Neighbourhood COVID-19 Outcomes and Vaccine Protection

1st Edition: October 2022

Purpose

To describe the relationship between neighbourhood-level COVID-19 vaccine protection and incidence of SARS-CoV-2 infection, hospitalization, and deaths, during the three waves driven by the Delta and Omicron variants in Ontario between August 1, 2021 and June 18, 2022 (Table 1). A neighbourhood was defined by the Forward Sortation Area of residence (FSA).

Highlights

- During all three waves of the pandemic (waves 4, 5 and 6), neighbourhoods with the highest vaccine protection had the lowest COVID-19 hospitalization rates (Figure 1; Tables 2a, 3a, 4a).

- COVID-19 vaccine protection contributed to a reduction in the risk of severe outcomes at the neighbourhood level across all three waves (Tables 2b, 3b, 4b). This reduction in risk was strongest during wave 4, and weakest during wave 6.

  - During wave 4 (August 1 to December 14, 2021), for every 10% increase in estimated vaccine protection, there was a 43% (Risk Ratio (RR) [95% Confidence Interval (CI)]: 0.57 [0.49-0.68]) decrease in neighbourhood risk of hospitalization, and a 48% (RR [95% CI]: 0.52 [0.38-0.72]) decrease in neighbourhood risk of mortality after adjusting for health region and three socio-demographic covariates (Table 2b).

  - During wave 5 (December 15, 2021 to February 28, 2022), for every 10% increase in estimated vaccine protection, there was a 17% (RR [95% CI]: 0.83 [0.68 - 1.01]) decrease in neighbourhood risk of hospitalization, and a 56% (RR [95% CI]: 0.44 [0.19 - 1.01]) decrease in neighbourhood risk of mortality after adjusting for health region and three socio-demographic covariates (Table 3b).

  - During wave 6 (March 1 to June 18, 2022), for every 10% increase in estimated vaccine protection, there was a 21% (RR [95% CI]: 0.79 [0.66 - 0.95]) decrease in neighbourhood risk of hospitalization, and an 18% (RR [95% CI]: 0.82 [0.63 - 1.08]) decrease in neighbourhood risk of mortality after adjusting for health region and three socio-demographic covariates (Table 4b).

- The contribution of COVID-19 vaccine protection on the risk of SARS-CoV-2 infection did not follow the same trends when compared to severe outcomes. This is likely due to changes with COVID-19 testing eligibility resulting in underestimated case counts captured in provincial surveillance information systems.

Data Sources

SARS-CoV-2 infection, hospitalization, and mortality data were based on information successfully extracted from the Public Health Case and Contact Management Solution (CCM) for all public health units (PHU) by PHO as of July 7, 2022.

COVID-19 vaccination data were based on information successfully extracted from the Ontario Ministry of Heath's COVaxON application as of June 19, 2022.

Population size data by FSA were extracted from the Ontario Health Insurance Plan (OHIP) Registered Persons Database (RPDB) as of December 7, 2021.[1]

The percentage of non-permanent residents and neighbourhood socio-demographic characteristics from aggregate dissemination area levels mapped to FSA were obtained from the 2016 Census.[2]

Methods

COVID-19 vaccine protection was estimated by applying weights for the number and recency of doses received by an individual divided by the total population for a given FSA. A weight of 1/3 for one dose ever received, 2/3 for more than one dose received with the most recent dose ≥120 days prior, and 1 for more than one dose received with the most recent dose <120 days prior. The cut-off is based on evidence of vaccine effectivness against severe outcomes following three doses.[3] This differs from vaccine coverage defined in the COVID-19 Vaccine Uptake in Ontario report.

Four neighbourhood risk groups were generated based on population-weighted quartiles of FSA-level COVID-19 vaccine protection estimates captured in COVaxON. The groups were arranged from highest vaccine protection (1) to lowest vaccine protection (4). Cumulative incidence of infection, hospitalization, and mortality per 100,000 population were generated using client information in CCM and RPDB population denominators. Vaccine protection estimates and interquartile ranges (IQRs) for each group were generated using the calculation described above and RPDB population denominators.

Infection, hospitalization, mortality, and vaccination records with missing or invalid FSA information were excluded.

Hospitalizations were excluded from this analysis when the earliest positive specimen collection date for an individual was either 1 day prior to or on the date of hospital admission.

FSAs with populations of less than 5,000 persons (n=27) were excluded due to unstable vaccine protection estimates that may be driven by recent population changes.

Because CCM captures COVID-19 information among non-residents, population denominators were adjusted to account for non-permanent residents in FSAs by applying available Census information on the percentage of non-permanent residents. Two FSAs with missing information on the percentage of non-permanent residents were assumed to have zero non-permanent residents and were not adjusted.

