COVID-19 Cases Among Facility-Staff by Neighbourhood of Residence and Social and Structural Determinants: An Observational Study

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Abstract

Background: Disproportionate risks of COVID-19 in congregate settings including long-term care homes, retirement homes, and shelters both affect and are affected by SARS-CoV-2 infections among facility-staff. In cities across Canada, there has been a consistent trend of geographic clustering of COVID-19 cases. However, there remain limited data on how COVID-19 among facility-staff reflect urban neighbourhood disparities, particularly stratified by the social and structural determinants of community-level transmission.

Objective: To compare the concentration of cumulative cases by geography and social/structural determinants across three mutually exclusive subgroups in the Greater Toronto Area (population 7.1 million): community, facility-staff, and healthcare workers (HCW) in other settings.

Methods: We conducted a retrospective, observational study using surveillance data on laboratory-confirmed COVID-19 cases (January 23 to December 13, 2020; prior to vaccination roll-out). We derived neighbourhood-level social/structural determinants from census data, and generated Lorenz curves and Gini coefficients to visualize and quantify inequalities in cases.

Results: The hardest-hit neighbourhoods (comprising 20% of the population) accounted for 53.4% of community cases, 48.6% of facility-staff cases, and 42.3% of other HCW cases. Compared with other HCW, cases in facility-staff more closely reflected the distribution of community cases. Cases in facility-staff reflected greater social and structural inequalities (larger Gini coefficients) than other HCW across all determinants. Facility-staff cases were also more likely than community cases to be concentrated in lower income neighbourhoods (Gini 0.24[0.15-0.38] vs 0.14[0.08-0.21] with lower household density (Gini 0.23[0.17-0.29] vs 0.17[0.12-0.22]) and with a greater proportion working in other essential services (Gini 0.29 [0.21-0.40], 0.22[0.17-0.28]).

Conclusions: COVID-19 cases among facility-staff largely reflects neighbourhood-level heterogeneity and disparities; even more so than cases in other HCW. Findings signal the importance of interventions prioritized and tailored to home geographies of facility-staff in addition to workplace measures, including prioritization and reach of vaccination at home (neighbourhood-level) and at work.

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Keywords: long-term care, nursing homes, staff, essential workers, retirement homes, shelters, congregate living

ABSTRACT

Background: Disproportionate risks of COVID-19 in congregate settings including long-term care homes, retirement homes, and shelters both affect and are affected by SARS-CoV-2 infections among facility-staff. In cities across Canada, there has been a consistent trend of geographic clustering of COVID-19 cases. However, there remain limited data on how COVID-19 among facility-staff reflect urban neighbourhood disparities, particularly stratified by the social and structural determinants of community-level transmission.

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Conclusion: COVID-19 cases among facility-staff largely reflects neighbourhood-level heterogeneity and disparities; even more so than cases in other HCW. Findings signal the importance of interventions prioritized and tailored to home geographies of facility-staff in addition to workplace measures, including prioritization and reach of vaccination at home (neighbourhood-level) and at work.

INTRODUCTION

Across Canada, the COVID-19 epidemic has been marked by a conflation of micro-epidemics across settings, including congregate living facilities (e.g. long-term care homes [LTCH], retirement homes, and shelters); essential workplaces; or households [1-6]. Many congregate facilities experienced outbreaks, with residents experiencing 3-5 fold higher test-positivity than the community-dwelling population [1, 3, 4, 7, 8]. Meanwhile, data on the community-dwelling population suggested a consistent pattern of geographic clustering of cases with 50% of cases occurring in approximately 25% of the population, and disproportionately affecting those residing in less affluent neighbourhoods and with a higher proportion of essential workers [9, 10].

What is less understood is how congregate facilities may be connected with neighbourhood disparities. Emerging data on congregate facility outbreaks suggested that facility-level spread between staff, between residents, and between staff and residents may have been partially triggered by undiagnosed infections and lack of support for effective isolation among staff [3, 7]. Reducing transmission in the wider community may reduce outbreaks in congregate settings. However, data on facility-staff are limited with few studies that characterized the socioeconomic, living, and working conditions of staff [11], and thus – the extent to which social and structural determinants of community-level transmission might influence outbreaks in congregate settings. Surveillance data on COVID-19 cases offer an opportunity to examine the pattern of cases among facility-staff and other health-care workers (HCW) against community cases and neighbourhood disparities. Lorenz curve, Gini coefficients, and Hoover index were traditionally used as measurements of economic inequality [12, 13] and have been used in a range of healthcare research to measure health inequality [14, 15], and recently have been applied in the context of COVID-19 pandemic [10, 16]. We sought to adapt the Lorenz curve, Gini coefficients, and Hoover index to compare the concentration of cases using neighbourhood-level rates and neighbourhood-level social and structural determinants across three mutually exclusive subgroups: community; facility-staff (LTCH, retirement homes, shelters); and other HCW not working in congregate settings (e.g. only working in hospitals). Our overarching objective was to determine if and how the pattern and magnitude of inequality and concentration in HCW COVID-19 cases differed between facility-staff and other HCW.

