomatic cases (RR=3.41, 95%CI 1.13-10.26)

CONCLUSIONS AND RELEVANCE: This study provides strong evidence of increased transmissibility in households due to VOCs and suggests that asymptomatic and pre-symptomatic transmission may be of particular importance for VOCs. Our study suggests that more aggressive public health measures will be needed to control VOCs and that ongoing research is needed to understand mechanisms of VOC transmissibility to curb their associated morbidity and mortality.

Introduction

The prevalence of variants having the N501Y mutation have rapidly increased globally,[1] including in Ontario, Canada, where this prevalence increased dramatically in February, 2021. These patterns of rapid strain replacement suggest increased transmissibility of variants with the N501Y mutation, which is present across variants of concern (VOC), including B.1.1.7, B.1.351, and P.1 lineages.[2] However the exact degree of increased transmissibility, and specific settings when increased transmissibility occurs, remains unclear. [1, 3,4,5] Higher secondary attack rates related to VOC index cases have been reported, [6] but have not been explored within households, which continue to be an important source of coronavirus disease 2019 (COVID-19) transmission.[7] The objective of this study was to compare secondary attack rates in households with VOC versus non-VOC index cases in Ontario, Canada.

Methods

We identified individuals with laboratory-confirmed COVID-19 reported in the Public Health Case and Contact Management Solution (CCM), Ontario's COVID-19 reporting system, and included households with index cases reported from February 7 to 27, 2021. VOC cases included either individuals confirmed as B.1.1.7 using whole genome sequencing or those that screened positive for the N501Y mutation using real-time PCR. B.1.1.7 accounted for 94% of confirmed VOC cases reported in Ontario until February 27, 2021.[8] All PCR-positive specimens in Ontario with cycle threshold ≤35 underwent screening for the N501Y mutation during the study period using real-time PCR. Non-VOC cases were those that screened negative for the N501Y mutation.

We grouped cases living in the same household based on residential address.[9] Index cases were defined as the first case in the household based on symptom onset date (or specimen collection date, if symptom onset date was not available) and secondary cases were included if they occurred 1-14 days after the index case. We excluded cases in congregate settings, as well as households with one individual or with >1 case with the same earliest symptom onset date. We used reported household size to calculate

secondary attack rates by dividing the number of secondary cases by the total number of household secondary contacts (i.e., household size minus one). Cases with and without symptoms were classified based on symptom information and onset date reported in CCM.

Poisson regression was performed for the unadjusted and adjusted analyses, overall and by strata. The models were specified with the count of household secondary cases as the outcome, the logarithm of household size as the offset and VOC status as a binary exposure covariate. Clustering was accounted for with a random intercept for household to account for known overdispersion.

Our unadjusted risk ratios (RR) included the entire cohort of households with a VOC or non-VOC index case in Ontario. Adjusted RRs were based on a propensity score matched analysis. VOC index cases were 1:1 matched to non-VOC index cases based on gender and age group, and matched on the logit of the propensity score, using a caliper width of 0.2 times the standard deviation.[10] The propensity score was based on a logistic regression model of VOC status as a function of five covariates: reported date, time between symptom onset and testing, association with a reported outbreak, as well as the neighbourhood proportion of visible minority residents (non-white and non-Indigenous population) and household crowding as determined using 2016 Canadian Census data.[11] Regression estimates were reported using RRs and 95% confidence intervals (CI). Statistical analysis was performed in R version 4.0.4.[12]

This study was approved by Public Health Ontario's Research Ethics Board.

Results

We identified 5,617 index cases and 3,397 secondary cases across the study period. Amongst index cases, 1,318 were classified as VOC (151 B.1.1.7 and 1,167 N501Y) and 4,299 were classified as non-VOC. The overall secondary attack rate was higher for VOC index cases (25.9%) compared to non-VOC (20.5%, $p<0.01$) with consistently higher secondary attack rates for VOCs across individual characteristics of the index cases (Table 1). The secondary attack rate of VOC index cases was 1.28 times

higher than that of non-VOC index cases (RR=1.28, 95% CI 1.16-1.42); a similar trend of increased secondary attack rate was observed across subgroups (Figure 1).

We included 1,259 index VOC and non-VOC cases in the propensity score-matched analysis. The secondary attack rate for VOC index cases in this matched cohort was 1.31 times higher than non-VOC index cases (RR=1.31, 95%CI 1.14-1.49), similar to the unadjusted estimate. In stratified analyses, the higher secondary attack rate for VOC compared to non-VOC index cases was accentuated for asymptomatic index cases (RR=1.91, 95% CI 0.96-3.80) and presymptomatic cases (RR=3.41, 95%CI 1.13-10.26)

Discussion

In our cohort, we estimated that the household secondary attack rate of VOC index cases was 31% higher than non-VOC index cases, providing evidence of increased transmissibility. This is consistent with previous VOC (i.e., B.1.1.7) secondary attack rate estimates from the United Kingdom (relative secondary attack rate (32%, 12.9% vs 9.7% among all contacts);[6] however, households are an important contributor to COVID-19 and provide a valuable setting in which to examine transmission.[7] Our estimates of increased transmission from asymptomatic and pre-symptomatic VOC index cases has not previously been reported and suggests an increased importance of prevention measures when individuals are not aware of their infection. The biological mechanism responsible for increased transmissibility has not been identified, but hypotheses include higher viral loads (i.e. increased transmission potential per contact), and prolonged viral shedding (i.e., longer infectious period).[3] The N501Y mutation has also been associated with enhanced binding affinity of severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) to angiotensin-converting enzyme 2 (ACE2) receptors.[13,14]

Limitations of this study include potential misclassification of secondary cases as index cases and small sample sizes in some subgroups. We may have underestimated secondary attack rates as we only captured diagnosed secondary cases and we lacked testing data on all household contacts; however, we do not

believe this would be differential by VOC status of the index case. Ontario implemented more stringent measures for close contacts of all cases (not just VOC cases) in early February in response to VOC introductions, including increased frequency of testing during quarantine and outbreaks.[15] If household contacts were more likely to test once VOC status was known, a similar increase in the risk ratio would be expected across symptom status, suggesting an independent effect of asymptomatic and presymptomatic VOC cases on transmission.

This study provides strong evidence of increased transmissibility in households due to VOCs and suggests that asymptomatic and pre-symptomatic transmission may be of particular importance for VOCs. Our study suggests that more aggressive public health measures will be needed to control VOCs. While measures effective for persons with unknown disease status such as physical distancing and masking may continue to be highly effective, measures focused on symptomatic individuals, such as public health contact tracing, may be increasingly ineffective unless extremely rapid. Ongoing research is needed to understand mechanisms of VOC transmissibility to curb their associated morbidity and mortality.

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Table 1. Characteristics of index cases by VOC status and household secondary attack rate

Index case characteristics	Non-variant		Variant of Concern	
	Index cases No. (%)	Secondary attack rate (%)	Index cases No. (%)	Secondary attack rate (%)
Total	4,299	20.5	1,318	25.9
Gender[a]				
Female	2,074 (48.2)	19.8	647 (49.1)	25.6
Male	2,214 (51.5)	21.1	660 (50.1)	26.2
Age group				
Median [IQR]	39 [27, 55]		37 [25, 52]	
0-9 years	195 (4.5)	17.0	55 (4.2)	23.0
10-19 years	351 (8.2)	17.0	114 (8.6)	20.1
20-29 years	783 (18.2)	15.8	319 (24.2)	21.8
30-39 years	837 (19.5)	20.8	225 (17.1)	25.2
40-49 years	681 (15.8)	20.4	233 (17.7)	26.3
50-59 years	711 (16.5)	25.9	186 (14.1)	34.9
60-69 years	457 (10.6)	25.3	126 (9.6)	32.5
70-79 years	188 (4.4)	22.1	45 (3.4)	24.3
≥80 years	96 (2.2)	21.9	15 (1.1)	47.8
Outbreak Related				
No	3,558 (82.8)	20.7	1,040 (78.9)	24.0
Yes	741 (17.2)	19.0	278 (21.1)	33.1
Testing delay[b]				
No symptoms	410 (9.7)	6.0	116 (8.9)	12.4
<0 days	159 (3.8)	6.3	71 (5.5)	16.0
0 days	431 (10.2)	13.9	137 (10.5)	15.5
1 day	769 (18.2)	21.6	258 (19.8)	28.7
2 days	672 (15.9)	21.9	207 (15.9)	33.2
3 days	498 (11.8)	23.9	138 (10.6)	24.5
4 days	335 (7.9)	23.6	86 (6.6)	31.4
≥5 days	960 (22.7)	26.2	288 (22.1)	30.1
Neighbourhood Characteristics				
Proportion of visible minorities[c]				
0-20%	1,128 (26.8)	19.7	229 (17.6)	24.0
21-40%	659 (15.7)	22.0	209 (16.1)	26.8
41-60%	649 (15.4)	22.4	224 (17.2)	21.7
61-80%	765 (18.2)	19.7	310 (23.9)	29.3
≥81%	1,001 (23.8)	20.3	327 (25.2)	26.3
Proportion of households with crowding[d]				
< 5%	2,381 (56.7)	21.5	640 (49.3)	27.4
≥ 5%	1,821 (43.3)	19.5	659 (50.7)	24.6

