How might structural and social inequalities have shaped the transmission dynamics of SARS-CoV-2?

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No Conflicts of Interest

CIHR IRSC Canadian Institutes of Health Research Instituts de recherche en santé du Canada

Outline

- Heterogeneity

- Prevention gap
  - →causes and (epidemic) consequences of heterogeneity in risks: acquisition, onward transmission, severity
  - →causes and (epidemic) consequences of heterogeneity in interventions: design → “reach” → effectiveness

Heterogeneity →

Exposure ("susceptibility")

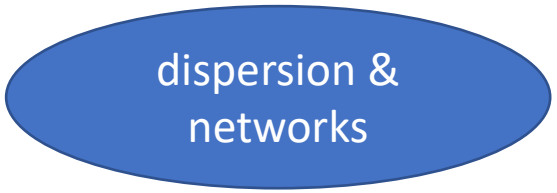
% of infections acquired (distribution of acquisition)

Onward transmission

% of secondary transmissions stem from specific "conditions"

Severity

health outcomes, if infected

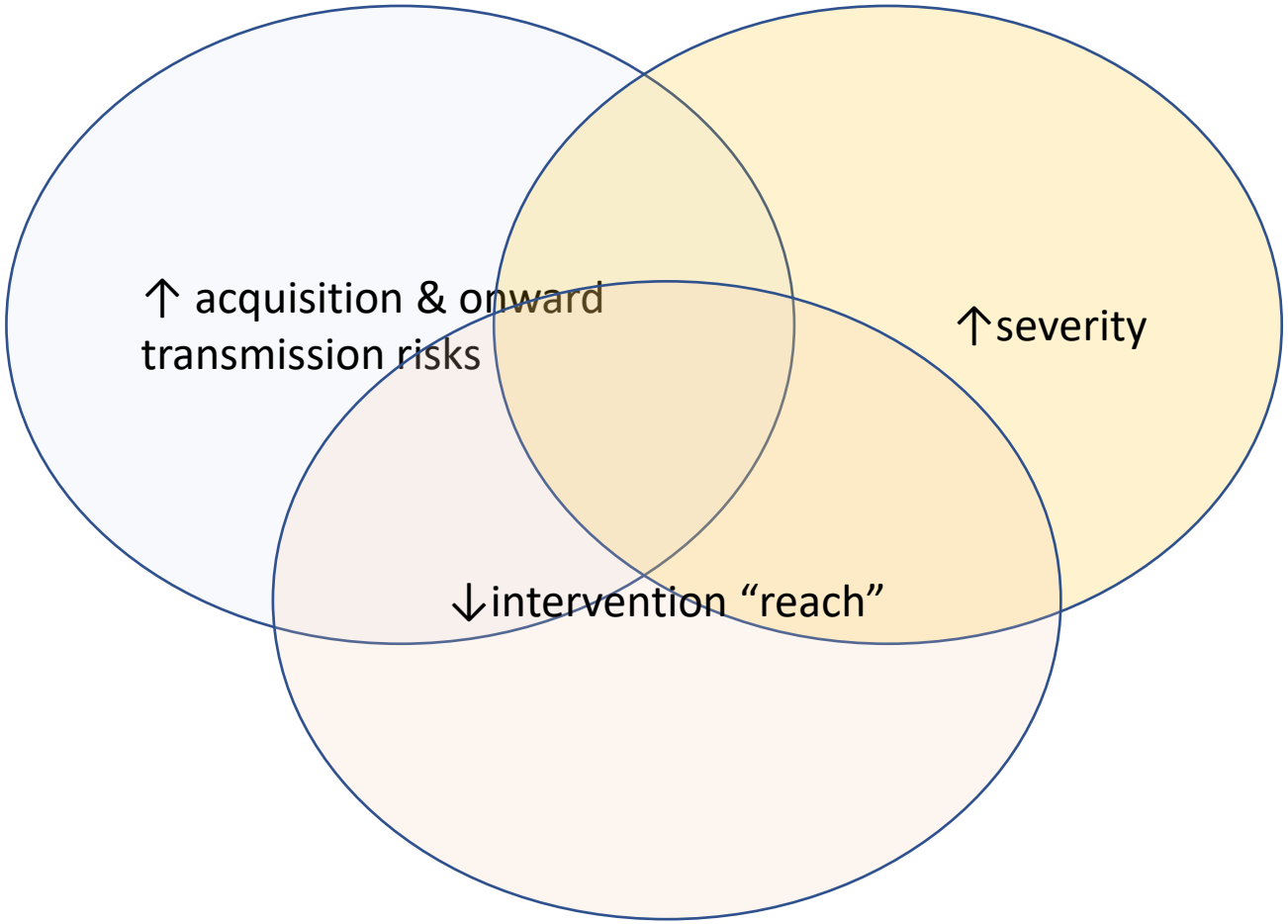


disproportionate exposure risks / resilience

disproportionate onward transmission risks / resilience

disproportionate severity risks / resilience

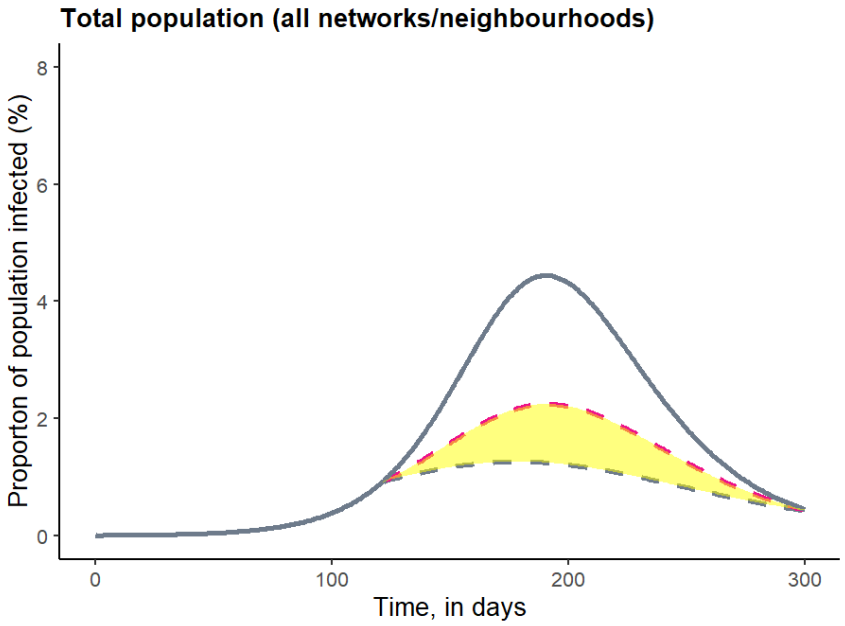
"Know your epidemic, know your response": a useful approach, if we get it right

