Technical Document

R Shiny application: https://mishra-lab.shinyapps.io/COVID_ON_SDOH/

The tool generates retrospective visualizations of the relationships between area-level social and structural determinants of health and COVID-19 cases. Our intention is to help users retrospectively examine patterns of heterogeneity in COVID-19 cases in Ontario. The tool does not include COVID-19 cases among residents of long-term care homes.

The purpose of this document is to describe the technical details of the tool and should be used in accompaniment with the Quick Reference Guide.

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Scope of Analysis

The unit of analysis is dissemination area, a census geographic unit composed of 400-700 residents. [1] Each social determinant of health was measured at the level of the dissemination area and provided by Statistics Canada from the 2016 Census. That is, the social and structural determinants of health are not measured at the individual-level, but at the area-level.

A person diagnosed with COVID-19 is first assigned to a dissemination area based on their place of stated residence. We excluded COVID-19 cases with missing information on the dissemination area because these cases could not be linked to area-level social and structural determinants of health. We excluded all cases of COVID-19 among residents of long-term care homes.

We included all dissemination areas in Ontario in this analysis, including dissemination areas without diagnosed COVID-19 cases.

Data Sources

COVID-19 cases

We used individual-level data from Ontario's Case and Contact Management (CCM+) surveillance system as part of Ontario Modelling Table (REB: University of Toronto Health Sciences Research Ethics Board (39253)). CCM+ includes person-level, anonymized, surveillance data which includes information on laboratory-confirmed cases by episode date, reported date, the dissemination area of residence, and demographic, exposure, and setting-specific characteristics. The subset of CCM+ data can be accessed here: https://data.ontario.ca/dataset/status-of-covid-19-cases-in-ontario. The full version of CCM+ data are not publicly available and may be able to request directly from Government of Ontario: https://www.ontario.ca/feedback/contact-us?id=532365&nid=138269

Area-level social and structural determinants of health

We extracted DA-level social determinants of health data, with the exception of income per person equivalent, from the 2016 Canadian Census. [2] We obtained the DA-level household income (after-tax per-person equivalent) from the Postal Code Conversion File Plus Version 7A/7D for each province. [3] This variable is generated by Statistics Canada using administrative data sources and captures household size to generate a per-person equivalent measure. [4]

Measures

The area-level social and structural determinants reflect prior research that identified area-level measures associated with test-positivity; and conceptual frameworks for mechanisms that lead to disproportionate risks of SARS-CoV-2 transmission [5] [6].

(1) *socio-demographic* variables reflecting proxies of socio-economic barriers and systemic racism (income; % visible minority; % recent immigration);
(2) *dwelling-related* variables (% not living in high-density housing; [7, 8] % multi-generational households); and
(3) *occupation-related* variables (% working in essential services [health; trades, transport, and equipment operation; sales and services; manufacturing and utilities; resources, agriculture, and production]) [9]

Detailed definition of each area-level variable is provided in Table 1.

Table 1. Social determinants of health – Variables from Statistics Canada 2016 Census of Population

Measure (*Source*)[a]	Definition of indicator	Notes[b] [10,11]
Population size (100% *of census sample*)	Total population count of a Dissemination Area	In this measure and where required, Dissemination Area population counts are adjusted (reduced) to remove residents of Long Term Care Homes (LTCH)[c].
Socio-demographic		
Household income (*100% of census sample*)[d]	Decile rank of a Dissemination Area's average total after-tax income, weighted by population	After-tax income is calculated for each household from the income for all household members. Calendar year 2015 is the reference period for all income variables in the 2016 Census. Single-person equivalent is used to account for households of different sizes. To limit variations in the cost of living, the ranking is calculated exclusively from DAs within the City of Toronto.
% recent immigration (*25% of census sample*)	Numerator: Number of persons who immigrated to Canada in the 5 year period between 2011 and 2016 Denominator: Total population within the Dissemination Area	2016 Census Dictionary states: 'Immigrant' refers to a person who is, or who has ever been, a landed immigrant or permanent resident. Such a person has been granted the right to live in Canada permanently by immigration authorities. 2016 Census Dictionary states: 'Period of immigration' refers to the period in which the immigrant first obtained landed immigrant or permanent resident status.
% visible minority (*25% of census sample*)	Numerator: Number of persons who belong to visible minority groups Denominator: Total population within the Dissemination Area	Visible minority groups are defined by the Employment Equity Act: "persons, other than Aboriginal peoples, who are non-Caucasian in race or non-white in colour". 2016 Census Dictionary states: "The visible minority population consists mainly of the following groups: South Asian, Chinese, Black, Filipino, Latin American, Arab, Southeast Asian, West Asian, Korean and Japanese."