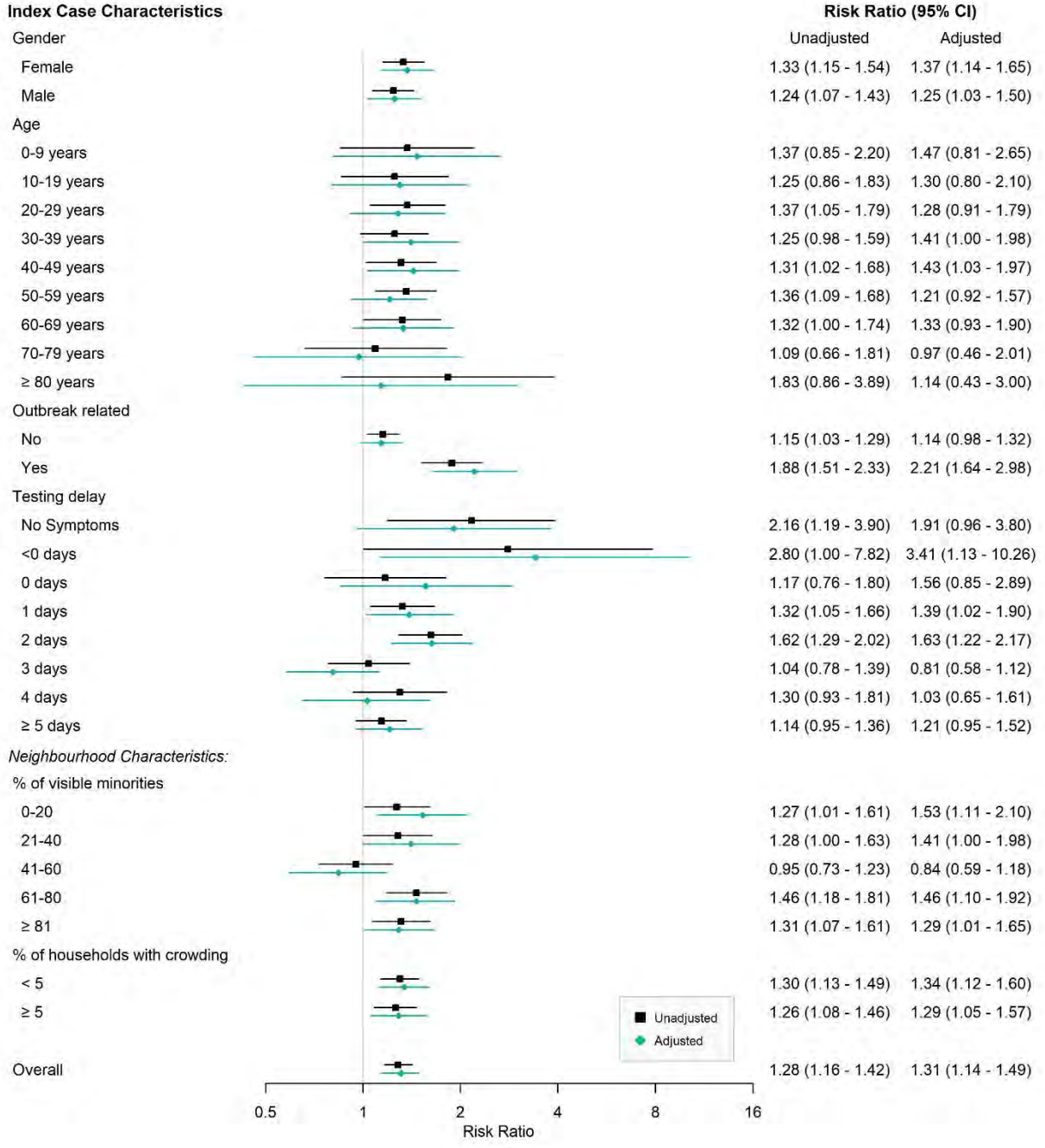
[a]This section does not include missing or other genders (22 index cases and 20 associated secondary cases and 73 household contacts).
[b]Testing delay: days between the index case symptom onset and specimen collection. Cases with no symptoms were defined as cases that were missing symptom onset date and did not have any COVID-19 symptoms flagged in CCM. Index cases with a testing delay of <0 days were those who were tested prior to the onset of their symptoms (i.e. presymptomatic). Those that did not report a symptom or did not report a symptom onset date and were not reported

as asymptomatic, or did not report a specimen collection date, were excluded from this section (82 index cases and associated 59 secondary cases and 235 household contacts).

[c]Percentage of visible minorities (non-white and non-Indigenous population) in an Aggregate Dissemination Area having population between 5,000 to 15,000 based on the 2016 Census of Population in Canada. Households missing this measure were excluded from this section (116 index cases and associated 48 secondary cases and 311 household contacts).

[d]Percentage of households in an ADA which have more than 1 person per room. Households missing this measure were excluded from this section (116 index cases and associated 48 secondary cases and 311 household contacts).

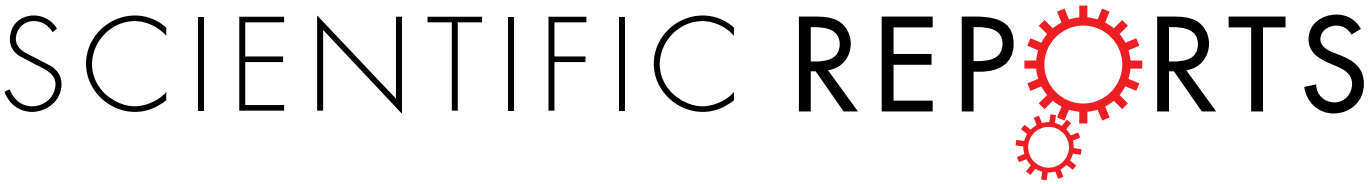
Figure 1. Risk ratio comparing household secondary attack rate associated with VOC vs. non-VOC index cases by characteristic of index case, unadjusted (black) and adjusted by 1:1 propensity-score matching (green) estimates



Note: Unadjusted risk ratio accounts for household clustering and includes the full cohort. Adjusted risk ratio refers to the propensity score-matched cohort.

This is "**Exhibit O**"
to the Affidavit of Matthew Hodge,
affirmed this 2nd day of July, 2021

A Commissioner, etc.



OPEN

Aerosol emission and superemission during human speech increase with voice loudness

Received: 14 June 2018
Accepted: 10 January 2019
Published online: 20 February 2019

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Mechanistic hypotheses about airborne infectious disease transmission have traditionally emphasized the role of coughing and sneezing, which are dramatic expiratory events that yield both easily visible droplets and large quantities of particles too small to see by eye. Nonetheless, it has long been known that normal speech also yields large quantities of particles that are too small to see by eye, but are large enough to carry a variety of communicable respiratory pathogens. Here we show that the rate of particle emission during normal human speech is positively correlated with the loudness (amplitude) of vocalization, ranging from approximately 1 to 50 particles per second (0.06 to 3 particles per cm^3) for low to high amplitudes, regardless of the language spoken (English, Spanish, Mandarin, or Arabic). Furthermore, a small fraction of individuals behaves as "speech superemitters," consistently releasing an order of magnitude more particles than their peers. Our data demonstrate that the phenomenon of speech superemission cannot be fully explained either by the phonic structures or the amplitude of the speech. These results suggest that other unknown physiological factors, varying dramatically among individuals, could affect the probability of respiratory infectious disease transmission, and also help explain the existence of superspreaders who are disproportionately responsible for outbreaks of airborne infectious disease.

It has long been recognized that particles expelled during human expiratory events, such as sneezing, coughing, talking, and breathing, serve as vehicles for respiratory pathogen transmission[1–6]. The relative contribution of each expiratory activity in transmitting infectious microorganisms, however, remains unclear[4]. Much previous research has focused on coughing[7–12] and sneezing[11,13,14] activities that yield relatively large droplets (approximately 50 μm or larger) easily visible to the naked eye. Less noticeable, but arguably more infectious for some diseases, are the smaller particles emitted during sneezing and coughing as well as during breathing[15–17] and talking[16,18,19]. These small particles are believed to be generated during breathing and talking from the mucosal layers coating the respiratory tract via a combination of a "fluid-film burst" mechanism within the bronchioles and from vocal folds adduction and vibration within the larynx[6,20,21]. The particles emitted during breathing and typical speech predominantly average only 1 μm in diameter[15–17] and are thus too small to see without specialized equipment; most people outside of the community of bioaerosol researchers are less aware of them.

Despite their small size, however, these micron-scale particles are sufficiently large to carry a variety of respiratory pathogens such as measles virus (50–500 nm)[22], influenza virus (100 nm–1 μm)[23], and *Mycobacterium tuberculosis* (1–3 μm)[24]. Indeed, recent work by Yan *et al.* has confirmed that significant amounts of influenza viral RNA are present in small particles (<5 μm) emitted by influenza-infected individuals during natural breathing, without coughing or sneezing[25]. These small particles are potentially more infectious than larger sneeze- or

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cough-generated droplets for several reasons. First, smaller particles persist in the air for longer time periods before setting by gravity, thus increasing the probability of inhalation by susceptible individuals[26]. Second, smaller particles have a larger probability of penetrating further into the respiratory tract of a susceptible individual to initiate a lower respiratory tract infection[4]. Third, and perhaps most importantly, speech can release dramatically larger numbers of particles compared to coughing. Early work by Papineni and Rosenthal[16] and Loudon and Roberts[19] reported that speaking (as exemplified by counting aloud) releases about 2–10 times as many total particles as a single cough. Similarly, Loudon and Roberts investigated the role of singing in the spread of tuberculosis and showed that the percentage of airborne droplet nuclei generated by singing is 6 times more than that emitted during normal talking and approximately equivalent to that released by coughing[27]. More recent work using advanced particle characterization techniques have yielded similar results[21,28–30]. Chao *et al.*[28] used an interferometric imaging technique to obtain the size distribution of particles larger than 2 μm and found that counting aloud from 1 to 100 releases at least 6 times as many particles as an individual cough. Likewise, Morawska and coworkers[21,29] reported that counting aloud for 10 seconds followed by 10 seconds of breathing, repeated over two minutes, releases half as many particles as 30 seconds of continual coughing, which in turn releases half as many particles as saying "aah" for 30 seconds. They also reported that more particles are released when speech is voiced, which involves vocal folds vibration, rather than whispered, which does not.

Despite the clear evidence that speech emits large quantities of potentially infectious particles, to date little is known about how particle emission is modulated by different types of speech. Notably, the above work measured neither the total duration nor the loudness of the vocalizations; it is also unclear whether counting aloud will have a distribution of phones (phonemes) that is representative of typical conversational speech. Many important questions remain unanswered. For example, does raising your voice cause an increase in particle emission, or alter the particle size distribution? Does it matter what language you speak? Do all individuals emit particles at similar rates?

To address these questions, we used an aerodynamic particle sizer (APS) placed in a laminar flow hood to characterize the number and size distribution of particles emitted by individual human volunteers while they performed various vocalizations and breathing activities. Using this approach, we find three key results:

(1) The particle emission rate during speech is linearly correlated with the amplitude (loudness) of vocalization, for four different languages tested.
(2) The particle size distribution is independent of vocalization loudness or language spoken.
(3) Some individuals emit particles at a rate more than an order of magnitude larger than their peers, i.e., they behave as "speech superemitters."