METHODS

Study design, setting, and population

We conducted a retrospective, observational study using provincial surveillance data on laboratory-confirmed COVID-19 cases reported between January 23, 2020 and December 13, 2020 in the Greater Toronto Area (population 7.1 million) [17], and in accordance with the RECORD statement [18]. We restricted the study to the period before SARS-CoV-2 vaccination due to differential vaccine allocation and coverage over time by each subgroup after vaccine roll-out [19].

Data sources and measures

We used person-level data from Ontario's centralized surveillance system [20] which includes information on laboratory-confirmed COVID-19 cases by reported date, demographic characteristics, exposure category, and setting specific characteristics (e.g., LTCH), and data on social and structural determinant measures from Statistics Canada 2016 Census [21]. The surveillance data classifies cases as a health-care worker (HCW) if a person works or volunteers in any health-care setting

(including LTCH, retirement home, shelter, hospital, clinic, or homecare). We stratified HCW into those associated with working/volunteering in a LTCH, retirement home, and/or shelter as facility-staff; and all others as “other HCW”. If a HCW fell into both categories (facility-staff and other HCW), then they were categorized as facility-staff.

We examined social/structural determinants at the level of the dissemination area (neighbourhood) because it was the smallest geographic unit (range of population size 400 to 700) for which census data were available. Other geographic units include the forward sortation area and census tracts, but the dissemination area is most commonly used when examining social/structural determinants because it reflects the smallest geographic unit and is less prone to ecological fallacy than larger geographic units[22]. We conceptualized and defined the social and structural determinants as reported previously [9, 10]. The variables are detailed in *Appendix 1* and are related to socio-economic status (per-person equivalent after tax income) and proxies for systemic racism (% visible minority, % recent immigration); or to the potential for increased contact rates: housing (% not living in high-density housing [23, 24], % living in multigenerational households) and employment in other essential services (i.e. excluding healthcare) [25] not amenable to remote work [26] .

Analyses

We aggregated the number of confirmed COVID-19 cases at the neighbourhood-level during study period into 3 mutually exclusive subgroups: community (excluding facility-staff, other HCW, congregate-facility residents, and travel-related cases); facility-staff (workers or volunteers in LTCH, retirement homes, and shelters); and other HCW. We generated Lorenz curves,Gini coefficients to quantify the magnitude of inequalities (i.e. the concentration in cases), and the Hoover index as an alternate measure for validation[15, 16, 27]. With Gini coefficient, a value closer to zero represents greater equality[28]. The Hoover index measures the percentage of cases that would need to be redistributed to achieve equality in how cases are distributed across neighbourhoods. As with the Gini coefficient, a larger Hoover index represents greater inequality [29]. We generated 95% confidence interval for Gini coefficients using bootstrapping [27, 30].

First, we compared the magnitude of geographic concentration in cases for each subgroup (y-axis) against the distribution of total cases (x-axis, community plus travel-related) at the neighbourhood-level. To examine the extent to which facility-staff and other HCW cases mirrored community cases, we generated a separate set of Lorenz curves and Gini coefficients using community cases on the x-axis. Second, to examine the magnitude of inequalities by each social/structural determinant, we ranked the cumulative proportion of the population by each determinant (e.g. from lowest to highest income decile]) on the x-axis. We included the detailed analytic plan in *Appendix 2*. We also generated spatial maps to describe and overlay cases among facility-staff and among other HCW, by one social determinant as an example (neighbourhood-level income).

Analyses were conducted in R (version 4.0.2) and spatial maps were generated using ArcGIS (version 10.7). The University of Toronto Health Sciences Research Ethics Board (protocol no. 39253) approved the study.

RESULTS

Of 92210 cases (excluding congregate-facility residents and travel-related) included during our study period, 83419, 4849, and 3942 were cases in the community, and among facility-staff, and other HCW, respectively (*Table 1*). Among facility-staff, there were 4241, 363, and 245 cases among

LTCH staff, retirement home staff, and shelter staff, respectively.

Table 1. Number of COVID-19 Cases in Mutually Exclusive Subgroups: Community[a], Facility-Staff[c], and Other Health-Care Workers in the Greater Toronto Area (January 23, 2020 to December 13, 2020).