Dwelling-related		
% suitable housing (*25% of census sample*)	Numerator: Number of private households[e] living in dwellings that have "enough bedrooms for the size and composition of the household." [2016 Census Dictionary] Denominator: Total number of private households within the Dissemination Area	The National Occupancy Standard is used to classify the suitability of accommodations. A suitable household is defined as "households where the required number of bedrooms based on the National Occupancy Standard does not exceed the reported number of bedrooms in the dwelling." The number of required bedrooms is determined using the following criteria: 1. A maximum of two persons per bedroom. 2. Household members, of any age, living as part of a married or common-law couple share a bedroom with their spouse or common-law partner. 3. Lone-parents, of any age, have a separate bedroom. 4. Household members aged 18 or over have a separate bedroom - except those living as part of a married or common-law couple. 5. Household members under 18 years old of the same sex share a bedroom - except lone-parents and those living as part of a married or common-law couple. 6. Household members under 5 years old of the opposite sex share a bedroom if doing so would reduce the number of required bedrooms. This situation would arise only in households with an odd number of males under 18, an odd number of females under 18, and at least one female and one male under the age of 5. https://www23.statcan.gc.ca/imdb/pUtil.pl?Function=getNote&Id=141809&NT=01
multi-generational households (*100% of census sample*)	Numerator: Number of persons who live in households where "at least one person [in the household is] living with a child and a grandchild." [2016 Census Dictionary] Denominator: Total of all persons who are classified by family status and household living arrangements	This measure is a count of persons whose households are described by a specific living arrangement. All persons in the same household are counted separately. In the numerator for this measure, family status includes persons who are married spouses, common-law partners, lone parent families, and the child(ren) of these persons. Persons living alone, with other relatives, or with non-relatives only are additionally included in the denominator count of persons. Couples can be opposite or same sex.
Occupation-related		
% essential services not amenable to remote working (25% *of census sample*)	Numerator: Number of persons in the labor force who have occupations in one of the following categories: Manufacturing/utilities, Trades/transport/equipment operators, Sales/services, Health, Resources/agriculture/production Denominator: Total labor force population aged 15 years and over in private households in the Dissemination Area	Occupations are assigned according to the National Occupancy Classification (2016). Occupation was chosen over "Industry" to better represent the type of work performed and skill-level required by a population rather than the industry that provides the employment. Numerators may be defined separately ("or") or added together in different combination sets ("and"). "Labor Force" is all persons in private households aged 15 years and older who were either employed or unemployed during the week of Sunday, May 1 to Saturday, May 7, 2016.

[a] "Sample" refers to the short-form Census questionnaire (*100%* sample) or to the long-form questionnaire, received by a random sample of households (*25%* sample). It is mandatory for recipients to respond to the questionnaires. Statistical inferences for the entire population are drawn from the subset of responses of the long-form questionnaire; these inferences are reported in the tabulated values provided by Statistics Canada. Note that income information was collected solely from administrative data sources (*100%* sample) and were not part of either questionnaire.

[b] Additional details about variable definitions may be included the Census Dictionary; please refer to Statistics Canada's Dictionary for the 2016 Census of Population for complete definitions. Some definitions provided here are taken verbatim from source.