Taken together, the results strongly suggest that individual human speech patterns and speech-associated particle emissions are highly heterogeneous and thus might play a role in the transmission of some respiratory pathogens. Furthermore, the results suggest a new hypothesis: that speech superemitters might contribute to the phenomenon of superspreading, in which a relative few contagious individuals infect a disproportionately large number of secondary cases during infectious disease outbreaks[31].

Results

Four separate types of experiments were performed. In the first experiment, participants said /ɑ/ (the vowel sound in 'saw') for five seconds, followed by 15 seconds of nose breathing, repeated six times in succession. This procedure mimics previous experimental measurements of particle emission during vocalization[21], but here the participants also systematically repeated the experiment at different voice amplitudes. Representative raw data for a single participant performing a series of six successive /ɑ/ vocalizations, at approximately the same loudness, are shown in Fig. 1. The simultaneous microphone recording (Fig. 1A) and APS measurements (Fig. 1B) demonstrate that the dynamics of particle release are highly correlated with the vocalization. Prior to and between vocalizations, during nose breathing in which exhaled air is directed away from the APS, the particle count is negligible, as is expected for the HEPA filtered air inside the laminar flow hood. Shortly after the vocalization commences, the number of particles rapidly increases and peaks, then decreases back to zero as the participant resumes nose breathing; the process then repeats at the next five-second vocalization. The approximately two-second lag between onset of vocalization and the observed increase in particle count is due to the time necessary for the released particles to reach the sensor in the APS. We emphasize that by design an APS does not measure 100% of the particles drawn into it, so the particle emission rates reported here do not represent the absolute number of particles emitted by the participant; the emission rates are best understood in relative terms, or in terms of the equivalent instantaneous concentrations of particles sampled from the funnel. As shown in the secondary axis of Fig. 1B, the instantaneous concentration of particles for this particular experiment was approximately 2 per cm^3 of sampled air.

The six vocalizations shown in Fig. 1A were made, to the best of the participant's ability, at the same loudness. Each participant then repeated a similar series of /ɑ/ vocalizations at different self-regulated voice amplitudes. Representative results for a single participant (F4) show that the particle emission rate (N), defined as the total number of particles emitted during a single vocalization divided by the measured duration (in seconds) of that vocalization, also correlates with the root mean square amplitude (A_{rms}) of the vocalization (Fig. 2A). In our set-up $A_{rms} = 0.45$ corresponds to an extremely loud conversational voice, as loud as comfortable without yelling (~98 decibels measured 6.5 cm from the participant's mouth, measured over background noise of approximately 65 decibels), while $A_{rms} = 0.02$ corresponds to a quiet vocalization just above whispering (~70 decibels; cf. Supplementary Fig. S1). As shown in Fig. 2A, the particle emission rate is linearly correlated with A_{rms} over this entire range of vocalization amplitudes, with the particle emission rate increasing from 6 to 53 particles per second at the quietest and loudest vocalizations respectively.

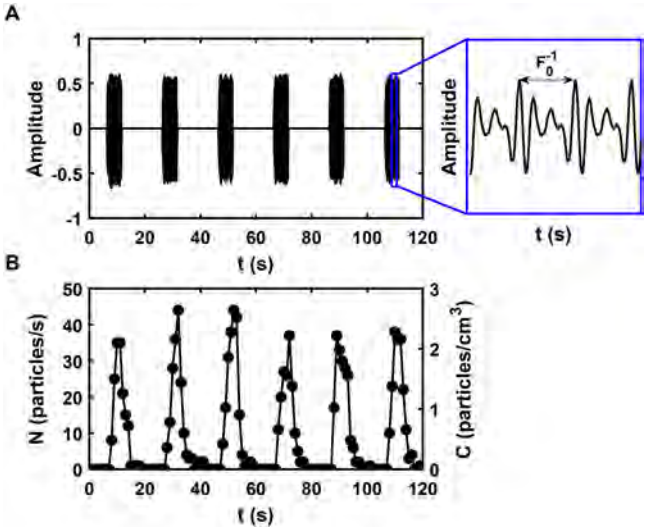

Figure 1. Representative raw data in which a participant (F4) said /ɑ/ for 5 seconds, followed by 15 seconds of nose breathing, repeated 6 times at approximately the same loudness. (**A**) The amplitude (arb. units) recorded by the microphone versus time. Magnification shows 13 ms of the waveform with fundamental frequency of F_0. (**B**) The corresponding number/concentration of particles measured by the APS versus time.

Although the particle emission rate increased with amplitude, the size distribution of the particles was not affected significantly (Fig. 2B), with the geometric mean particle diameter remaining near 1 μm regardless of voice amplitude (Supplementary Fig. S2A). Because the particle size remains similar regardless of amplitude, the increased particle counts shown in Fig. 2 indicate that the total volume of emitted respiratory fluid (i.e., the proteinaceous liquid droplets aerosolized from the serous and mucoid layers lining the respiratory tract) increases considerably with the vocalization loudness. Note that the characteristic time scale for evaporative drying of 1-micron diameter droplets is on the order of 100 milliseconds[26], which is much less than the time required for the particles to move from the participant's mouth into the detection module within the APS, suggesting that the particles measured here had fully dried into droplet nuclei prior to measurement (see methods and Supplementary Fig. S3).

Experiments with multiple participants indicated that these trends are conserved over a larger sample size (Fig. 2C). The particle emission rate increased approximately linearly with A_{rms} for each of the study participants, although the absolute magnitude varied between individuals. One participant (F3) released as many as 200 particles per second at higher amplitudes; another (F2) released as few as 1 particle per second at lower amplitudes. Notably, the data with this cohort of non-elderly adults reveal no obvious trends with gender or age (Supplementary Figs S4A, B). Similarly, no clear correlation was observed with the body mass index (BMI) of the participants (Supplementary Figs S4C, D).

To more closely represent normal conversational speech, the participants read aloud a short passage of text in English at varied loudness (quiet, intermediate, or loud). Representative raw data for a single participant (F4) indicate that the particle emission rate also correlates with voice amplitude for normal speech (Fig. 3A,B). To quantify the loudness, we take A_{rms} here as the average over the entire approximately two-minute duration of the vocalization, excluding pauses between words. Aggregated data for 10 participants confirms that the particle emission rate for normal English speech correlates linearly with A_{rms} (Fig. 3C); speaking loudly yielded on average a 10-fold increase in the emission rate compared to speaking the same series of words quietly. Again, the size distributions (Fig. 3D) and geometric mean diameter of particles (Supplementary Fig. S2B) were insensitive to voice amplitude. The reading experiment also was repeated in different languages to test whether choice of language matters; the results (Supplementary Fig. S5) confirmed the increasing trend between particle emission rate and amplitude, but exhibited no significant difference in the particle emission rate among the languages tested (Supplementary Fig. S6). Likewise, we measured the temperature and humidity during the experiments, and found no significant impact of temperature or humidity on either the particle emission rate or the mean particle size (Supplementary Figs S7 and S8).

A key recurring feature of the data is that some individual participants emitted many more particles than others. Because all participants spoke at slightly different amplitudes, we used linear regressions of the particle emission rate versus amplitude for each individual (cf. Fig. 2A) to calculate a normalized particle emission rate at the loudness amplitude of 0.1 (approximately 85 dB). Using this approach, the results for 40 people show that the particle emission rate for different individuals follows a long-tailed distribution for both vocalization of /ɑ/ (Fig. 4A) and reading of English text aloud (Fig. 4B). At this loudness, the normalized particle emission rates ranged from approximately 1 to 14 particles per second between different individuals, with an average of approximately 4 particles per second. Notably, the rates have a sizeable standard deviation well approximated by a lognormal fit (red curves in Fig. 4). In other words, although half of the participants emitted fewer than 3 particles per second, a small fraction of individuals (8 out of 40) emitted considerably more. These "speech superemitters,"

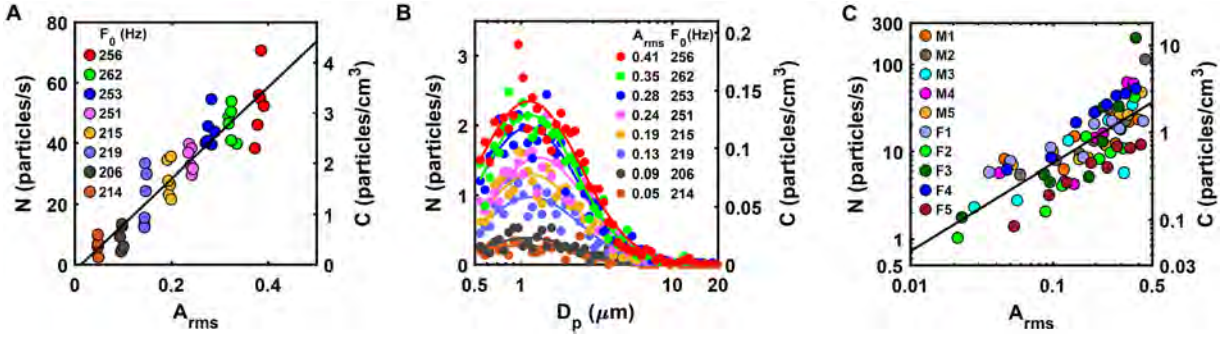

Figure 2. Particle emission rate/concentration while saying /ɑ/ at 8 different amplitudes, repeated 6 times at each amplitude. (**A**) Particle emission rate/concentration versus root mean square amplitude, A_{rms} (arb. units) for a representative participant (F4). Solid line is the best linear fit, with correlation coefficient $\rho = 0.932$ and Pearson's p value $= 5.9 \times 10^{-22}$. (**B**) Corresponding particle size distribution for the data presented in (**A**). (**C**) Aggregated particle emission rate/concentration versus root mean square amplitude, A_{rms} (arb. units) for 10 participants, 5 males (denoted as M1 to M5) and 5 females (denoted as F1 to F5). There are 8 data points for each participant, each representing the average of repeating /ɑ/ six times at approximately the same voice amplitude (cf. Fig. 1). Solid line is a power law fit with exponent 1.004, correlation coefficient $\rho = 0.774$ and Pearson's p value $= 3.8 \times 10^{-17}$.