To examine the relationship between SARS-CoV-2 incidence (infection, hospitalization, and mortality) and COVID-19 vaccine protection at the FSA-level, risk ratios (RR) with 95% confidence intervals (95% CI) were calculated using a negative binomial regression model. The exposure of interest was the vaccine protection from the start date of the wave. For each outcome, numerators were the cumulative counts of infection, hospitalization, or deaths for the wave while the denominator, considered as an offset, was the FSA population.

Two models were employed to generate risk ratios: 1) an unadjusted model that included just the FSA vaccine protection variable to produce Ontario-wide estimates, 2) a model that adjusted for health region (Central East, Central West, East, North, South West, and Toronto) and neighbourhood socio-demographic Census covariates that were previously identified to be associated with SARS-CoV-2 incidence: proportion of unsuitable housing (whether there are enough bedrooms for the size and composition of the household), average dwelling size (number of persons per dwelling), and proportion of seniors (proportion aged over 65 years).[4]

Table 1: Prevalent SARS-CoV-2 Sublineages in Ontario by Wave

Wave	Most Prevalent SARS-CoV-2 Variants (PANGO lineage)
Wave 4 (August 1 to December 14, 2021)	Delta (AY.74, AY.25.3, AY.103, AY.25.1)
Wave 5 (December 15, 2021 to February 28, 2022)	Omicron (BA.1, BA.1.1)
Wave 6 (March 1 to June 18, 2022)	Omicron (BA.2, BA.1.1, BA.2.12.1)

Sublineages included in the table represent approximately the top 50% of samples detected by Whole Genome Sequencing during each time period. Further information on SARS-CoV-2 sublineages can be found in the SARS-CoV-2 Genomic Surveillance in Ontario report.

Results

Figure 1: Relationship between Neighbourhood Vaccine Protection and COVID-19 Hospitalizations per 100,000 population in Ontario by Wave
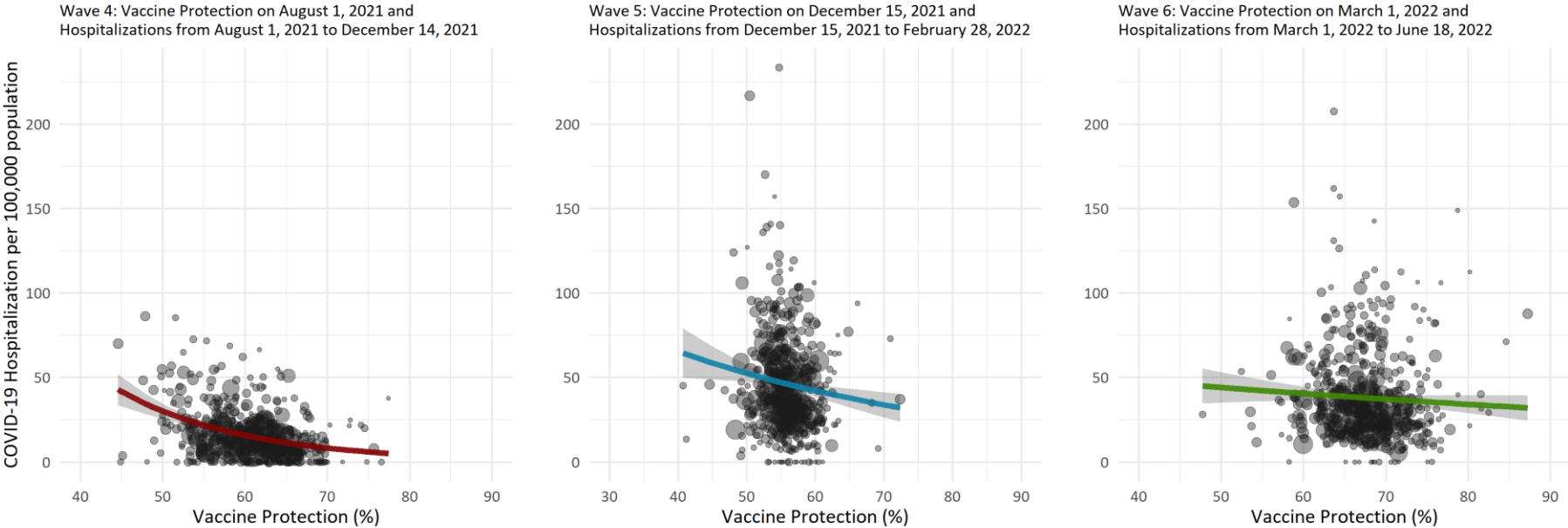
Note: The size of points is proportional to population of individual FSAs. The solid line represents model fit for Ontario-wide relationship between vaccine protection and COVID-19 hospitalization. The shaded region represents the 95% confidence intervals for the model fit.
Data Sources: CCM, COVaxON, and RPDB (see Data Sources)

