Open Forum Infectious Diseases

BRIEF REPORT

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

Huiting Ma,[1,a] Adrienne K. Chan,[2,a3,4,5] Stefan D. Baral,[6] Christine Fahim,[1] Sharon Straus,[1,7] Beate Sander,[4,8] and Sharmistha Mishra[1,3,4,5]

[1]Li Ka Shing Knowledge Institute, St Michael's Hospital, Unity Health Toronto, Toronto, Ontario, Canada, [2]Division of Infectious Diseases, Sunnybrook Health Sciences, University of Toronto, Toronto, Ontario, Canada, [3]Dalla Lana School of Public Health, University of Toronto, Toronto, Ontario, Canada, [4]Institute of Health Policy, Management and Evaluation, University of Toronto, Toronto, Ontario, Canada, [5]Division of Infectious Diseases, Department of Medicine, University of Toronto, Toronto, Ontario, Canada, [6]Department of Epidemiology, Johns Hopkins School of Public Health, Baltimore, Maryland, USA, [7]Department of Medicine, University of Toronto, Toronto, Ontario, Canada, and [8]University Health Network, University of Toronto, Toronto, Ontario, Canada

Person-level surveillance (N = 14 million) and neighborhood-level income data were used to explore magnitude of inequalities in COVID-19 hospitalizations and deaths over 5 waves in Ontario, Canada. Despite attempts at equity-informed policies alongside fluctuating levels of public health measures, the magnitude of inequalities in hospitalizations and deaths remained unchanged across waves.

Keywords. COVID-19; health equity; infectious diseases; public health; social determinants of health.

Economically marginalized communities have faced disproportionately higher risks for infection and death from coronavirus disease 2019 (COVID-19) across Canada [1]. Health disparities were evident early in the pandemic, at the intersections of housing, occupations, and structural racism [2]. Public health measures designed as restrictions to limit person-to-person contacts continued across waves, including in-person school closures, limitations on public and personal gatherings, and closure of nonessential businesses or services [3]. In Ontario, policies attempting to address health inequities were also temporarily enacted in subsequent waves, including temporary income support [4], temporary eviction moratoria [5], 3-day paid sick leave [6], and geographic prioritization of vaccine eligibility and allocation [7]. It was anticipated that health disparities would be mitigated during subsequent waves. We used metrics of inequality (Lorenz curve and concentration/Gini coefficients) to characterize changes in the magnitude of concentration in COVID-19 hospitalization and deaths by neighborhood-level income among 14 million Ontario residents across 5 waves.

METHODS

We conducted a retrospective, population-based observational study using linked person-level data on all laboratory-confirmed diagnoses of COVID-19 and outcomes in Ontario, the Ontario vaccination database for vaccination status, and Statistics Canada 2016 Census data for dissemination area (DA)–level household income per person equivalent, reported using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guideline. The study population comprised individuals who were hospitalized or died following COVID-19 diagnosis between 26 February 2020 and 28 February 2022, and excluded travel-related cases and residents of long-term care homes. We defined the 5 waves as follows: (1) wave 1: 26 February 2020 to 31 August 2020 (length of wave, 188 days); (2) wave 2: 1 September 2020 to 28 February 2021 (length of wave, 181 days); (3) wave 3: 1 March 2021 to 31 July 2021 (length of wave, 153 days); (4) wave 4: 1 August 2021 to 14 December 2021 (length of wave, 135 days); (5) wave 5: 15 December 2021 to 28 February 2022 (length of wave, 75 days).

First, we described the magnitude of inequality in median household income (per person equivalent) across DAs (ie, geographic concentration of income) with a Lorenz curve and by estimating the corresponding co–Gini coefficient (co-Gini) [8]. Then, we generated Lorenz curves for outcomes by DA-level income quintile, and estimated the co-Gini (where a co-Gini of zero represents complete equality and 1 represents complete inequality) in each wave [8]. Analyses were conducted in R software (version 4.0.2). We further described patterns in vaccination coverage over time (by number of doses) and cumulative rates of prior known infection by income quintiles as potential factors related to protective factors when describing observed inequalities in hospitalizations and deaths.