Subgroup	Number of COVID-19 cases	Number (%) of dissemination areas[b] with zero cases (N = 8,278 total dissemination areas in the region)
Community[a]	83,419	1,058 (12.8%)
Facility-staff[c]	4,849	5,771 (69.7%)
Other health-care workers	3,942	5,879 (71.0%)

[a]Excluding residents of congregate settings and facility-staff (long-term care homes, retirement homes, and shelters), other health-care workers, and travel-related cases; [b]Dissemination area refers to the geographic unit of measurement for the social and structural determinants examined in this study generated from Statistics Canada [31]. In the Greater Toronto Area (population 7.1 million), the median population size of a dissemination area is 561 (interquartile: 442-800) residents; [c]Including staff and volunteers who work in long-term care homes, retirement homes, and shelters and excluding all other health-care workers.

Geographic concentration of cases across subgroups

The most affected neighbourhoods (x-axis) comprising 20% of the total population accounted for 53.9% (44937/83419) of community cases, 48.6% (2356/4849) of congregate-setting worker cases, and 42.3% (1669/3942) of other HCW cases (*Figure 1*). Compared with other HCW, cases among facility-staff more closely reflected the geographic distribution of community cases (Gini 0.06 vs 0.16; Hoover 0.05 vs 0.12) (*Appendix 3*).