[c] Due to reporting methods used by CCM+, case counts among "Long-Term Care Residents" may also include cases that are reported for residents of "nursing home[s] or other chronic care facility[ies]". Adjustments in population counts described here only include adjustments to Dissemination Areas that have one (or more) LTCH facility identified by the Ontario Ministry of Health. The adjustments are made by subtracting the total number of beds in the facility from the population count of the DA.

[d] Income deciles for the City of Toronto / Toronto Public Health Unit were tabulated by ICES from data contained in PCCF+ (version 7B) and adjusted for population size. **Ref: Statistics Canada. 2018. Postal Code Conversion File Plus (PCCF+) Version 7B, Reference Guide. November 2018 Postal codes**.

[e] Where referenced, "household" refers to a "private household". The 2016 Census Dictionary states: "Private household" refers to a person or group of persons who occupy the same dwelling and do not have a usual place of residence elsewhere in Canada or abroad."

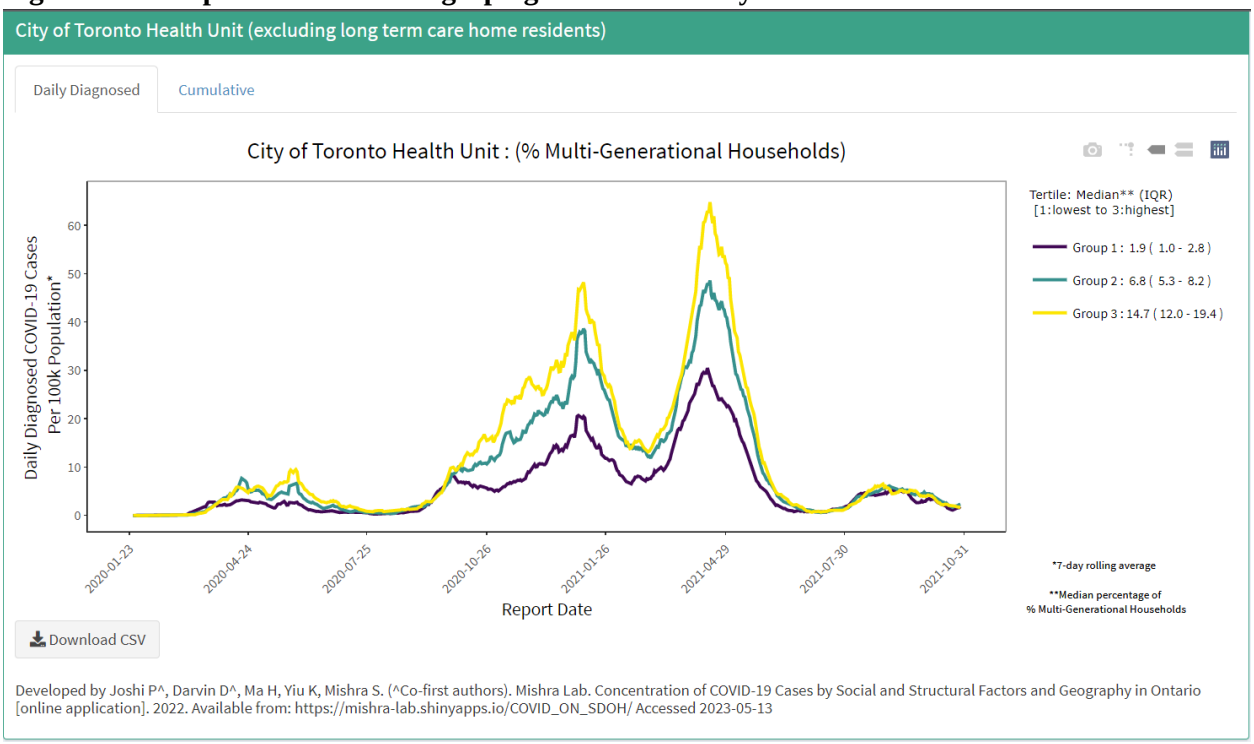
Analyses: Creation of Tertile and Quintile Ranking (Statistical Grouping)

For each social and structural determinant, we ranked Dissemination Areas from lowest to highest. There are two statistical group options available: tertile and quintile. In tertile ranking, the ranked dissemination areas are divided into three groups with equal population size in each group. Using household income as an example, tertile 1 represents the dissemination areas with the lowest median household income and tertile 3 represents those with the highest. In quintile ranking, the ranked dissemination areas are divided into five groups with equal population size in each group. Using household income as an example, quintile 1 represents the Dissemination Areas with the lowest household income and quintile 5 represents those with the highest. Users have the option of displaying daily diagnosed and cumulative epidemic curves by both tertile and quintile ranking.