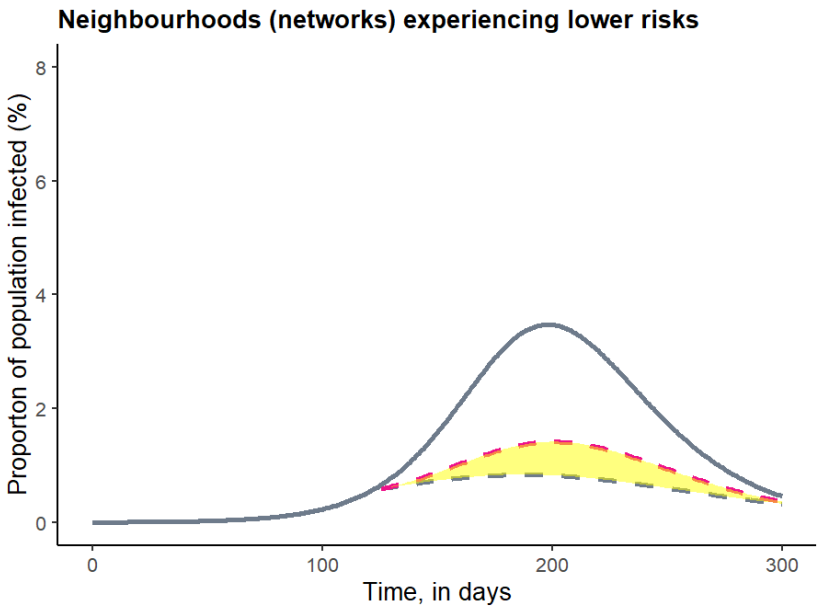


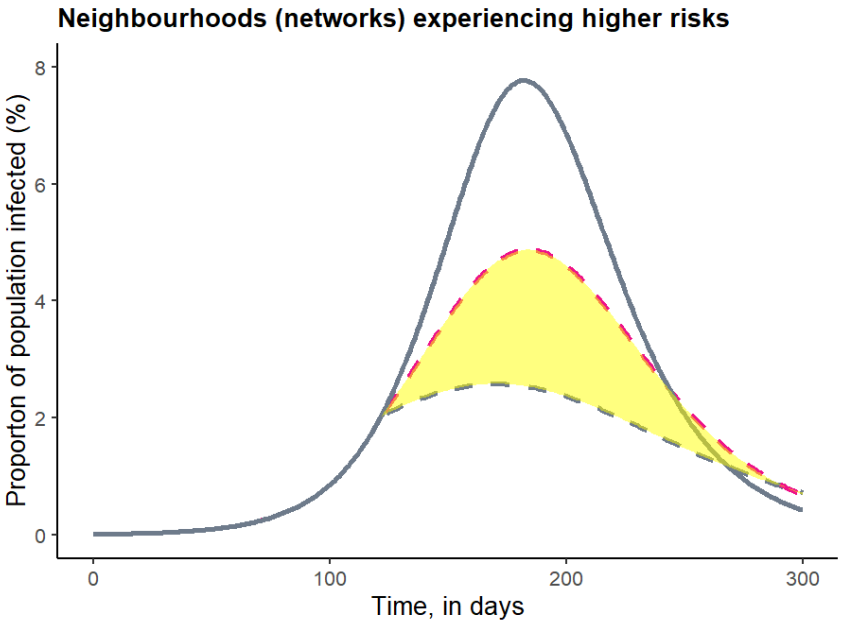
Wilson D, Halperin D. Lancet. 2008;372(9637):423-6.

For whom did we design the public health response to COVID?

Prevention gaps → undermine the anticipated impact of broad-scale strategies







Base-case

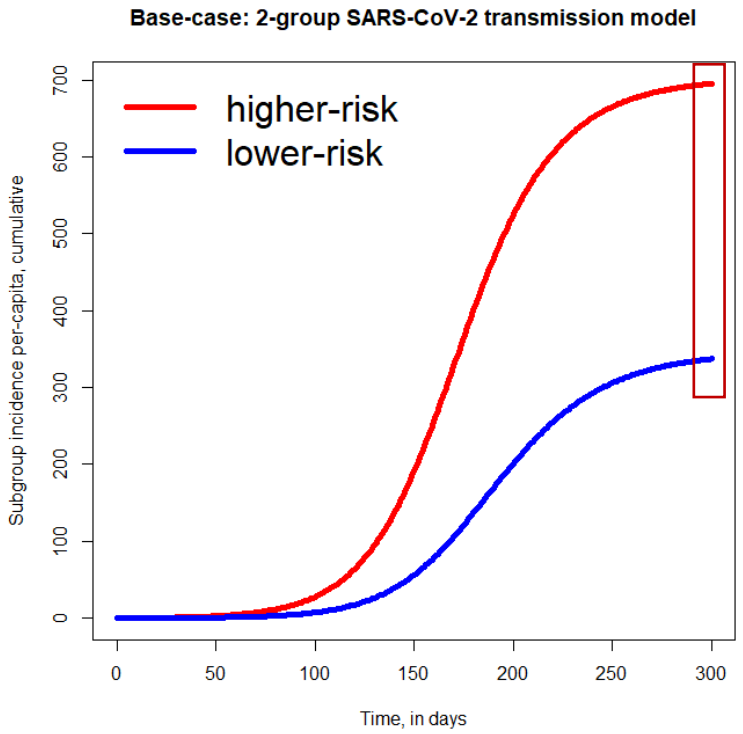