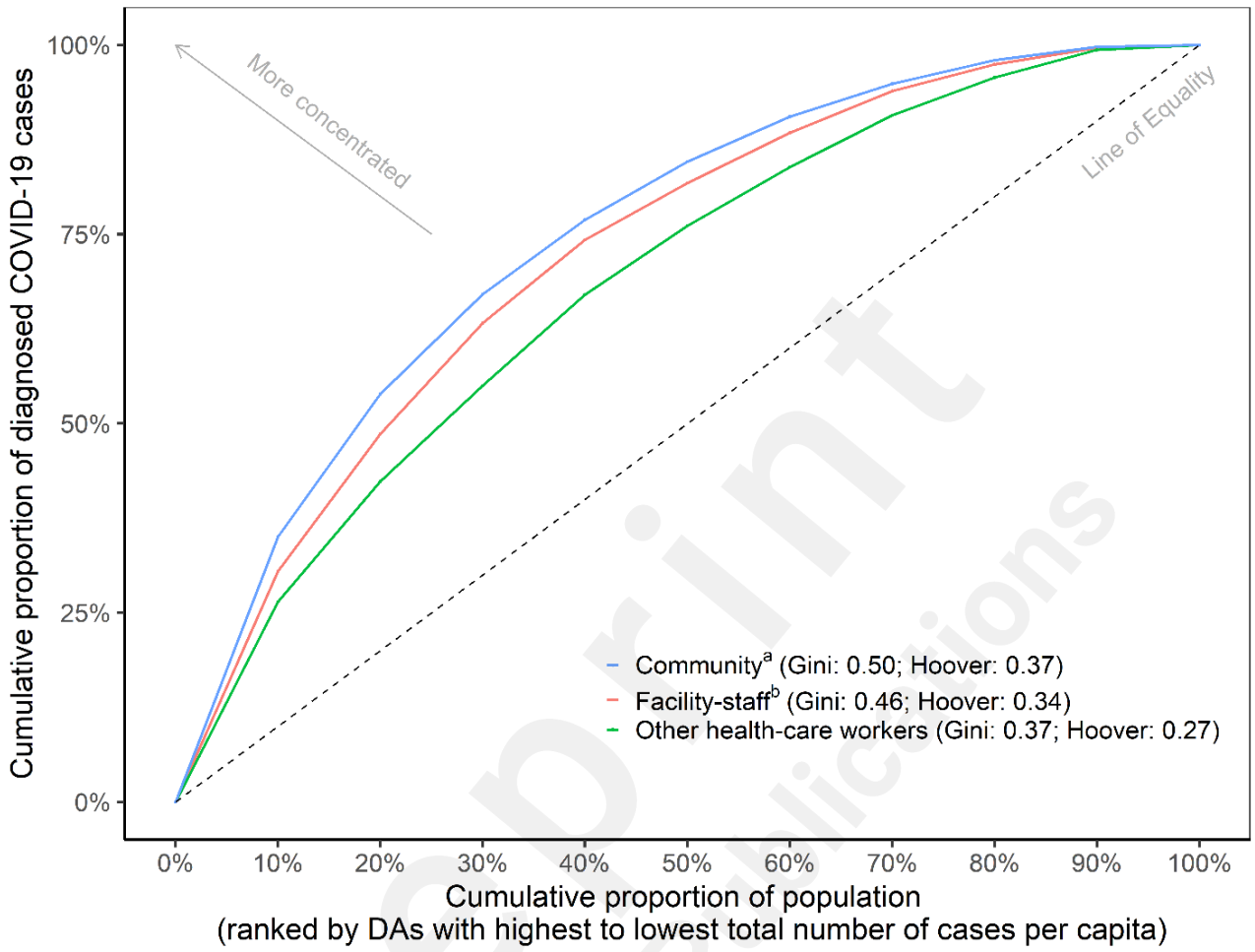

Figure 1. Geographic Concentration of COVID-19 Cases in Community[a] Population, Facility-Staff[b], and Among Other Health-Care Workers in the Greater Toronto Area (January 23, 2020 to December 13, 2020). The magnitude of concentration is depicted by Lorenz curves (dashed line represents the line of equality), and the corresponding Gini coefficient for each subgroup. The x-axis represents the cumulative proportion of the population ranked by dissemination areas from the highest to the lowest number of cumulative cases per capita. For example, 53.4% of cumulative cases in the community, 48.6% of cases among facility-staff, and 42.3% of cases among other health-care workers were diagnosed in 20% of the population. [a]Excluding residents of congregate settings and facility-staff (long-term care homes, retirement homes, and shelters), other health-care workers, and travel-related cases. [b]Including staff and volunteers who work in long-term care homes, retirement homes, and shelters and excluding all other health-care workers. DA: dissemination areas.

Differences in concentration of cases across subgroups by social and structural determinants

Appendix 4 depicts the Lorenz curves and Gini coefficients by each social/structural determinant. Cases among facility-staff reflected greater social and structural inequalities (larger Gini coefficients and larger Hoover index) than other HCW across all determinants (*Figure 2*,

Appendices 4 and 5). Appendix 6 depicts how cases among facility-staff and among other HCW were clustered along neighbourhood-level income. Although facility-level cases mirrored that of community cases (*Appendix 3*), there were greater inequalities in facility-level versus community cases with respect to income (Gini 0.24[0.15-0.38] vs 0.14[0.08-0.21]), household density (Gini 0.23[0.17-0.29] vs 0.17[0.12-0.22]) and other essential services (Gini 0.29 [0.21-0.40] versus 0.22[0.17-0.28]).