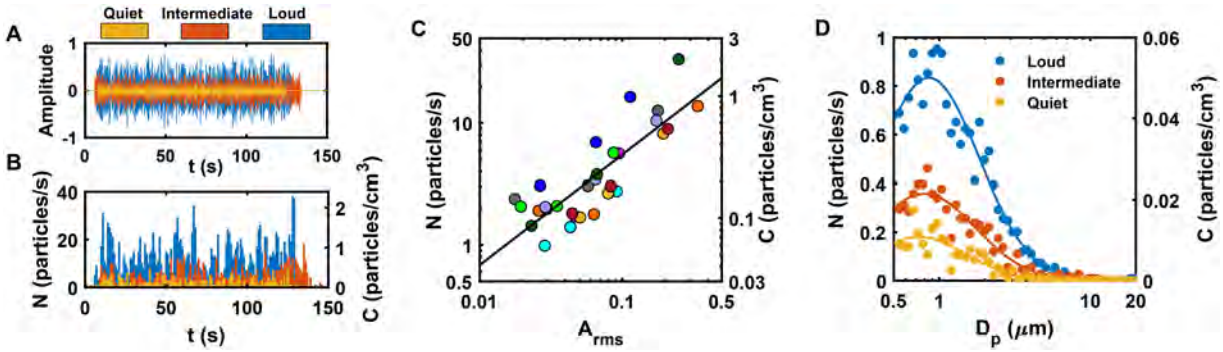

Figure 3. Particle emission rate/concentration while reading a passage of text aloud (the "Rainbow" passage), at three different loudness levels. (**A**) Superimposed representative recordings of amplitude (arb. units) for an individual (F4) reading the passage at three different voice amplitudes, and (**B**) the corresponding number/concentration of particles measured by the APS versus time. Color code same as in (**A**). (**C**) Particle emission rate/concentration as a function of root mean square amplitude, A_{rms}, for 10 participants. There are 3 points for each person, representing 3 voice amplitudes, color code same as Fig. 2C. Solid line is a power law fit with exponent 0.96, correlation coefficient $\rho = 0.865$ and Pearson's p value $= 6.8 \times 10^{-10}$. (**D**) Representative particle size distribution for the one individual (F4).

whose individual particle emission rate exceeded the group mean by one standard deviation or more, consistently released an order of magnitude more particles than their peers. For vocalizing /ɑ/, Fig. 4A shows that 15% of the participants emitted 32% of the total particles, while Fig. 4B shows that, for reading aloud in English, 12.5% of the participants emitted 40% of the total particles. Supplementary Fig. S9A shows that 4 out of these 8 individuals are superemitters for both saying /ɑ/ and passage reading activities, while 2 of them are only superemitters while saying /ɑ/, and 2 of them are superemitters while reading a text passage. We repeated the passage reading experiment for two of the participants (M5 and F4) on three different days separated by several months (Supplementary Fig. S9B), and the results show that the particle emission rates remained almost unchanged for at least these two individuals (F4, a superemitter, and M5, a non-superemitter) despite the long time period between measurements.

To help interpret our findings we also compared the particle emission rates of four different types of breathing with speech at three levels of loudness using the same experimental set-up. The breathing experiments included nose breathing, mouth breathing, a "deep-fast" mode, and a "fast-deep" mode (see methods for details). The results show that the particle emission rate for speech is significantly higher than all types of breathing tested here (Fig. 5A). Furthermore, the corresponding geometric mean diameters of the particles generated during speech are slightly larger on average than those generated during breathing (Fig. 5B), consistent with prior work and the hypothesis that vocalization activates laryngeal particle generation[21]. Note that in Fig. 5A the speech outliers correspond to a single participant who is a speech superemitter (F4), but this individual was not also responsible

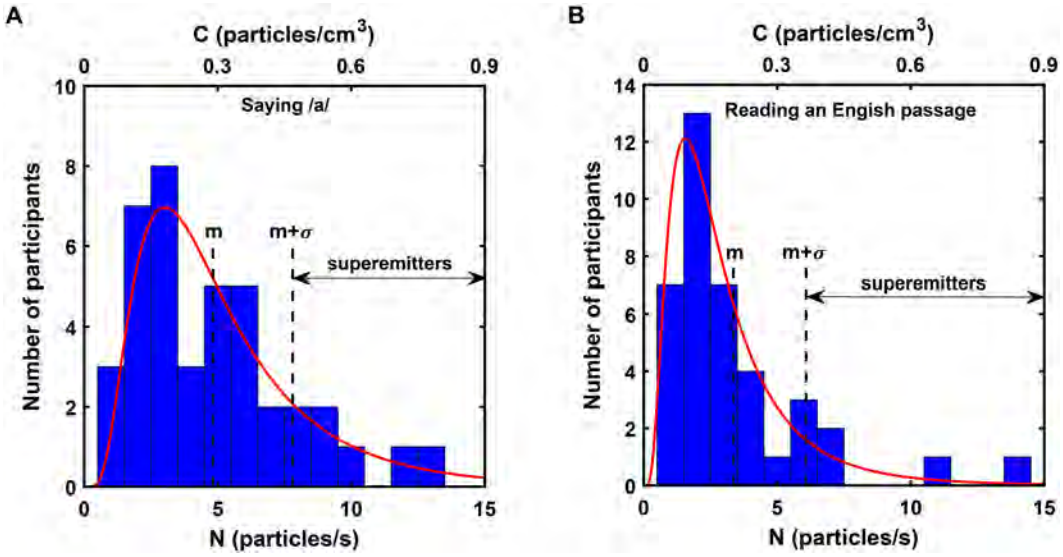

Figure 4. Histogram of particle emission rate/concentration at voice amplitude of 0.1 (approximately 85 dB). (**A**) For saying /ɑ/, with median of M = 4.3 particles/s, mean of m = 4.8 particles/s and standard deviation of σ = 3.0 particles/s. (**B**) For reading an English passage (10 people read the "Rainbow" passage and 30 people read chapter 24 of "The Little Prince") with median of M = 2.5 particles/s, mean of m = 3.4 particles/s and standard deviation of σ = 2.7 particles/s. Particle emission rates larger than m + σ are labeled superemitters. Red curves are lognormal fits found via nonlinear regression.

for the observed outliers of "fast-deep" and "nose" breathing activities. In other words, the "breathing high producers" as defined by Edwards *et al.*[15] are not necessarily also speech superemitters.

Discussion

Given that the results clearly indicate that particle emission rate is correlated with vocalization amplitude, a natural question is: why? The particles emitted during breathing and speech are hypothesized to be formed primarily by a "fluid-film burst" mechanism inside the small airways of the lungs and/or via vocal folds vibration and adduction at the larynx[6,20,21]. During exhalation the elastic walls of the respiratory bronchioles contract, and the mucosal fluid on the lumen surface forms a continuous film that can completely fill the airway. During the subsequent inhalation, the bronchioles expand and the film ruptures, yielding particles that are drawn into the alveoli and subsequently exhaled. A similar mechanism is believed to occur in the larynx, as the vocal folds repeatedly close and open during vocalization[21]; when the vocal folds come into contact during adduction, fluid films that form between them can then rupture during their subsequent abduction. Our direct comparison of particles emitted during various types of breathing versus speech demonstrates that even quiet speech yields significantly more particles than normal breathing (Fig. 5A). Coupled with the observation that the particles generated during speech on average are slightly larger (Fig. 5B), the results suggest that laryngeal particle generation, which presumably does not occur during normal breathing, is at least partially responsible for the observed larger rates of particle emission. Indeed, the fundamental frequency or "pitch" of vocalization (i.e., the frequency at which the vocal folds open and close) increases slightly with amplitude (cf. Supplementary Fig. S11 and Gramming *et al.*[32]), so the increased amplitude could reflect an increased opportunity for particles to form at the larynx.

Complicating matters, however, vocalization at a larger voice amplitude requires a larger exhalation flow rate[33,34]. A possible interpretation of our observations is that the underlying physical mechanism of particle release hinges on the combination of laryngeal particle generation rate and the time integral of the exhalation flow rate during vocalization[35]. If the volume of exhaled air is larger when the voice amplitude is higher, a larger fraction of particles formed in bronchiolar film rupture may escape from the lungs, with consequently more emitted particles, thus increasing the particle concentration in the exhaled air. Since our measurements only gauge the particle emission rate (and equivalent concentration), it is difficult to decouple the relative contributions of these two mechanisms. Fitting our particle size distributions to constrained bimodal lognormal distributions provides some evidence consistent with the interpretation presented by Johnson *et al.*[21] that there are two modes, presumably due to bronchiolar versus laryngeal generation, but we do not find any significant difference in particle emission rates for the two modes as a function of vocalization amplitude (Supplementary Fig. S10 and cf. Fig. 5B). Furthermore, it is less understood how particles originating in the respiratory tract might deposit in more proximal regions instead of being emitted during exhalation. Particle deposition efficiency during nasal exhalation is known to depend on exhalation flow rate in a convoluted fashion, with Brownian diffusion, sedimentation, and inertial impaction all playing roles at different length and time scales within the respiratory tract[36]. Nonetheless, our results strongly suggest that, in general, more particles escape the respiratory tract if the vocalization is louder.