RESULTS

There was geographic heterogeneity in the median household income across neighborhoods (DAs), with a co-Gini of 0.16

Received 28 October 2022; editorial decision 19 December 2022; accepted 21 December 2022; published online 23 December 2022

[a]H. M. and A. K. C. contributed equally to this work as co–first authors.

Correspondence: Sharmistha Mishra, MD, PhD, St Michael's Hospital, Unity Health Toronto, 209 Victoria St, Room 315, Toronto, ON, M5B 1T8, Canada (sharmistha.mishra@utoronto.ca).

Open Forum Infectious Diseases®

https://doi.org/10.1093/ofid/ofac690

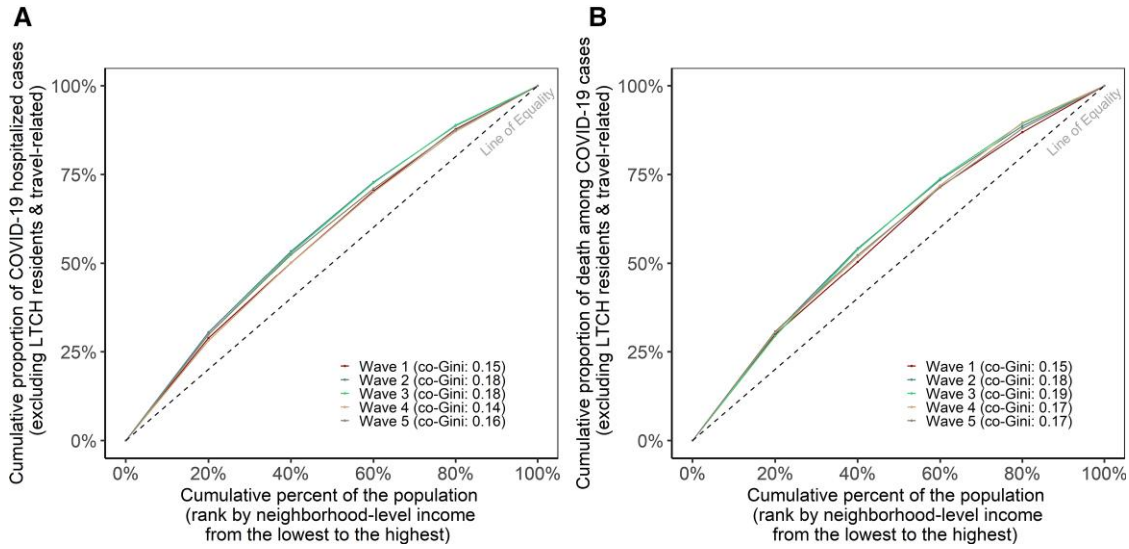

Figure 1. Lorenz curves depicting inequality in coronavirus disease 2019 (COVID-19) hospitalizations (*A*) and deaths (*B*) by income for each of the 5 waves. Wave 1 (wild-type): 26 February 2020 to 31 August 2020 (length of wave, 188 days); wave 2 (wild-type and emergence of Alpha variant): 1 September 2020 to 28 February 2021 (length of wave, 181 days); wave 3 (Alpha and emergence of Delta variant): 1 March 2021 to 31 July 2021 (length of wave, 153 days); wave 4 (Delta): 1 August 2021 to 14 December 2021 (length of wave, 135 days); wave 5 (predominantly Omicron variant): 15 December 2021 to 28 February 2022 (length of wave, 75 days) [8]. The cumulative numbers of hospitalizations and deaths due to COVID-19 in each wave were as follows: wave 1: 3611 and 935; wave 2: 9590 and 2295; wave 3: 11 901 and 2184; wave 4: 3475 and 531; wave 5: 9425 and 2143. The co–Gini coefficient refers to the magnitude of concentration or inequality. Neighborhood-level income refers to the per-person equivalent, after-tax income and accounting for regional cost of living, and is derived from the 2016 Census. The farther the Lorenz curve from the line of equality, the greater the inequality/concentration. Abbreviation: co-Gini, co–Gini coefficient; LTCH, long-term care home.