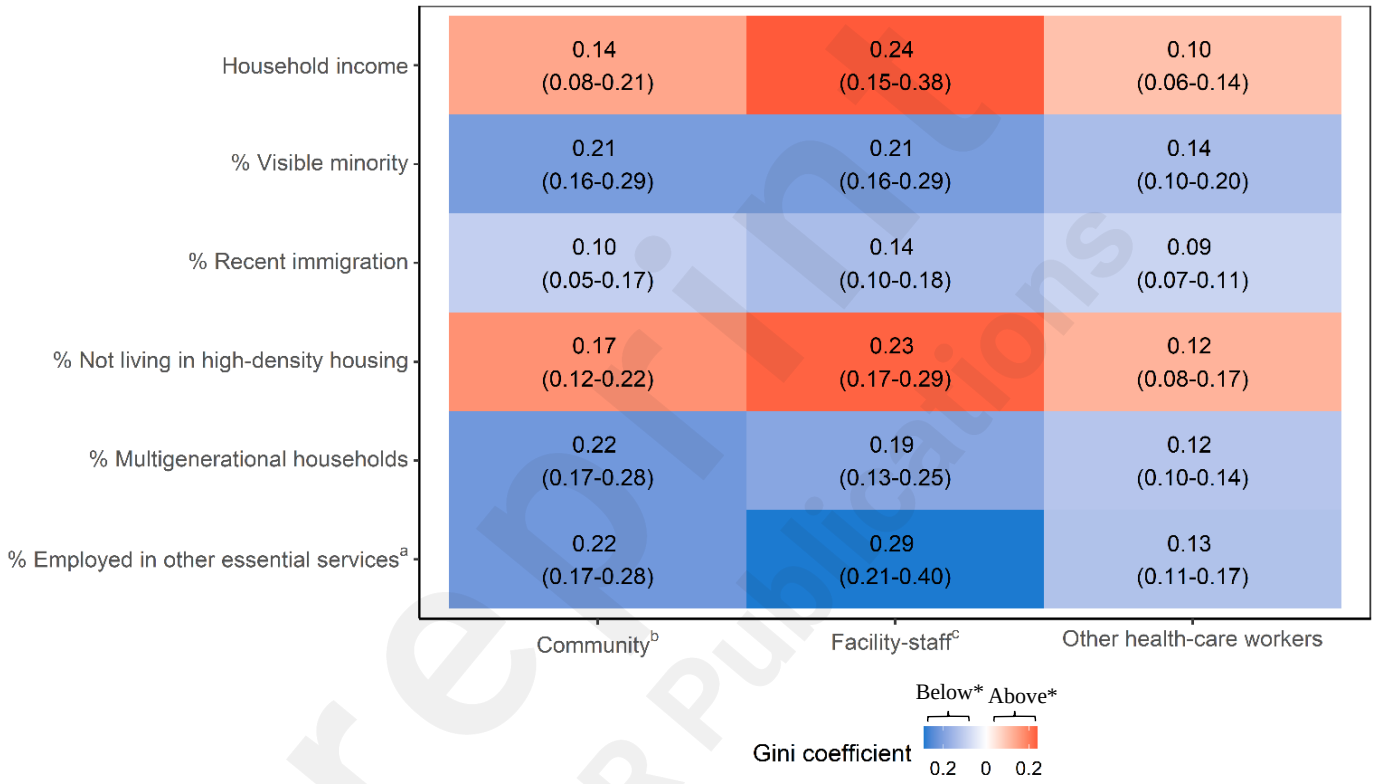

Figure 2. Magnitude of Concentration by Social and Structural Determinants in COVID-19 Cases in the Community[b], Among Facility-Staff[c], and Among Other Health-Care Workers in the Greater Toronto Area (January 23, 2020 to December 13, 2020). Heat map with the estimated Gini coefficient of cumulative COVID-19 cases by household income, % visible minority, % recent immigration, % not living in high-density housing, % multigenerational households, and % employed in other essential services. [*]Gini coefficient above the line of equality is depicted in red and below the line of equality is depicted in blue. [a]Other essential services include: trades, transport and equipment operation; sales and services; manufacturing and utilities; resources, agriculture, and production [32]. [b]Excluding residents of congregate settings and facility-staff (long-term care homes, retirement homes, and shelters), other health-care workers, and travel-related cases. [c]Including staff and volunteers who work in long-term care homes, retirement homes, and shelters and excluding all other health-care workers.

DISCUSSION

We found that the distribution of COVID-19 cases among facility-workers mirrored neighbourhood heterogeneity and social and structural disparities, a pattern that was less evident with other HCW. Facility-staff cases reflected greater inequalities by social and structural determinants than cases among other HCW, and with some determinants (income, other essential workers), greater inequalities than community cases.

Cases among facility-staff more closely reflected the geographic distribution of community cases, than the distribution of other HCW cases and community cases. The similar distributions of facility-staff and community cases could occur if there was an equal distribution of facility-staff living across neighbourhoods and the infection rate ratio between facility-staff and community was the same across neighbourhoods. The implication of this potential mechanism is that most infections among facility-staff would have been acquired outside the facility or workplace. The Lorenz curve patterns may also occur if facility-staff were more likely, than other HCW, to live in harder hit neighbourhoods with greater social and structural disparities, irrespective of workplace exposures in congregate facilities.

Although our study was centered on the Greater Toronto Area, findings are likely to be generalizable to other large, urban cities and metropolitan areas with similar patterns of social and structural inequalities. In Canada, most congregate facilities are concentrated in the large cities [33] and previous research comparing 16 cities demonstrated a similar neighbourhood clustering of COVID cases by social and structural determinants [10]. Data on neighbourhood characteristics of LTCH staff in the United States [11] suggest workers tend to live in lower income neighbourhoods, and individual-level data in Canada suggest that that a high proportion of LTCH staff identify as racialized women with low household income [34]. In current LTCH staffing models across Canada and the United States, approximately 60-90% of workers who provide direct care to residents are providing services as unregulated staff (personal support workers, care aides, orderlies, and nurse assistants) [35-39] and receive the lowest wages in the healthcare sector at or just above minimum wage [35] and often in the context of contract or casual work without benefits [35, 36, 40-44].

Our study suggests that cases among facility-staff may disproportionately intersect with household exposures that are connected with other essential workplaces, or amplified in the context of household density [21]. Our study was limited by a lack of confirmed denominators for setting-specific workers in the region, but data from England and Wales suggest a 2-fold increased rate of COVID-19 among LTCH workers versus other HCW [45]. Based on government reports, there are just over 100000 employees serving 78000 LTCH residents in the province [35], such that the ratio of staff to LTCH residents in Ontario is approximately 1 staff for every 0.78 LTCH resident. If we extrapolate the provincial ratio to the Greater Toronto Area, where 28316 LTCH residents reside, the city would have approximately 36303 LTCH staff. With 4241 cases among LTCH staff in the Greater Toronto Area during our study period, and a total population in the Greater Toronto Area of 6.8 million [1], the cumulative rate of COVID-19 cases among LTCH staff (at 11682 per 100000) would have been 9.5-fold higher than that of the community (1227 cases per 100000).