But what if strategy does not work *as well* for neighbourhoods experiencing higher risks?

Design & assume strategy will reach everyone "equally": (e.g. everyone can ↓ contact rates by 25%)

Mishra et al, in preparation

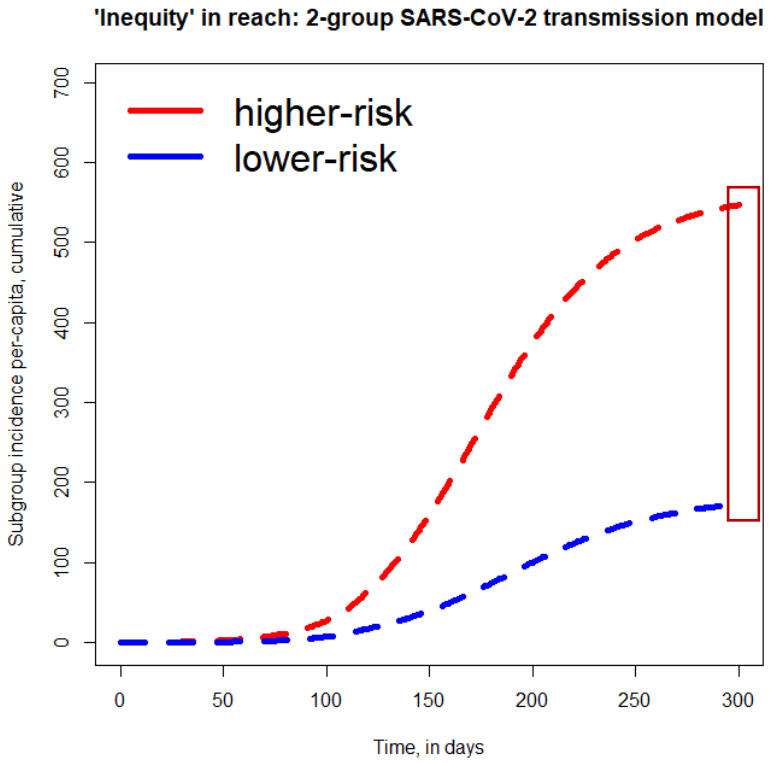
Overall reduction but with ↑inequity over time without additional resources tailored to mechanisms that place networks/communities at higher-risk