Results: Descriptive Statistics

Descriptive statistics for each social and structural determinant and statistical groupin (tertile, quintile) are provided at the right side of the graph. The median is the value in the middle of the statistical group, and the interquartile range indicates the 25th to 75th percentile of the data around the median. Using household income in the City of Toronto health unit as an example, the median annual household income value within tertile 1 is $32,097 and the interquartile range within teritle 1 is $27,246.20 to $35,062.80.

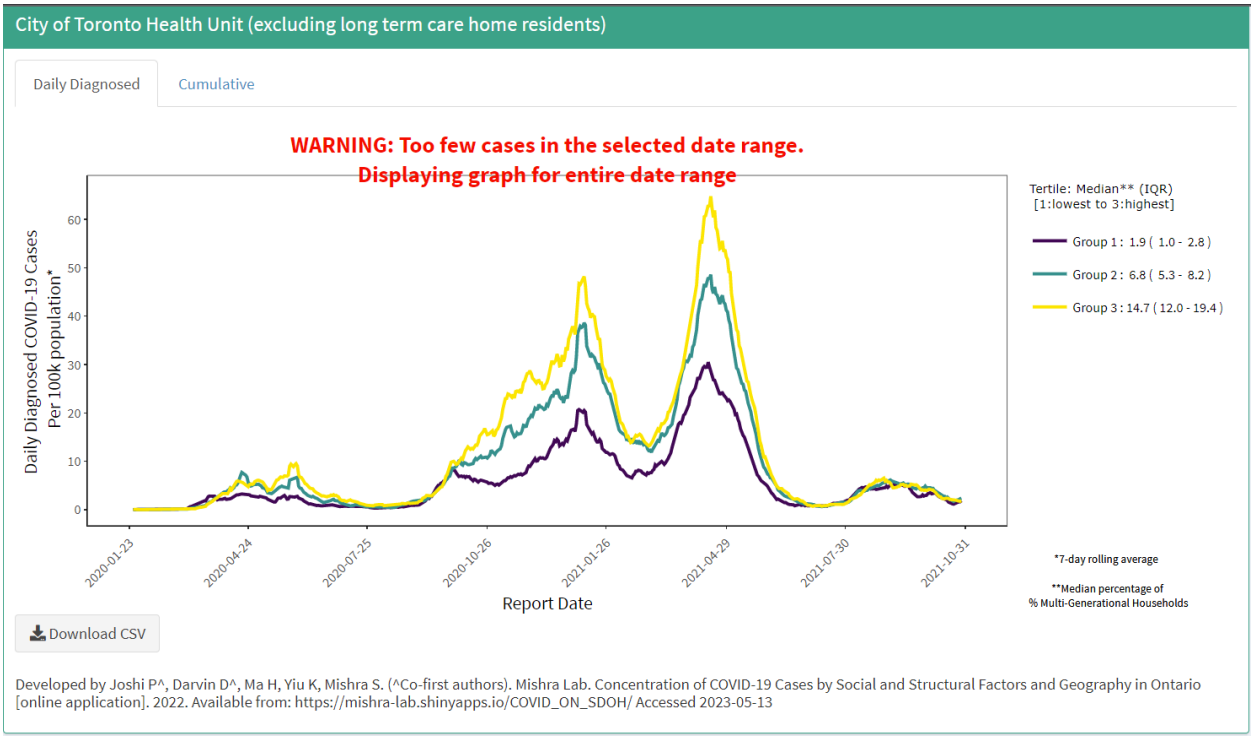
Figure 1. Descriptive statistics and graph generated for City of Toronto Health Unit