This study has several limitations. First, we derived the DA-level social determinants from the

2016 Census data, which may not be representative of the population during the COVID-19 pandemic. Second, the occupation status in CCM+ data could have been misclassified due to possible misinterpretation of the question in self-reporting and facility-staff or HCW may work in multiple settings. Third, we did not have data on the residence of all HCW across the various congregate settings to compare neighbourhood-level per-HCW rates of cases. Finally, data were not available to link cases among HCW to specific facilities, to directly examine how cases in communities influenced outbreaks in congregate settings.

The findings have implications for COVID-19 modeling and interventions. The magnitude of inequalities can be used as calibration or validation targets for epidemic and prediction models to reproduce the observed pattern of cases in relation to the distribution of overall cases and by social and structural determinants. In doing so, detection systems (e.g. neighbourhood wastewater surveillance) designed to predict the potential for exposures in congregate facilities could leverage data on underlying vulnerabilities in the neighbourhood of residence of facility-staff. A study in the United States found that neighbourhood characteristics of the residence of LTCH staff was the most important predictor of LTCH outbreaks [11]. These data could then be used to implement strategies to mitigate risks. For example, proximal strategies to reduce community-level transmission risks conferred through social and structural inequalities have the potential to reduce workplace exposure risks. Examples include systematically addressing the lived realties of workers that make physical distancing challenging (e.g. household density) or that remain barriers to effective isolation and quarantine (e.g. precarious job security and absence of benefits such as paid sick leave), with interventions such as wrap-around care including access to food, medications, child/senior care (especially in the context of multigenerational households) to facilitate staff quarantine and/or isolation. Prioritizing vaccination coverage in the hardest-hit neighbourhoods is another example to indirectly reduce workplace exposures in LTCH, retirement homes, and shelters. Finally, findings highlight an urgent need for a long-term commitment and resources to comprehensively address social and structural barriers at a systems-level (integration of health, education, social services, public health, and labor) given the long-standing history of infectious disease outbreaks in facilities and disparities experienced by its staff even before COVID-19 [36].

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AUTHOR CONTRIBUTIONS
HM and SM conceived of and designed the study with input from KY. HM, DD, SM conducted literature review. HM developed the analysis plan with input from SM. HM led data management, data cleaning, data linkage, and variable creation; with support from DD and DL. GM sourced and generated the census-level data and wrote the appendix related to the census variables. HM executed the analysis plan and conducted the statistical analysis. HM wrote the first draft of manuscript. All authors (HM, KY, SB, CF, GM, DD, DL, AC, SS, and SM) provided critical input into study design, interpretation of results, and manuscript review and editing.

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DATA STATEMENT
Data statement: Reported COVID-19 cases were obtained from the Case and Contact Management Solutions via the Ontario COVID-19 Modelling Consensus Table and with approval from the University of Toronto Health Sciences Research Ethics Board (protocol no. 39253). The analyses, conclusions, opinions and statements expressed herein are solely those of the authors and do not reflect those of the funding or data sources; no endorsement is intended or should be inferred.

CONFLICTS OF INTEREST
The authors have no conflicts of interest to disclose.