Our results also clearly show that some participants release many more particles than others, for as-yet unclear reasons. It is known that the Rayleigh-Plateau instability that gives rise to small droplets during the "film burst" is

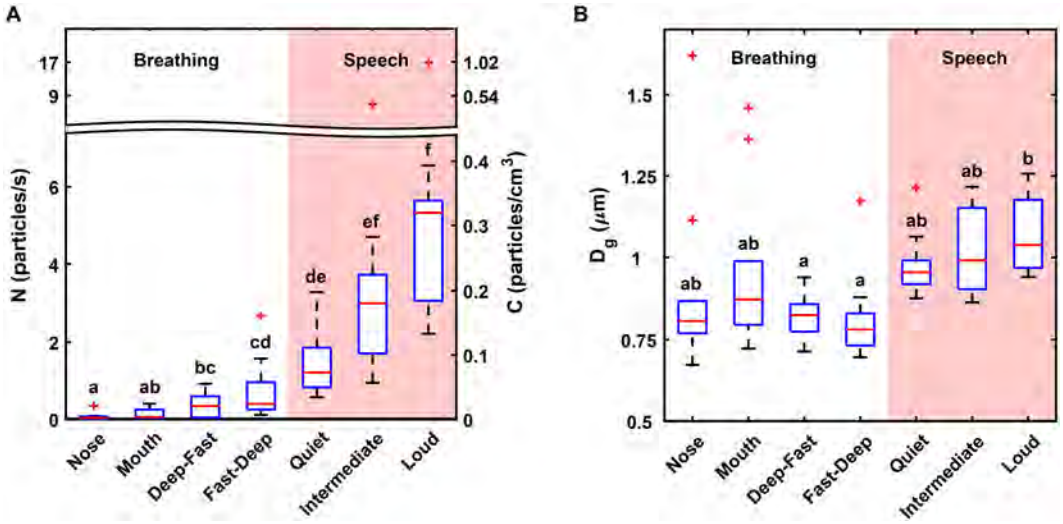

Figure 5. Comparison of (**A**) emission rate/concentration and (**B**) corresponding geometric mean diameters of particles emitted during various modes of breathing versus speech at different loudness levels. "Nose" denotes normal nasal breathing; "Mouth" denotes normal mouth breathing; "Deep-Fast" denotes deep, slow nasal inhalation followed by fast mouth exhalation; "Fast-Deep" denotes fast nasal inhalation followed by deep (i.e., slow and prolonged) mouth exhalation. "Quiet", "Intermediate", and "Loud" denote loudness levels while reading aloud a passage of text ("Rainbow" passage) at respective amplitudes. Red lines indicate medians, while bottom and top of blue boxes indicate the 25th and 75th percentiles respectively; sample size is n = 10. Outliers (defined as values that exceed 2.7 standard deviations) are indicated with red plus signs. Note that the 2 outliers for speech in (**A**) are a different individual (F4) than the two outliers observed for nose and fast-deep breathing (M24 and M5 respectively). Scheffe groups are indicated with letters; groups with no common letter are considered significantly different with $p < 0.05$, cf. Supplementary Table S1. Note that (**A**) has different scales above and below the break.

sensitive to the interfacial tension, density, and viscosity of the fluid[37], so one possible explanation is that the mucosal fluids in different people have different material properties and correspondingly generate more or fewer drops. Notably, different disease states are known to alter the physicochemical properties of the mucosal fluid lining the respiratory tract[38], so it is possible that infected individuals might generate markedly different quantities of particles than those emitted by the healthy individuals tested here. Intriguingly, Edwards *et al.*[15] found that delivering nebulized isotonic saline to individuals decreased the number of particles exhaled during normal breathing for a few hours after inhalation of the saline; further tests are warranted with speech. Alternatively, it is possible that individual manners of articulation affect the amount of internal deposition of the particles before they manage to escape the mouth. Our tests of different languages yielded no significant differences, at odds with previous speculation that language spoken might have played a role in the epidemiology of SARS coronavirus transmission[39], and suggesting that some as yet unknown physiological factor causes the dramatic variation among individuals.

Regardless of the underlying physical mechanism, from an epidemiological perspective the existence of speech superemitters motivates consideration of a new hypothesis: that speech superemitters contribute to "superspreading" of infectious diseases transmitted by emitted airborne particles. A superspreader is a contagious individual who infects a disproportionately large number of susceptible contacts[31,40,41]. To date, several airborne superspreading events have been documented, such as the MERS-CoV outbreak in South Korea in 2015 and the SARS-CoV outbreak in 2003, the latter being initiated in Hong Kong and spreading to Canada, Vietnam, and Singapore through travel[40–43]. In the case of respiratory infectious diseases in particular, the underlying physiological and immunological factors that contribute to heterogeneity in individual infectiousness remain poorly understood, despite the epidemiological importance of respiratory superspreaders. Quantifying infectious pathogen loads in exhaled air is technically challenging, relative to other contagious substances like blood, urine, and feces. Many factors presumably affect the secondary attack rate attributable to any infectious individual, including the herd immunity status of others in proximity. Nonetheless, our results suggest that, for respiratory infections transmitted from person to person via airborne particles, the existence of speech superemitters might help explain the existence of superspreaders. A similar hypothesis was advanced by Edwards *et al.*[15] in response to their observation of variability between individuals in the number of particles emitted during mouth breathing. Interestingly, our data show that speech superemitters are not necessarily breathing superemitters as well (Fig. 5A), suggesting that respiratory superemission during vocalized speech has a different underlying physiology than superemission during tidal breathing.

Our results indicate that speech is potentially of much greater concern than breathing for two reasons: the particles on average are larger, and thus could potentially carry a larger number of pathogens, and much greater quantities of particles are emitted compared to breathing, thus increasing the odds of infecting nearby susceptible individuals. Laryngeal particle generation during speech is also potentially important since some studies suggest that human influenza viruses attach more abundantly to the large airways of the upper respiratory tract than to

the bronchiolar and alveolar cells in the lower respiratory tract, while MERS-CoV and avian influenza viruses mainly cause lower respiratory tract infections due to the greater presence of these virus receptors deeper within the lung[44–47]; likewise there is evidence that laryngeal tuberculosis is potentially more contagious than typical pulmonary tuberculosis[48].

A second key epidemiological implication of our results is that simply talking in a loud voice would increase the rate at which an infected individual releases pathogen-laden particles into the air, which in turn would increase the probability of transmission to susceptible individuals nearby[49]. For example, an airborne infectious disease might spread more efficiently in a school cafeteria than a library, or in a noisy hospital waiting room than a quiet ward. Moreover, our data suggest a related hypothesis, that infected individuals could be transmitting significant numbers of respiratory pathogens via speech in the absence of overt clinical signs of illness like coughing or sneezing. More research is needed; however, the presence of asymptomatic or paucisymptomatic superspreaders would have important public health implications in the surveillance for and mitigation of infectious disease epidemics that are spread by airborne respiratory particles. The data presented here strongly suggest that further efforts to test these hypotheses are warranted.

Methods

Human subjects. The University of California Davis Institutional Review Board approved this study and all research was performed in accordance with relevant guidelines and regulations of the Institutional Review Board. We recruited 48 healthy volunteers (26 males and 22 females, ranging in age from 18 to 45 years old) by posting flyers at the University of California Davis campus over the time period May 2016 to March 2018. Informed consent was obtained from all participants prior to study participation. All participants completed a brief questionnaire including age, gender, weight, height, general health status, and smoking history. Only participants who self-reported as healthy non-smokers were included in the study. The subject in Supplementary Fig. S12 provided her written informed consent for the publication of identifying information/images in an online open-access publication.

Experimental set-up. A photograph of the experimental set-up is provided as Supplementary Fig. S12. An aerodynamic particle sizer (APS, TSI model 3321) operating at a total flow rate of 5 L/min (sheath flow rate $\cong$ 4 L/min, sample flow rate $\cong$ 1 L/min) was placed inside a HEPA filtered laminar flow hood that provided class 10 air. A plastic funnel (diameter = 10 cm) was connected to the APS sampling inlet via a conductive silicon tube (distance between funnel hole to APS inlet = 7.5 cm, tube inner diameter = 1.2 cm). During each experiment, participants sat at the laminar flow hood, in front of the APS, and spoke into the funnel. For the majority of speaking and breathing experiments, a nose rest across the funnel opening was used to position participants' mouths approximately 7.5 cm away from the funnel inlet (hole) and also to divert nasal exhalations away from the APS. During "nose-breathing" experiments, the nose rest was removed to allow nasal exhalations to be drawn into the APS. Note that participants' faces did not touch the funnel, so that air was free to move around the side of their faces; in this sense the cone was a semi-confined environment and not all expired particles were necessarily sampled by the APS. Also note that the sheath flow inside of an APS is filtered, so the particle emission rates sampled by the APS automatically remove 80% of the particles sampled from the funnel. Equivalent concentrations reported on the secondary axes in Figs 1 through 5 are determined from the raw particle counts using the sample flow rate, i.e., $C = \frac{\text{particles}}{\text{s}} \times \frac{\text{s}}{\text{cm}^3} = \frac{\text{particles}}{\text{cm}^3}$. Also note that the APS measures the size distribution of particles larger than 0.5 µm, but only detects the presence of particles between 0.37 µm and 0.5 µm without providing precise size measurements. For this reason Figs 1–5 exclude the counts of particles smaller than 0.5 µm; including them has little impact on the results since the vast majority of particles were larger than 0.5 microns.

A microphone (audio-technica PRO 37) and a decibel meter (Extech, 407760) were placed immediately on either side of the funnel to record the vocalizations. A computer screen with word prompts and a timer was placed behind the APS to guide participants in making requested vocalizations for the specified duration. The timing, duration, repetition, and order of vocalization and breathing experiments were coordinated by customized code written in LabVIEW (National Instruments). A digital hygrometer was used to measure the ambient temperature and relative humidity inside the laminar flow hood during all experiments. The participants were not allowed to drink or eat during the experiment, but they were free to rest between experiments for a few minutes as needed; data from each individual participant was gathered over an approximately 1-hour time period. We performed the experiments in an indoor (controlled) environment, so the ambient temperature varied only from approximately 20 to 25 °C, while the ambient relative humidity measured inside the laminar flow hood varied from a low of approximately 45% to a high of 80%. Control experiments indicate that the particle size distribution was independent of whether the particles were expired early or late during a sustained vocalization (Supplementary Fig. S3), indicating that transient fluctuations in the humidity inside the funnel due to exhalation had no impact on the final measured size distribution. Particles with initial diameter of less than 20 µm dry to approximately half of their initial diameter in less than 1 second[49,50]. Different correction factors have been suggested in the literature that one can use to estimate the initial size of the particles[49,51]; here we focus on the final size distribution because epidemiologically it is the final size distribution governs the deposition efficiency of the particles in the respiratory tract of nearby susceptible individuals[52].