Results: Generation of Graphs

For date ranges with at least one day where the number of daily diagnosed cases is 5 or less in the selected public health unit, a graph of daily diagnosed epidemic curve specific to that time period will not be generated; instead, a warning message and a graph covering the full date range will be displayed (Figure 2). This feature is designed to minimize the misinterpretation of context and data caused by low case numbers during certain periods over the course of the pandemic. Short time intervals with low case numbers sometimes demonstrate unusual relationships between COVID-19 cases and social or structural determinants. If we only focus on time periods with low case numbers, we may be led to an interpretation that may not be representative of the true relationship between social and structural determinants of health and COVID-19 infection levels.

Figure 2. Graph generated for entire date range with a warning message when daily diagnosed cases are less than 5



Considerations when interpreting graphs

Daily case counts do not equal infection rate. Case counts only include individuals who received a COVID-19 test with PCR (not rapid tests) and tested positive. Case counts would be influenced by availability and eligibility criteria for testing (such as case definitions used to guide testing). Definition of cases and eligibility criteria for COVID-19 testing in Ontario have been updated and changed throughout the course of the pandemic [12,13]. Thus, the data and graphs generated with this tool should be interpreted in the context of testing and the larger context and supporting literature.

Software

All analyses were conducted in R (version 4.0.2). The online tool is hosted on the Shiny Server.

Related Publications

Enclosed is a list of related peer-reviewed publications that have harnessed reporting of COVID-19 reported cases by area-level social determinants of health:

- Ma H, Chan AK, Baral SD, Fahim C, Straus S, Sander B, et al. Which curve are we flattening? The disproportionate impact of COVID-19 among economically marginalized communities in Ontario, Canada, was unchanged from wild-type to omicron. Open Forum Infect Dis. 2023;10(1): ofac690. Available from: https://doi.org/10.1093/ofid/ofac690.
- Wang L, Calzavara A, Baral S, Smylie J, Chan KA, Sander B, et al. Differential patterns by area-level social determinants of health in Coronavirus Disease 2019 (COVID-19)-related mortality and non-COVID-19 mortality: A population-based study of 11.8 million people in Ontario, Canada. Clin Infect Dis. 2022. Epub ahead of print. Available from: https:// 10.1093/cid/ciac850.
- Xia Y, Ma H, Moloney G, Garcia HAV, Sirski M, Janjua N, et al. Geographic concentration of SARS-CoV-2 cases by social determinants of health in metropolitan areas in Canada: a cross-sectional study. CMAJ. 2022;194(6):195-204. Available from https://doi.org/10.1503/cmaj.211249.
- Ma H, Yiu KCY, Baral SD, Fahim C, Moloney G, Darvin D, et al. COVID-19 cases among congregate care facility staff by neighbourhood of residence and social and structural determinants: observational study. JMIR Public Health Surveill. 2022;8(10):e34927. Available from: https://doi.org/10.2196/34927.
- Chagla Z, Ma H, Sander B, Baral S, Moloney G, Mishra S. Assessment of the burden of SARS-CoV-2 variants of concern among essential workers in the Greater Toronto Area,

Canada. JAMA Netw Open. 2021;4(10):e2130284. Available from: https://doi.org/10.1001/jamanetworkopen.2021.30284.

- Rao A, Ma H, Moloney G, Kwong JC, Juni P, Sander B, et al. A disproportionate epidemic: COVID-19 cases and deaths among essential workers in Toronto, Canada. Ann Epidemiol. 2021;63:63 – 67. Available from: https://doi.org/10.1016/j.annepidem.2021.07.010.
- Mishra S, Ma H, Moloney G, Yiu K.C.Y, Darvin D, Landsman D, et al. Increasing concentration of COVID-19 by socioeconomic determinants and geography in Toronto, Canada: an observational study. Ann Epidemiol. 2021;S1047-2797(21)00216-7. Epub ahead of print. Available from: https://doi.org/10.1016/j.annepidem.2021.07.007.

Citing the R Shiny Application

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