(Supplementary Figure 1). Over the study period, hospitalizations and deaths were concentrated among the 20% of the population living in the lowest-income neighborhoods (Figure 1, Supplementary Figure 2). The magnitude of inequality in hospitalization and mortality by income remained unchanged across waves (range in co-Gini, 0.14–0.19), despite less inequality by income in vaccination (Figure 2).

Vaccine coverage was consistently higher in high-income areas (especially with third doses, Supplementary Figure 3). Together, the magnitude of inequality in hospitalizations and deaths was 10-fold higher (Figures 1 and 2) than magnitude of inequality in vaccination (Supplementary Figure 2) and in the combination of vaccination and/or past known infection (Supplementary Figures 4 and 5).

DISCUSSION

Despite attempts at equity-informed policies [4] alongside fluctuating levels of public health measures, the magnitude of inequalities in hospitalizations and deaths by income remained at levels observed during the first wave—prior to vaccination and discussion or implementation of equity-informed policies—and despite rising levels of hybrid immunity.

Our analysis follows a descriptive metric of inequality over time, signaling the need for future explanatory modeling to explore mechanisms that perpetuated health disparities to inform responses. Limitations of our study include our restriction to area-level measures of income rather than individual-level, and a descriptive analysis without biological factors related to severity once infected, including age, sex, and comorbidities [9, 10]. Comorbidities, for example, are confounders, but prior studies consistently demonstrated that social determinants remain a critical determinant of COVID-19 deaths at a population level even after accounting for comorbidities [11]. Our study was not designed to systematically examine the role of vaccination and/or prior infection, including considerations of time since either event. However, the observation of a small magnitude of inequality in past known infection and vaccination suggest that differential levels of hybrid immunity alone may be insufficient to explain persistent inequalities in hospitalizations and deaths.

Our findings raise questions about the extent to which the public health measures and interventions as implemented were able to sufficiently address differential exposure risks in Ontario. Future work would continue to benefit from rigorously evaluating and teasing apart the impact of various interventions on not just the overall magnitude of hospitalizations and deaths, but on the differential impact across subgroups [12] and contexts: answering questions about who benefited from various strategies and interventions and how and why they worked (ie, the pathways by which direct and indirect benefits accrued). It has been well-established in Canada and across countries [9, 10, 13] that