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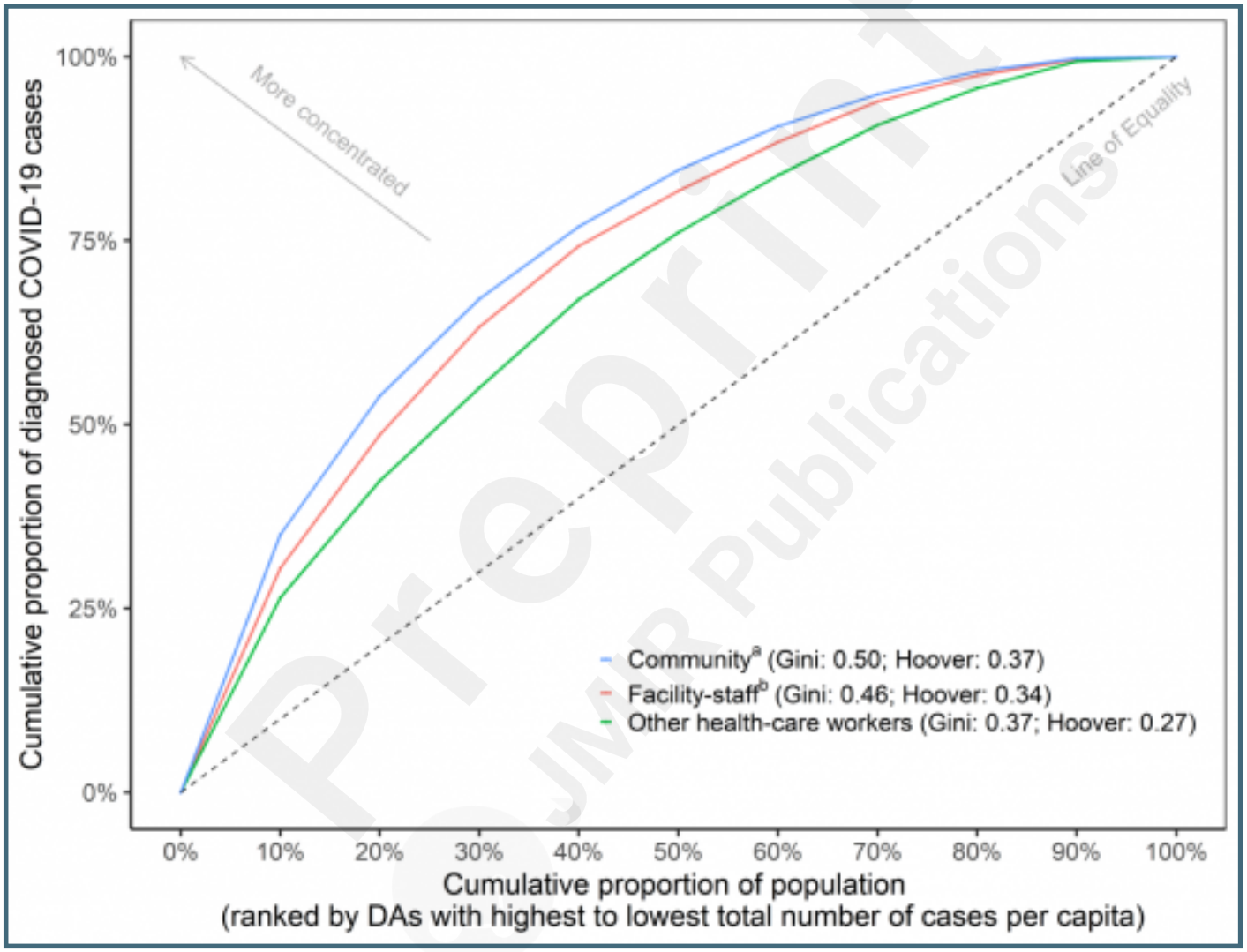
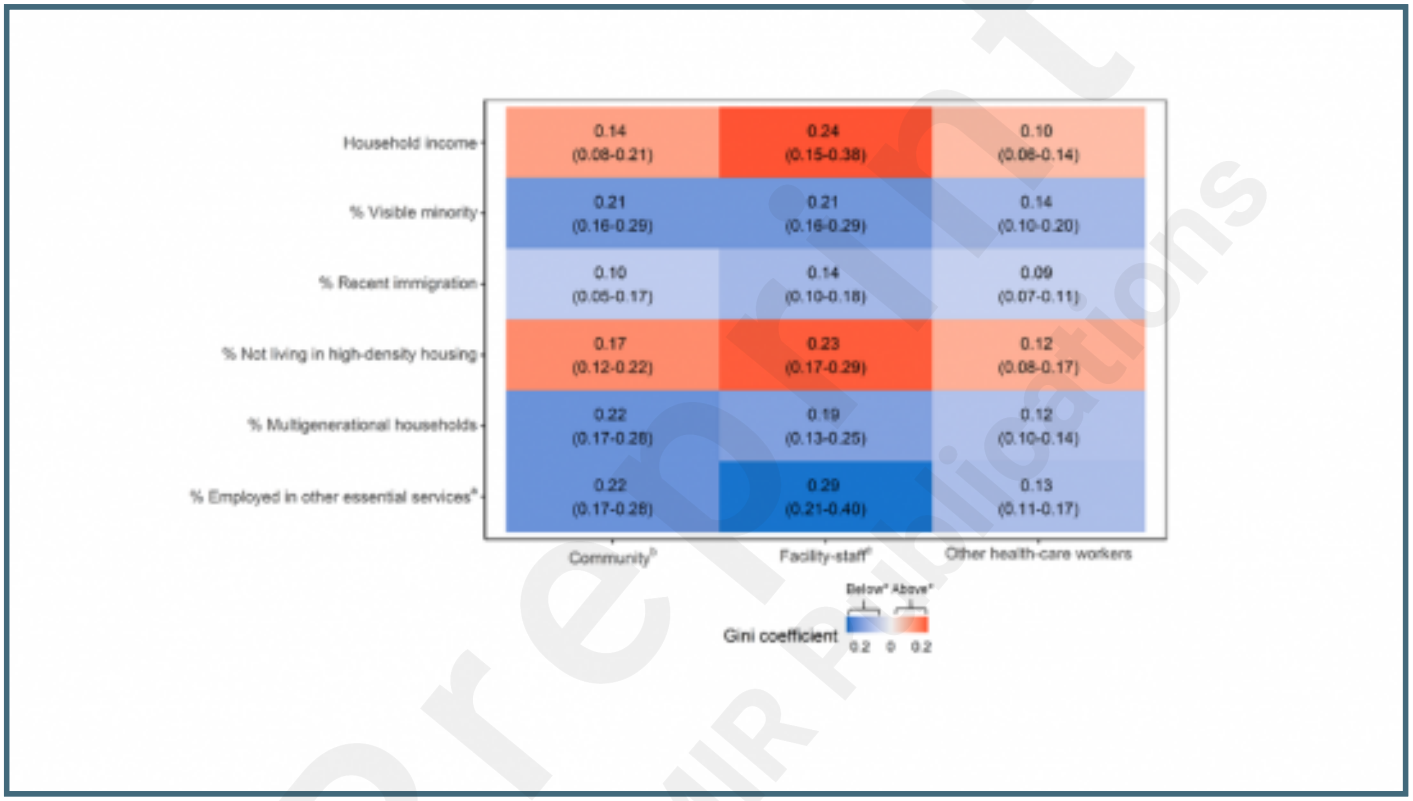
Supplementary Files