Table 2a: Wave 4 Neighbourhood Demographic Characteristics, Vaccine Protection on August 1, 2021, and Cumulative Infection, Hospitalization, and Mortality between August 1, 2021 and December 14, 2021

Wave 4	Risk Group 4 (Low)	Risk Group 3	Risk Group 2	Risk Group 1 (High)
Number of FSAs	134	103	117	128
COVID-19 Measures				
Vaccine Protection (%, [IQR])	65.9 (64.6-67.9)	62.1 (61.5-62.8)	59.3 (58.3-60.1)	54.6 (52.5-56.2)
Infection per 100,000 residents	132.0	189.3	188.0	209.1
Hospitalization per 100,000 residents	1.7	2.8	2.7	3.5
Mortality per 100,000 residents	0.2	0.5	0.5	0.7
Demographic Factors				
Average Dwelling Size (N)	2.6	2.6	2.6	2.5
Senior (%)	18.5	16.9	17.4	16.6
Unsuitable Housing (%)	3.9	5.4	6.6	6.7

IQR – interquartile range; Risk groups were determined by quartiles of COVID-19 vaccine protection estimates
Data Sources: CCM, COVaxON, RPDB, Census (see Data Sources)

Table 2b: Wave 4 Association between Vaccine Protection on August 1, 2021 and Cumulative Infection, Hospitalization, and Mortality between August 1, 2021 and December 14, 2021 (n=482 FSAs)

Model	Infection (RR [95% CI])	Hospitalization (RR [95% CI])	Mortality (RR [95% CI])
Unadjusted	0.78 (0.72 - 0.85)	0.57 (0.50 - 0.67)	0.45 (0.34 - 0.60)
Adjusted[†]	0.79 (0.73 - 0.86)	0.57 (0.49 - 0.68)	0.52 (0.38 - 0.72)

RR – risk ratio. CI – confidence intervals.
[†]Adjusted model included health region and the following Census covariates: proportion of unsuitable housing, average dwelling size, and proportion of seniors.

Table 3a: Wave 5 Neighbourhood Demographic Characteristics, Vaccine Protection on December 15, 2021, and Cumulative Infection, Hospitalization, and Mortality between December 15, 2021 and February 28, 2022

	Risk Group 4 (Low)	Risk Group 3	Risk Group 2	Risk Group 1 (High)
Number of FSAs	143	112	105	122
COVID-19 Measures				
Vaccine Protection (%, [IQR])	59.1 (58.0-60.4)	56.4 (55.9-56.8)	54.8 (54.4-55.0)	52.4 (51.0-53.2)
Infection per 100,000 residents*	824.6	1,008.8	1,094.9	914.5
Hospitalization per 100,000 residents	3.9	4.7	5.9	5.5
Mortality per 100,000 residents	0.09	0.05	0.18	0.20
Demographic Factors				
Average Dwelling Size (N)	2.5	2.6	2.6	2.5
Senior (%)	19.4	17.2	16.4	16.0
Unsuitable Housing (%)	3.7	4.9	6.7	7.5

IQR – interquartile range
*COVID-19 test eligibility was changed on December 31, 2021 and infection estimates are likely underestimated
Data Sources: CCM, COVaxON, RPDB, Census (see data sources)

Table 3b: Wave 5 Association between Vaccine Protection on December 15, 2021 and Cumulative Infection, Hospitalization, Mortality between December 15, 2021 and February 28, 2022 (n=482 FSAs)

Model	Infection (RR [95% CI])	Hospitalization (RR [95% CI])	Mortality (RR [95% CI])
Unadjusted	1.12 (1.06 - 1.19)	0.83 (0.68 - 1.00)	0.44 (0.21 - 0.94)
Adjusted†	1.25 (1.18 - 1.32)	0.83 (0.68 - 1.01)	0.44 (0.19 - 1.01)

RR – risk ratio. CI – confidence intervals.
†Adjusted model included health region and the following Census covariates: proportion of unsuitable housing, average dwelling size, and proportion of seniors.

Table 4a: Wave 6 Neighbourhood Demographic Characteristics and Vaccine Protection on March 1, 2022 and Cumulative Infection, Hospitalization, Mortality between March 1, 2022 and June 18, 2022

	Risk Group 4 (Low)	Risk Group 3	Risk Group 2	Risk Group 1 (High)
Number of FSAs	141	107	106	128
COVID-19 Measures				
Vaccine Protection (%, [IQR])	72.4 (71.1-74.2)	68.5 (67.9-69.1)	66.1 (65.5-66.9)	62.6 (60.1-63.7)
Infection per 100,000 residents*	386.2	453.6	421.5	342.4
Hospitalization per 100,000 residents	2.6	3.6	4.0	3.9
Mortality per 100,000 residents	0.7	0.8	1.1	0.9
Demographic Factors				
Average Dwelling Size (N)	2.5	2.6	2.6	2.5
Senior (%)	18.3	17.4	17.1	16.7
Unsuitable Housing (%)	3.5	4.6	6.4	8.1