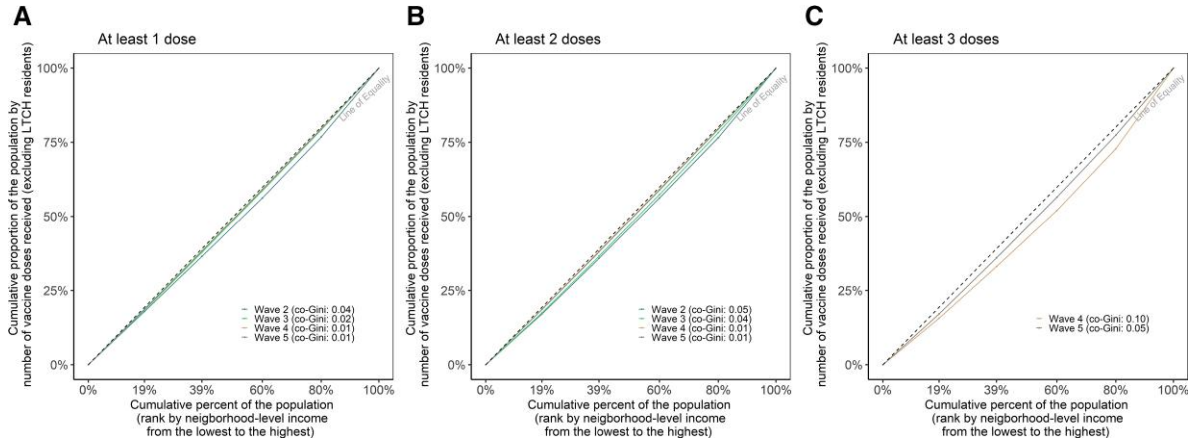

Figure 2. Lorenz curves of at least 1 dose (*A*), at least 2 doses (*B*), and at least 3 doses (*C*) of vaccination by income. Wave 1 (wild-type): 26 February 2020 to 31 August 2020 (length of wave, 188 days); wave 2 (wild-type and emergence of Alpha variant): 1 September 2020 to 28 February 2021 (length of wave, 181 days); wave 3 (Alpha and emergence of Delta variant): 1 March 2021 to 31 July 2021 (length of wave, 153 days); wave 4 (Delta): 1 August 2021 to 14 December 2021 (length of wave, 135 days); wave 5 (predominantly Omicron variant): 15 December 2021 to 28 February 2022 (length of wave, 75 days) [28]. Neighborhood-level income (after-tax, per-person equivalent) quintiles where the lowest quintile (quintile 1) represents areas with the lowest average total after-tax income and the highest quintile (quintile 5) represents areas with the highest average total after-tax income. Abbreviations: co-Gini, co–Gini coefficient; LTCH, long-term care home.

differential exposure risks to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), and subsequent mortality, were amplified at the intersections of household crowding and size [11, 14], workplace exposures [15, 16], and systemic barriers to prevention and care (including access to therapeutics; see [17–19]). Our findings should not be interpreted as though the public health measures, strategies, and interventions did not work, as evidence points to large, overall prevention in COVID-19 deaths [20]. Evaluation of temporary income support and eviction moratoria have been known to be associated with improved outcomes with respiratory viruses [21], with evidence of impact in the context of COVID-19 [22, 23]. Access to and uptake of SARS-CoV-2 vaccines has had a large impact on mortality [7, 24] and remains a critical equity-informed strategy by prioritizing and mobilizing to reach disproportionately higher coverage at the intersections of the highest exposure and severity risks [25, 26]. Indeed, the early phase of vaccine rollout in Ontario adopted a geographically prioritized allocation strategy [7] and narrowed the gap in vaccine coverage by income, suggesting additional efforts were needed to narrow the gap in health outcomes stemming from persistent, residual, and higher levels of exposure risks and/or access to care and therapeutics. Rather, the findings of this study signal a need to systematically evaluate and disentangle the differential impact of various strategies and interventions to explain why gaps have yet to narrow, even within subnational jurisdictions, and to implement the combination of policies, strategies, and resources required if reducing health disparities is a priority for pandemic planning and pandemic response.

Equality in intervention reach is often insufficient to redress longstanding inequities [27], and overall reductions in cases and deaths are insufficient metrics of comparative success [6] when existing health disparities persist [26]. Equity and effectiveness of programs are inherently linked [7] and ongoing evaluation of both is central to inform the public health response to future waves of COVID-19 and other rapidly emergent pandemics.

Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Notes

Acknowledgments. We thank the Ontario Ministry of Health Data Analytics Branch for supporting access to data via the Ontario COVID-19 Modelling Consensus Table. We thank Linwei Wang (MAP Centre for Urban Health Solutions, Unity Health Toronto) for her feedback on the manuscript and Kristy Yiu (MAP Centre for Urban Health Solutions, Unity Health Toronto) for support with study logistics and coordination.

Author contributions. H. M., A. K. C., and S. M. conceived of and designed the study. H. M., A. K. C., and S. M. conducted literature review. H. M., with input from A. K. C. and S. M., developed the analysis plan. H. M. executed the analysis plan and conducted the statistical analysis. H. M. and A. K. C. wrote the first draft of the manuscript. All authors provided critical input into study design, interpretation of results, and manuscript review and editing.