Vocalization experiments. *"/ɑ/" experiments.* Participants (n = 10, 5 males, M1 to M5, and 5 females, F1 to F5) voiced /ɑ/ (the vowel sound in 'saw') for five seconds, followed by 15 seconds of nose breathing, repeated six times in succession. The participant repeated the series of six /ɑ/ vocalizations, to the best of the participant's ability, at the same amplitude. Each participant completed eight sets of /ɑ/ experiments, each set performed at different, self-regulated voice amplitude. Timed prompts with directions for the requested vocalization appeared on the computer screen, which displayed a timer and an amplitude (loudness) gauge to help the participants regulate their voice amplitude. The requested amplitudes were presented to participants in a random order.

"Rainbow passage" experiments. Participants (n = 10, 5 males, M1 to M5, and 5 females, F1 to F5) read aloud a 330-word excerpt of text in English, known in linguistics research as the Rainbow passage[53]. Participants were asked to read the Rainbow passage aloud three times, at a comfortable pace, over approximately 2 minutes per reading. Each of the three readings was performed at a different self-regulated amplitude: quiet, intermediate, and loud. Quiet was defined for participants as "just louder than a whisper," intermediate as a "normal conversational voice," and loud as "giving a loud lecture".

"The Little Prince" experiments. Bilingual participants (n = 30) fluent in both English and either Spanish (n = 10, 5 males, M6 to M10, and 5 females, F6 to F10), Mandarin (n = 10, 5 males, M11 to M15, and 5 females, F11 to F15), or Arabic (n = 10, 6 males, M16 to M21, and 4 females, F16 to F19) read Chapter 24 of "The Little Prince[54]" aloud six times, three times in English translation, each time at a different amplitude (quiet, intermediate, and loud) and three times in their respective language, again at three loudness levels.

Breathing/speaking experiments. Participants (n = 10, 6 males, M5 and M22 to M26, and 4 females, F4 and F20 to F22) alternated four silent breathing patterns with vocalized speech at three amplitudes. For breathing measurements, the breathing patterns were designated as "nose" (both inhalation and exhalation through the nose), "mouth" (both inhalation and exhalation through the mouth), "deep-fast" (deep, slow inhalation for ~3 seconds through the nose, holding it for ~1 second, followed by fast exhalation through the mouth (~1 second)), and "fast-deep" (rapid inhalation through the nose (~1 second), holding it for ~1 second, followed by slow exhalation through the mouth for ~3 seconds). Each breathing experiment was performed over 2 minutes, and at a comfortable pace for the participants. Between performing different breathing patterns, participants were asked to read the Rainbow passage in a "quiet," "intermediate," or "loud" voice, as prompted by the computer in random order.

Statistical analysis. Data analysis was performed in MATLAB (MathWorks), with data fits performed as noted in figure legends. Pearson's linear correlation coefficients and p values were calculated for linear fits. Lognormal fits were made via nonlinear regression, and median, mean, and standard deviation were calculated. Box-and-whisker plots show the median (red line), interquartile range (blue box), and range (black whiskers). To analyze the breathing/speaking experiments data presented in Fig. 5, Stata/SE 15.1 was used to perform general linear mixed model (GLMM) analysis to account for person-level correlations, and post hoc pairwise comparisons were performed and adjusted for multiple comparisons using Scheffe's method.

Data Availability

All relevant data are available from the corresponding authors upon request.

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Acknowledgements

We thank the National Institute of Allergy and Infectious Diseases of the National Institutes of Health (NIAID/NIH), grant R01 AI110703, and the NIEHS UC Davis Core Centre, grant P30-ES023513, for supporting this research, and P. Dayal for assistance with statistical analysis.

Author Contributions

S.A., A.S.W., C.D.C., S. B., N.M.B. and W.D.R. designed research; S.A. performed experiments; S.A. and W.D.R. analysed the data; S.A. and W.D.R. wrote the manuscript, and all co-authors reviewed the manuscript.

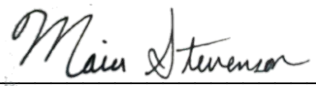
Additional Information

Supplementary information accompanies this paper at https://doi.org/10.1038/s41598-019-38808-z.

Competing Interests: The authors declare no competing interests.

Publisher's note: Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This is "**Exhibit P**"
to the Affidavit of Matthew Hodge,
affirmed this 2nd day of July, 2021



A Commissioner, etc.

Ontario is now in Step 2 of the Roadmap to Reopen. Follow the restrictions and public health measures.

Ontario

Reopening Ontario

Learn about the Roadmap to Reopen, the province's three-step plan to safely and gradually lift public health measures based on ongoing progress of provincewide vaccination rates and improvements of key public health and health care indicators.

Ontario is in Step 2 of the Roadmap to Reopen as of **June 30 at 12:01 a.m.**

Overview

The Roadmap to Reopen is a three-step plan to safely and cautiously reopen the province and gradually lift public health measures.

The plan is based on:

- the provincewide vaccination rate
- improvements in key public health and health care indicators

In Step 2 of the roadmap, we must all continue to follow the public health measures, advice and restrictions (https://covid-19.ontario.ca/public-health-measures) .

Guiding principles

Step 1: An initial focus on resuming outdoor activities with smaller crowds where the risk of transmission is lower, and permitting limited indoor settings with restrictions.

Step 2: Further expanding outdoor activities and resuming limited indoor services with small numbers of people and with face coverings being worn.

Step 3: Expanding access to indoor settings, with restrictions, including where there are larger numbers of people and where face coverings can't always be worn.

Moving through the steps

The province will remain at each step for **at least 21 days** to evaluate any impacts on key public health and health system indicators. It can take up to two weeks for COVID-19 vaccinations to offer protection against the virus.

The province will remain in Step 1 for at least 21 days to evaluate any impacts on key public health and health system indicators.

If at the end of the 21 days the province has met the following vaccination thresholds, and there are continued improvements in other key public health and health system indicators, the province may move to the next step of the

roadmap:

- **Step 1:** 60% of adults vaccinated with one dose
- **Step 2:** 70% of adults vaccinated with one dose and 20% vaccinated with two doses
- **Step 3:** 70 to 80% of adults vaccinated with one dose and 25% vaccinated with two doses

Roadmap to reopen – key highlights

Vaccination rate
plus key public health and health care indicators

Step 1

60%

Adults with one dose

Permit with restrictions

Outdoor spaces begin reopening, limited indoor settings with restrictions

- Outdoor social gatherings and organized public events for up to 10 people
- Outdoor dining for up to 4 people per table
- Essential retail capacity at 25%
- Non-essential retail capacity at 15%
- Religious services, rites and ceremonies indoors at 15% capacity and outdoors with capacity limited to permit physical distancing of 2 metres
- Outdoor sports training (no games or practices), fitness classes and personal training up to 10 people
- Day camps
- Overnight camping at campgrounds and campsites, including Ontario Parks and short-term rentals
- Outdoor horse racing and motor speedways without spectators
- Outdoor pools and wading pools

+21 days before next stage
Vaccination rate
plus key public health and health care indicators

Step 2

70%

Adults with one dose
20% Fully vaccinated

Permit with restrictions

Open indoors with small numbers and face coverings and expand outdoors

- Outdoor social gatherings and organized public events for up to 25 people
- Indoor social gatherings and organized public events for up to 5 people
- Outdoor dining for up to 6 people per table
- Essential and other select retail permitted at 50% capacity
- Non-essential retail capacity at 25%
- Stores in shopping malls open, with restrictions
- Larger indoor religious services, rites, or ceremonies, including wedding services and funeral services at 25% capacity
- Outdoor religious services, rites, or ceremonies, including wedding services and funeral services, capped at the number of people that can maintain a physical distance of two metres
- Overnight camps
- Personal care services where face coverings can be worn at all times at 25% capacity
- Outdoor fitness classes are capped at the number of people who can maintain 3 metres of distance
- Public libraries permitted at 25% capacity
- Outdoor meeting and event spaces at 25% capacity
- Outdoor amusement and water parks at 25% capacity
- Outdoor sports games, leagues and events at 25% capacity
- Outdoor cinemas, performing arts, live music events and attractions at 25% capacity
- Outdoor horse racing and motor speedways at 25% capacity

+21 days before next stage
Vaccination rate
plus key public health and health care indicators

Step 3

70-80%

Adults with one dose
25% Fully vaccinated

Permit with restrictions

Expand indoors where face coverings can’t always be worn

- Larger indoor and outdoor social gatherings and organized public events
- Indoor dining
- Essential and non-essential retail with limited capacity
- Larger indoor religious services, rites or ceremonies, including wedding services and funeral services with capacity limits
- Indoor meeting and event spaces
- Indoor sports and recreational facilities

- Indoor seated events
- Indoor attractions and cultural amenities
- Casino and bingo halls
- Other outdoor activities from Step 2 permitted to operate indoors

Roadmap to reopen at a glance

This is a high-level overview of what can reopen in each step.

Read our public health measures, advice and restrictions (https://covid-19.ontario.ca/public-health-measures) for a more detailed summary or refer to *O. Reg. 263/20 (https://www.ontario.ca/laws/regulation/200263)* for a complete list of public health and workplace safety measures and restrictions for Step 2.