IQR – interquartile range
*COVID-19 test eligibility was changed on December 31, 2021 and infection estimates are likely underestimated
Data Sources: CCM, COVaxON, RPDB, Census (see Data Sources)

Table 4b: Wave 6 Association between Vaccine Protection on March 1, 2022 and Cumulative Infection, Hospitalization, Mortality on June 18, 2022 (n=482 FSAs)

Model	Infection (RR [95% CI])	Hospitalization (RR [95% CI])	Mortality (RR [95% CI])
Unadjusted	1.19 (1.11 - 1.27)	0.86 (0.72 - 1.02)	0.93 (0.71 - 1.22)
Adjusted[†]	1.18 (1.11 - 1.26)	0.79 (0.66 - 0.95)	0.82 (0.63 - 1.08)

RR – risk ratio. CI – confidence intervals.
[†]Adjusted model included health region and the following Census covariates: proportion of unsuitable housing, average dwelling size, and proportion of seniors.

Technical Notes/Limitations

The PHUs were categorized into regions as follows:

- Toronto: Toronto Public Health

- Central East: Durham Region Health Department; Haliburton, Kawartha, Pine Ridge District Health Unit; Peel Public Health; Peterborough Public Health; Simcoe Muskoka District Health Unit; and York Region Public Health

- Central West: 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; and Wellington-Dufferin-Guelph Public Health

- Eastern: Ottawa Public Health; Eastern Ontario Health Unit; Hastings Prince Edward Public Health; Kingston, Frontenac and Lennox & Addington Public Health; Leeds, Grenville & Lanark District Health Unit; and Renfrew County and District Health Unit

- Northern (North West and North East merged): Northwestern Health Unit; Thunder Bay District Health Unit; Algoma Public Health; North Bay Parry Sound District Health Unit; Porcupine Health Unit; Public Health Sudbury & Districts; and Timiskaming Health Unit

- South West: Chatham-Kent Public Health; Grey Bruce Health Unit; Huron Perth Public Health; Lambton Public Health; Middlesex-London Health Unit; Southwestern Public Health; and Windsor-Essex County Health Unit

CCM is a dynamic disease reporting system, which allows ongoing updates to data previously entered. As a result, data extracted from CCM represent a snapshot at the time of extraction and may differ from previous or subsequent reports.

The data only represent infection, hospitalization, and mortality outcomes reported to public health units and recorded in CCM. As a result, all counts will be subject to varying degrees of underreporting due to a variety of factors, such as disease awareness and medical care seeking behaviours, which may depend on severity of illness, clinical practice, changes in laboratory testing, access to testing and reporting behaviours.

On December 31, 2021, COVID-19 test eligibility was updated, which changed the population being tested so counts of SARS-CoV-2 infection are an underestimate of the true number of infected individuals in Ontario. As such, data should be interpreted with caution.

Immunity acquired from infection was not accounted for in this analysis.

Further technical notes and data caveats for COVID-19 vaccination information captured in COVaxON can be found in the COVID-19 Vaccine Uptake in Ontario report; additional details on the data on COVID-19 infections, hospitalizations and mortality can be found in the Technical Notes of the Ontario COVID-19 Data Tool.

References

1. Chung H, Fung K, Ishiguro L, Paterson M, Bronskill S, Kwong J, et al. Characteristics of COVID-19 diagnostic test recipients, Applied Health Research Questions (AHRQ) # 2021 0950 080 000. Toronto, ON: Institute for Clinical Evaluative Sciences; 2020.

2. Statistics Canada. Dictionary, census of population, 2016: complete A to Z index [Internet]. Ottawa, ON: Government of Canada; 2016 [modified 2019 Jan 3; cited 2021 Nov 10]. Available from: https://www12.statcan.gc.ca/census-recensement/2016/ref/dict/az1-eng.cfm?topic=az1

3. Buchan SA, Chung H, Brown KA, Austin PC, Fell DB, Gubbay JB, et al. Effectiveness of COVID-19 vaccines against Omicron or Delta symptomatic infection and severe outcomes. medRxiv 21268565 [Preprint]. 2022 Jan 28 [cited 2022 Sep 26]. Available from: https://doi.org/10.1101/2021.12.30.21268565

4. Van Ingen T, Akingbola S, Brown KA, Daneman N, Buchan SA, Smith BT, et al. Neighbourhood-level risk factors of COVID-19 incidence and mortality. medRxiv 21250618 [Preprint]. 2021 Jan 31 [cited 2022 Sep 26]. Available from: https://doi.org/10.1101/2021.01.27.21250618

Citation

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Publication History

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