Patient consent. This study does not include factors necessitating patient consent. The University of Toronto Health Sciences Research Ethics Board approved the study (protocol number 39253).

Data statement. Reported COVID-19 cases were obtained from Case and Contact Management Solutions, and vaccination status was obtained from the provincial COVaxON Vaccination Management System via the Ontario COVID-19 Modelling Consensus Table and with approval from the University of Toronto Health Sciences Research Ethics Board (protocol number 39253). Data are not publicly available.

Disclaimer. The funders did not have any role in the study design; collection, analysis, and interpretation of data; writing of the manuscript; or the decision to submit for publication. 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.

Financial support. This work was supported by the Public Health Agency of Canada COVID-19 Immunity Task Force (grant number 2021-HQ-000143 to A. K. C., S. D. B., C. F., S. S., and S. M.) and the Canadian Institutes of Health Research (grant number VS1-175536 to A. K. C., S. B., and S. M.). S. M. is supported by a Tier 2 Canada Research Chair in Mathematical Modeling and Program Science. B. S. is supported by a Tier 2 Canada Research Chair in Economics of Infectious Diseases. S. S. is supported by a Tier 1 Canada Research Chair in Knowledge Translation and Quality of Care.

Potential conflicts of interest. The authors: No reported conflicts of interest.

References

1. Xia Y, Ma H, Moloney G, 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:E195–204.
2. McKenzie K, Dube S, Petersen S. Tracking COVID-19 through race-based data. **2021**. https://www.wellesleyinstitute.com/publications/tracking-covid-19/. Accessed 28 October 2022.
3. Polisena J, Ospina M, Sanni O, et al. Public health measures to reduce the risk of SARS-CoV-2 transmission in Canada during the early days of the COVID-19 pandemic: a scoping review. BMJ Open **2021**; 11:e046177.
4. Government of Canada. Canada Emergency Response Benefit (CERB): closed. https://www.canada.ca/en/services/benefits/ei/cerb-application.html#h2.03. Accessed 8 December 2022.
5. Government of Ontario. Archived—renting: changes during COVID-19 (coronavirus). **2022**. https://www.ontario.ca/page/renting-changes-during-covid-19#:~:text=The%20typical%20evictions%20process%20is, also%20known%20as%20the%20Board%20. Accessed 8 December 2022.
6. Government of Ontario. Ontario extending COVID-19 paid sick days. **2021**. https://news.ontario.ca/en/release/1001296/ontario-extending-covid-19-paid-sick-days. Accessed 8 December 2022.
7. Mishra S, Stall NM, Ma H, et al. A vaccination strategy for Ontario COVID-19 hotspots and essential workers. **2021**. https://covid19-sciencetable.ca/sciencebrief/a-vaccination-strategy-for-ontario-covid-19-hotspots-and-essential-workers/. Accessed 8 December 2022.
8. Lorenz MO. Methods of concentration of wealth. Am Stat Assoc **1905**; 9:209.
9. Chang D, Chang X, He Y, Tan KJK. The determinants of COVID-19 morbidity and mortality across countries. Sci Rep **2022**; 12:5888.
10. Mouhayyar CA-O E, Jaber LT, Bergmann M, Tighiouart H, Jaber BA-O. Country-level determinants of COVID-19 case rates and death rates: an ecological study. Transbound Emerg Dis **2022**; 69:e906–15.
11. Wang L, Calzavara A, Baral S, et al. Differential patterns by area-level social determinants of health in COVID-19 related mortality and non-COVID-19 mortality: a population-based study of 11.8 million people in Ontario. Canada [manuscript published online ahead of print 28 October 2022]. Clin Infect Dis **2022**. https://doi.org/10.1093/cid/ciac850