Gatherings

Step 1

Maximum 10 people for outdoor gatherings

Outdoor end-of-school-year celebration ceremonies held by a school or private school are exempt from outdoor gathering limits, with restrictions

Retirement homes are exempt from gathering limits

Step 2

Maximum 25 people for outdoor gatherings

Maximum 5 people for indoor gatherings

Step 3

Larger indoor and outdoor gatherings with size limits

Religious services, rites or ceremonies, including wedding services and funeral services (does not apply to receptions)

Step 1

15% capacity indoors of the room

Outdoor permitted with capacity limited to permit physical distancing of 2 metres

Step 2

Indoor permitted at 25% capacity of the room

Outdoor permitted with capacity limited to permit physical distancing of 2 metres

Step 3

Larger indoor religious services, rites and ceremonies

Outdoor permitted with capacity limited to permit physical distancing of 2 metres

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Retail

Step 1

Essential and select retail at 25% capacity and can sell all goods (including discount and big box)

Non-essential retail at 15% capacity

Retail stores in malls closed unless the stores have a street facing entrance

Restrictions on shopping malls

Step 2

Essential retail at 50% capacity

Non-essential retail at 25% capacity

Stores in shopping malls open

Step 3

Essential and non-essential retail open with capacity limited to permit physical distancing of 2 metres

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Liquor stores

Step 1

Open at 25% capacity

Step 2

Open at 50% capacity

Step 3

Open with capacity limited to permit physical distancing of 2 metres

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Restaurants and bars

Step 1

Outdoor dining with 4 people per table from different households and other restrictions

Step 2

Outdoor dining with 6 people per table and other restrictions

Karaoke permitted with restrictions (outdoor only)

Step 3

Indoor dining with capacity and other restrictions

Outdoor dining with capacity limited to permit physical distancing of 2 metres

Buffets permitted

Karaoke permitted with restrictions

Personal care services

Step 1

Closed

Sensory deprivation pods permitted when prescribed or administered by a regulated health professional, with restrictions

Step 2

Open at 25% capacity

Appointment required

Services that require the removal of a face covering not permitted

Step 3

Open with capacity limited to permit physical distancing of 2 metres and other restrictions

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Sports and recreational fitness facilities

Step 1

Outdoor fitness classes, outdoor sports training (no games or practices) and outdoor personal training, with 10 patrons maximum

Closed for indoor use except for high-performance athletes and day camps

Step 2

Outdoor sports leagues open

Training for professional or amateur athletes and/or competitions

Closed for indoor use except for high-performance athletes and day or overnight camps

Step 3

Indoor open, with restrictions

Outdoor open, with restrictions

Personal fitness and training

Step 1

Outdoor fitness classes – 10 people maximum, 3 metres distance

Outdoor personal training – 10 people maximum, 3 metres distance

Outdoor sports training only – 10 people maximum, 3 metres distance (no games or practices)

Step 2

Outdoor fitness classes and personal training – with limit on the number of patrons, 3 metres distance

Step 3

Outdoor and indoor fitness classes and personal training permitted, with restrictions

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Outdoor recreational amenities

Step 1

Open with restrictions

Step 2

Open with restrictions

Step 3

Open

Water features

Step 1

Outdoor pools, splash pads, spray pads, whirlpools, wading pools and water slides open

Step 2

Outdoor pools, splash pads, spray pads, whirlpools, wading pools and water slides open

Step 3

Indoor and outdoor pools, splash pads, spray pads, whirlpools, wading pools and water slides open

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Meeting and event spaces

Step 1

Closed with exceptions for certain purposes including social services, government operations, court services, in-person examinations for select professions (subject to conditions)

Step 2

Outdoor spaces open at 25% capacity and other restrictions

Indoor meeting and event spaces closed, with exceptions for certain purposes, including for viewing for potential booking of a future event

Step 3

Indoor spaces open with capacity and other restrictions, including for tradeshows, conferences and exhibitions

---

Day camps

Step 1

Open based on guidance from the Chief Medical Officer of Health (PDF) (https://www.health.gov.on.ca/en/pro/programs/publichealth/coronavirus/docs/2019_summer_day_camps_guidance.pdf)

Step 2

Open based on guidance from the Chief Medical Officer of Health (PDF) (https://www.health.gov.on.ca/en/pro/programs/publichealth/coronavirus/docs/2019_summer_day_camps_guidance.pdf)

Step 3

Open based on guidance from the Chief Medical Officer of Health (PDF) (https://www.health.gov.on.ca/en/pro/programs/publichealth/coronavirus/docs/2019_summer_day_camps_guidance.pdf)

Overnight camps

Step 1

Closed

Step 2

Open based on guidance from the Chief Medical Officer of Health

Step 3

Open based on guidance from the Chief Medical Officer of Health

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Commercial film and TV production

Step 1

Open with no audience, no more than 50 performers on set, and other restrictions

Step 2

Open with no audience, and other restrictions

Step 3

Open with capacity restrictions for studio audiences, and other restrictions

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Performing arts

Step 1

Outdoor open for rehearsing or performing a recorded or broadcasted event – 10 people maximum, spectators not permitted

Step 2

Indoor closed, permitted only for the purpose of rehearsing or performing a recorded or broadcasted event – spectators not permitted

Outdoor open, including live music, with spectator capacity at 25% and other restrictions

Step 3

Indoor open, including live music, with spectator capacity and other restrictions

Outdoor open, including live music, with spectator capacity and other restrictions

---

Cinemas

Step 1

Drive-in open

Step 2

Indoor closed

Outdoor open with spectator capacity at 25% and other restrictions

Step 3

Indoor open with spectator capacity and other restrictions

Outdoor open with spectator capacity and other restrictions

Casino, bingo halls and gaming establishments

Step 1

Closed

Step 2

Closed

Step 3

Open with capacity and other restrictions

Horse racing

Step 1

Outdoor with capacity and crew restrictions

No spectators

Step 2

Outdoor open with spectator capacity at 25% and other restrictions

Step 3

Open with spectator capacity and other restrictions

Motorsports and speedways

Step 1

Outdoor with capacity and crew restrictions

No spectators

Step 2

Outdoor open with spectator capacity at 25% and other restrictions

Step 3

Open with spectator capacity and other restrictions

Short-term rentals (does not include hotels, motels, lodges or resorts, but does apply to cabins and cottages)

Step 1

Open

Indoor pools, communal steam rooms, saunas or indoor whirlpools, indoor fitness centres, or other indoor recreational facilities closed

Step 2

Open

Indoor pools, communal steam rooms, saunas or indoor whirlpools, indoor fitness centres, or other indoor recreational facilities closed

Step 3

Open

Indoor pools, communal steam rooms, saunas or indoor whirlpools, indoor fitness centres, or other indoor recreational facilities open with some restrictions

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Hotels, motels, lodges, resorts and other shared rental accommodation

Step 1

Open. Indoor pools, communal steam rooms, saunas or indoor whirlpools, indoor fitness centres, or other indoor recreational facilities closed

Step 2

Open. Indoor pools, communal steam rooms, saunas or indoor whirlpools, indoor fitness centres, or other indoor recreational facilities closed

Step 3

Open. Indoor pools, communal steam rooms, saunas or whirlpools, indoor fitness centres, or other indoor recreational facilities open with some restrictions

---

Public libraries

Step 1

Curbside pickup for materials

Access to computers, photocopiers, and similar services permitted

Step 2

Open with 25% capacity and other restrictions

Step 3

Open, with capacity limited to permit physical distancing of 2 metres and other restrictions

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Museums and attractions

Step 1

Outdoor zoos, landmarks, historic sites, botanical gardens, and similar outdoor attractions open with capacity limited to 15% for ticketed areas and other restrictions

Step 2

Outdoor waterparks open with 25% capacity and other restrictions

Outdoor amusement parks open with 25% capacity and other restrictions, including on rides

Step 3

Indoor museums and art galleries, Zoos and aquariums, waterparks, and amusement parks open with capacity restrictions

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Fairs and rural exhibitions

Step 1

Closed

Step 2

Outdoor open at 25% capacity and other restrictions

Step 3

Indoor and outdoor open at reduced capacity and other restrictions

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Teaching and instruction (for example, recreational classes and lessons)

Step 1

Outdoor open, 10 patrons maximum, 2 metres physical distancing and other restrictions

Step 2

Outdoor open, with distancing and other restrictions

Step 3

Indoor and outdoor open with distancing and other restrictions

---

Tour and guide services

Step 1

Outdoor open, 10 patrons maximum, 2 metres physical distancing and other restrictions

Boat tours and motor vehicle tours not permitted

Step 2

Outdoor open, with capacity at 25% and other restrictions

Step 3

Indoor and outdoor open with capacity and other restrictions

Construction

Step 1

All construction open

Step 2

All construction open

Step 3

All construction open

Driving instruction

Step 1

Not permitted, except for drivers of commercial vehicles

Step 2

Driving instruction permitted with restrictions

Step 3

Driving instruction permitted with restrictions

Ontario Parks and campgrounds

Step 1

Open

Step 2

Open

Step 3

Open

Marinas and boating clubs

Step 1

Permitted with clubhouses, and other indoor amenities closed

Recreational boating permitted but only members of a household can gather on a boat

Step 2

Permitted with clubhouses, and other indoor amenities closed

Step 3

Open with restrictions

Strip clubs

Step 1

Permitted to operate as a restaurant in alignment with restaurant restrictions

Step 2

Permitted to operate as a restaurant in alignment with restaurant restrictions

Step 3

Permitted to operate as a strip club in alignment with restaurant and performance restrictions

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Domestic services

Step 1

Open to support children, seniors or vulnerable persons

Step 2

Open

Step 3

Open

Photography studios and services

Step 1

Outdoor open and by appointment only, with restrictions

Step 2

Outdoor and limited indoor open with restrictions

Step 3

Outdoor and indoor open with restrictions

Community centres and multi-purpose facilities

Step 1

Open for social services, child care and day camps, mental health support services or addictions support services, and permitted indoor and outdoors activities and services, with restrictions

Step 2

Open for social services, child care and day and overnight camps, mental health support services or addictions support services, and permitted indoor activities and services, with restrictions

Step 3

Open with restrictions

Real estate open houses

Step 1

Showings by appointment only

Step 2

Showings by appointment only

Step 3

Open

Drive-in and drive through events

Step 1

Open with restrictions

Step 2

Open with restrictions

Step 3

Open with restrictions

Health and safety training

Step 1

Indoor: 10 person limit

Outdoor: 10 person limit

Physical distance of at least two metres from every other person in the instructional space, except where necessary for teaching and instruction that cannot be effectively provided if physical distancing is maintained

Step 2

Indoor: 10 person limit

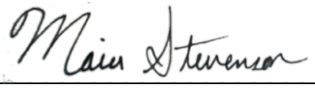
Outdoor open, with capacity and other restrictions

Step 3

Indoor and outdoor open with capacity and other restrictions

Updated: June 30, 2021
Published: April 27, 2020

This is "**Exhibit Q**"
to the Affidavit of Matthew Hodge,
affirmed this 2nd day of July, 2021



A Commissioner, etc.

TORONTO

COVID-19

Toronto is in Step Two of the Province's Roadmap to Reopen. Get health updates and information about COVID-19 vaccines at toronto.ca/covid19 (https://www.toronto.ca/home/covid-19).