Figures

Geographic concentration of COVID-19 cases in communitya population, facility-staff, and among other health-care workers in the Greater Toronto Area (January 23, 2020 to December 13, 2020). The magnitude of concentration is depicted by Lorenz curves (dashed line represents the line of equality), and the corresponding Gini coefficient for each subgroup. The x-axis represents the cumulative proportion of the population ranked by dissemination areas from the highest to the lowest number of cumulative cases per capita. For example, 53.4% of cumulative cases in the community, 48.6% of cases among facility-staff, and 42.3% of cases among other health-care workers were diagnosed in 20% of the population. aExcluding residents of congregate settings and facility-staff (long-term care homes, retirement homes, and shelters), other health-care workers, and travel-related cases. bIncluding staff and volunteers who work in long-term care homes, retirement homes, and shelters and excluding all other health-care workers. DA: dissemination areas.



Magnitude of concentration by social and structural determinants in COVID-19 cases in the community, among facility-staff, and among other health-care workers in the Greater Toronto Area (January 23, 2020 to December 13, 2020). Heat map with the estimated Gini coefficient of cumulative COVID-19 cases by household income, % visible minority, % recent immigration, % not living in high-density housing, % multigenerational households, and % employed in other essential services. *Gini coefficient above the line of equality is depicted in red and below the line of equality is depicted in purple. aOther essential services include: trades, transport and equipment operation; sales and services; manufacturing and utilities; resources, agriculture, and production [27]. bExcluding residents of congregate settings and facility-staff (long-term care homes, retirement homes, and shelters), other health-care workers, and travel-related cases. cIncluding staff and volunteers who work in long-term care homes, retirement homes, and shelters and excluding all other health-care workers.



Multimedia Appendixes

Social determinants of health – Variables from Statistics Canada 2016 Census of Population.
URL: http://asset.jmir.pub/assets/91ef337bda268c3b934a2a495294588e.docx

Detailed analytic plan.
URL: http://asset.jmir.pub/assets/f5069156644e5cea8530cc5d6e3b51c3.docx

Geographical concentration of COVID-19 cases among facility-staff, other health-care workers compared with community cases in the Greater Toronto Area, from January 23, 2020 to December 13, 2020.
URL: http://asset.jmir.pub/assets/fa3a49230c37282bb549c8702095b37c.docx

Lorenz curves and gini coefficients of COVID-19 cases in the community, among facility-staff, and among other health-care workers by social determinants in Greater Toronto Area, from January 23, 2020 to December 13, 2020.
URL: http://asset.jmir.pub/assets/a6634217f53099c40aa318eff98f9849.docx

Magnitude of concentration by social and structural determinants in COVID-19 cases in the community, among facility-Staff, and among other health-care workers in the Greater Toronto Area (January 23, 2020 to December 13, 2020).
URL: http://asset.jmir.pub/assets/a43dc117b886f4888637f12601615057.docx

Map overlay of household income deciles by dissemination areas and distribution of COVID-19 facility-staff (A) and other health-care workers cases (B) in the Greater Toronto Area (January 23, 2020 to December 13, 2020).
URL: http://asset.jmir.pub/assets/9cd3bbb26bb19d7da1c9dee150eadd4b.docx

CONSORT (or other) checklists

RECORD checklist.
URL: http://asset.jmir.pub/assets/e8b2fa00f969194556e432e4d8bfa267.pdf