12. Flores Anato JL, Ma H, Hamilton MA, et al. Impact of a vaccine passport on first-dose COVID-19 vaccine coverage by age and area-level social determinants in the Canadian provinces of Québec and Ontario: an interrupted time series analysis. medRxiv [Preprint]. Posted online 20 October **2022**. https://doi.org/10.1101/2022.10.18.22281192
13. McGowan VJ, Bambra C. COVID-19 mortality and deprivation: pandemic, syndemic, and endemic health inequalities. Lancet Public Health **2022**; 7:e966–75.
14. Burström B, Tao W. Social determinants of health and inequalities in COVID-19. Eur J Public Health **2020**; 30:617–8.
15. Public Health Agency of Canada. Social inequalities in COVID-19 mortality by area- and individual-level characteristics in Canada, January to July/August 2020. **2021**. https://health-infobase.canada.ca/src/doc/PDF_COVID-19_Mort_Can_2020_EN.pdf. Accessed 8 December 2022.
16. Chen Y-H, Riley AR, Duchowny KA, et al. COVID-19 mortality and excess mortality among working-age residents in California, USA, by occupational sector: a longitudinal cohort analysis of mortality surveillance data. Lancet Public Health **2022**; 7:e744–53.
17. Sundaram ME, Calzavara A, Mishra S, et al. Individual and social determinants of SARS-CoV-2 testing and positivity in Ontario, Canada: a population-wide study. CMAJ **2021**; 193:E723–34.
18. Wiltz JL, Feehan AK, Molinari NAM, et al. Racial and ethnic disparities in receipt of medications for treatment of COVID-19—United States, March 2020–August 2021. MMWR Morb Mortal Wkly Rep **2022**; 71:96–102.
19. Underhill K, Johnson OCA. Vaccination equity by design. Yale Law J Forum **2021**; 131.
20. Ogden NH, Turgeon P, Fazil A, et al. Counterfactuals of effects of vaccination and public health measures on COVID-19 cases in Canada: what could have happened? Can Commun Dis Rep **2022**; 48:292–302.
21. Zhai Y, Santibanez TA, Kahn KE, Black CL, de Perio MA. Paid sick leave benefits, influenza vaccination, and taking sick days due to influenza-like illness among U.S. workers. Vaccine **2018**; 36:7316–23.
22. Schnake-Mahl AS, O'Leary G, Mullachery PH, et al. Higher COVID-19 vaccination and narrower disparities in US cities with paid sick leave compared to those without. Health Aff **2022**; 41:1565–74.
23. Pichler S, Wen K, Ziebarth NR. COVID-19 emergency sick leave has helped flatten the curve in the United States. Health Aff **2020**; 39:2197–204.
24. Johnson AG, Amin AB, Ali AR, et al. COVID-19 incidence and death rates among unvaccinated and fully vaccinated adults with and without booster doses during periods of Delta and Omicron variant emergence—25 U.S. jurisdictions, April 4–December 25, 2021. MMWR Morb Mortal Wkly Rep **2022**; 71:132–8.
25. Wrigley-Field E, Kiang MV, Riley AR, et al. Geographically targeted COVID-19 vaccination is more equitable and averts more deaths than age-based thresholds alone. Sci Adv **2021**; 7:eabj2099.
26. Peterson A, Charles V, Yeung D, Coyle K. The health equity framework: a science- and justice-based model for public health researchers and practitioners. Health Promot Pract **2021**; 22:741–6.
27. Bambra C. Pandemic inequalities: emerging infectious diseases and health equity. Int J Equity Health **2022**; 21:6.
28. Ontario Agency for Health Protection and Promotion (Public Health Ontario). Weekly epidemiological summary: COVID-19 in Ontario: focus on September 18, 2022 to September 24, 2022 (week 38). **2022**. https://www.publichealthontario.ca/-/media/Documents/nCoV/epi/2022/09/covid-19-weekly-epi-summary-report-sept-30.pdf?rev=05a73172a54d4172b83792224ecb5caf&sc_lang=en. Accessed 28 October 2022.