Programs & Services for Tuberculosis (TB)

It is estimated that one in three people worldwide is infected with the TB bacteria. In Toronto, about 300 people become sick with **tuberculosis (https://www.toronto.ca/?page_id=28540)** every year. Treatment for TB disease involves taking medication every day for six months or longer. Although treatment can take a long time, a person can be cured of TB once treatment is complete.

Different specialty teams in the TB program work together to provide support for individuals with TB as well as their families and to help prevent the spread of TB in Toronto.

Expand All | Collapse All

Case Management Teams

- Provide case management services for people with active TB
- Ensure adequate TB treatment is received and completed
- Follow-up of individuals exposed to TB
- Educate clients and contacts
- Order TB medication for clients with TB disease and contacts with TB infection

Directly Observed Therapy

Directly Observed Therapy (https://www.toronto.ca/community-people/health-wellness-care/health-programs-advice/tuberculosis-tb/programs-services-for-tuberculosis-tb/directly-observed-therapy-dot-in-tuberculosis-tb/)

- Ensure clients take medication correctly
- Monitor for side effects
- Prevent/Reduce drug resistance caused by interrupted drug therapy
- Collaborates with Case Management Teams regarding client care

Homeless and Corrections Team

- Manage TB disease and infection in the **homeless/underhoused and corrections populations (https://www.toronto.ca/community-people/health-wellness-care/health-programs-advice/tuberculosis-tb/tuberculosis-tb-and-homeless-service-settings/)**
- Ensure adequate TB treatment is received and completed
- Follow-up of individuals exposed to TB
- Educate shelters, drop-in centers, clients, contacts and within correctional facilities
- Coordinate TB follow-up upon discharge from correctional facilities
- Liaise with Ministry of Community Safety and Correctional Services and other Toronto Public Health programs

Medical Surveillance and Drug Order Team

Medical Surveillance (https://www.toronto.ca/community-people/health-wellness-care/health-programs-advice/tuberculosis-tb/programs-services-for-tuberculosis-tb/tuberculosis-tb-medical-surveillance/) and Drug Order Team

- Immigrants, refugees, visitors, visa students/workers identified through immigration surveillance are monitored for TB disease
- Monitor clients with TB infection identified through routine surveillance
- Order TB medication for clients with TB infection on immigration and routine surveillance
- Order TB medication for Toronto clinicians whose clients live outside of Toronto

Prevention Team

Provide free educational materials, presentations, and consultation to clients, community agencies and health professionals

- Health promotion and community development
- Outreach to populations at higher risk for TB disease and health professionals
- Create and develop multi-language resource materials for clients and health professionals
- Partner with community agencies to increase TB awareness

Social Work for TB Clients

- .Provide assessment, counselling and referral
- Focus on income and housing
- Provide internal and external consultation

TB STOP Drop-in

TB STOP (https://www.toronto.ca/community-people/health-wellness-care/health-programs-advice/tuberculosis-tb/tuberculosis-tb-and-homeless-service-settings/?accordion=tb-stop-drop-in) provides drop-in services for people who are homeless and under-housed as well as for service providers to the homeless in Toronto:

- Symptom screening
- Sputum collection
- Referrals to other health professionals as appropriate
- TB skin testing

Contact Information

Tuberculosis Program
Toronto Public Health
Monday to Friday
8:30 a.m. - 4:30 p.m.

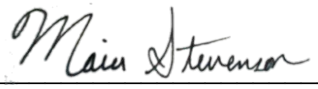
Ask to speak to someone in the TB Program.
Telephone: 416-338-7600
Email: targettb@toronto.ca (mailto:targettb@toronto.ca)

Related Information

Tuberculosis (TB) & Homeless Service Settings (https://www.toronto.ca/community-people/health-wellness-care/health-programs-advice/tuberculosis-tb/tuberculosis-tb-and-homeless-service-settings/)

Tuberculosis (TB) Information for Health Professionals (https://www.toronto.ca/community-people/health-wellness-care/information-for-healthcare-professionals/communicable-disease-info-for-health-professionals/tuberculosis-information-for-health-professionals/)

This is "**Exhibit R**"
to the Affidavit of Matthew Hodge,
affirmed this 2nd day of July, 2021



A Commissioner, etc.

Public Health Ontario | Santé publique Ontario

Ontario COVID-19 Data Tool

The Ontario COVID-19 Data Tool provides epidemiological information on COVID-19 activity in Ontario to-date. Explore the most recent COVID-19 data including: daily case counts, hospitalizations and deaths (Case trends), total or recent cases counts by age and sex, map by public health unit, source of COVID-19 infection (acquisition), outbreaks and laboratory testing.

Additions to the Ontario COVID-19 Data Tool as of May 28th, 2021:

- Vaccine uptake data on the Summary, Map and Vaccines sections
- COVID-19 reproduction number and doubling time

The COVID-19 Data Tool is updated Monday to Fridays at 11:30 a.m. except on statutory holidays. For weekend case counts see the **Daily Epidemiological Summary.**

For questions about the data, please contact **EPIR@oahpp.ca**.

Public health unit

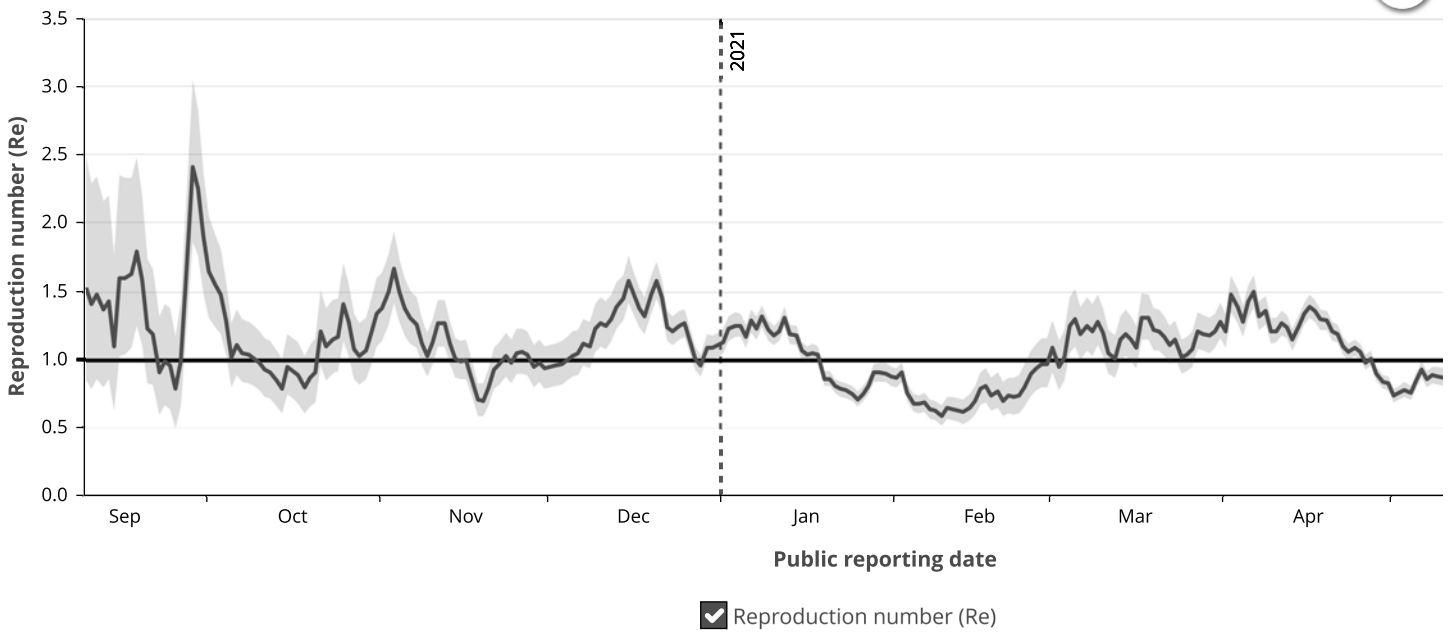
Niagara Region Public Health

09 Sep 2020 — 22 Jun 2021

doubling time in Niagara Region Public Health

September 9, 2020 to June 22, 2021

Reproduction data are updated weekly on Tuesdays. Scroll over the data line to view doubling time estimates. An Re greater than 1 means that the overall number of new cases is increasing, while an Re less than 1 means the overall number of new cases is decreasing. An Re equal to 1 means the overall number of new cases will remain stable.



The Re is not shown when there are fewer than 12 cases in the last 7 days for a local public health unit.

95% Credible Interval (CI): There is a 95% probability that the true estimate lies within this interval based on the observed data. This interval is highlighted in light purple on the graph.

Doubling time (Td) is an estimate of the number of days it will take for the number of daily COVID-19 cases to double given the current trends in incidence. When this estimate is greater than 100 days, it is reported as >100.

Public reporting date is the date the public health unit reported the case to Public Health Ontario plus one day to account for the delay in public reporting.

Reproduction number (Re) is the average number of secondary cases of infection generated by each person infected with COVID-19. An Re greater than 1 means that the overall number of new cases is growing in a region. An Re equal to 1 means the overall number of new cases will remain stable. An Re less than 1 means the overall number of new cases is decreasing and suggests that COVID-19 is coming under control in a region.

« Previous Next »

Related Information

Coronavirus Disease 2019 (COVID-19)

External Resources

COVID-19 case data: All Ontario - Government of Ontario

COVID-19 cases in schools and child care centres - Ministry of Education

COVID-19 Hospitalizations - Government of Ontario

COVID-19 Vaccines Status - Government of Ontario

Updated 30 June 2021

Kitchener Court File No.: CV-21-00000095-0000
St. Thomas Court File No.: CV-21-08
Welland Court File No.: CV-21-00013361-0000

TRINITY BIBLE CHAPEL ET AL., CHURCH OF GOD (RESTORATION) AYLMER ET AL., WELLANDPORT UNITED REFORMED CHURCH, and STEPHEN RICHARDSON

Applicants/Respondents

-and -

THE ATTORNEY GENERAL OF ONTARIO

Respondent/Applicant

ONTARIO
SUPERIOR COURT OF JUSTICE

(ST. THOMAS)

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