Cumulative Incidence Rate Ratio: 2.06



base-case

Cumulative Incidence Rate Ratio: 3.16

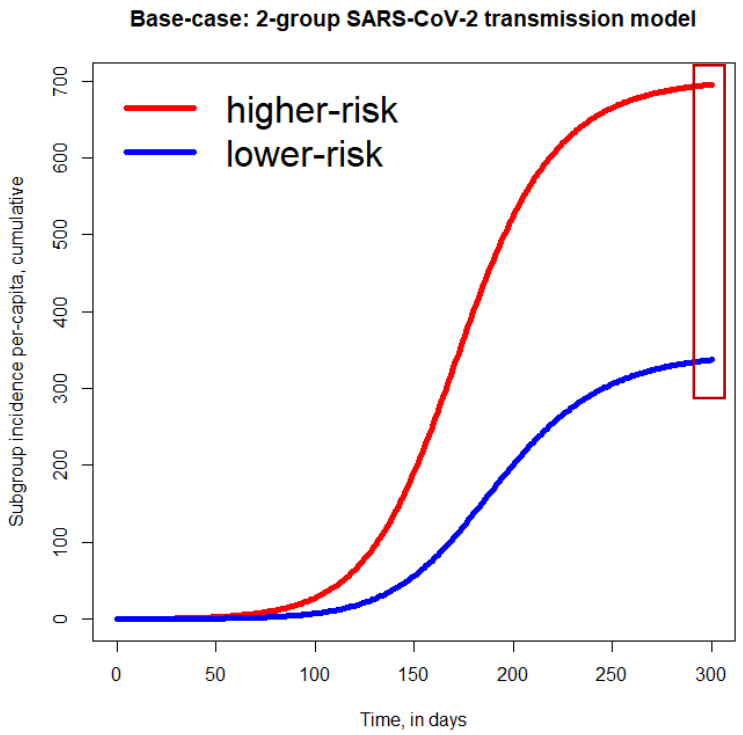


higher-risk neighbourhoods can only reduce their contact rates by 10%,
all others can reduce contact rates by 25%

Mishra et al, in preparation

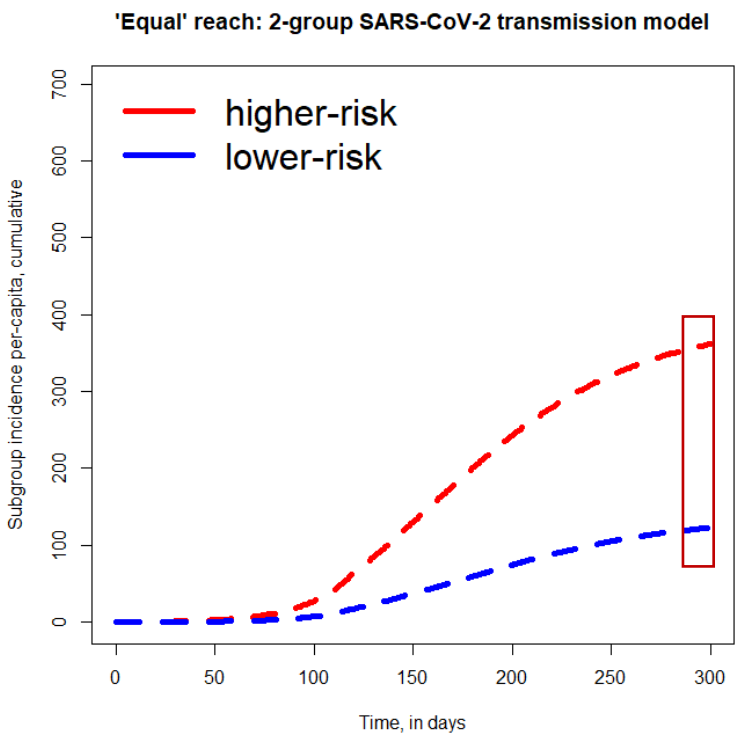
“Equal reach” may ↑inequity over time

Cumulative Incidence Rate Ratio: 2.06



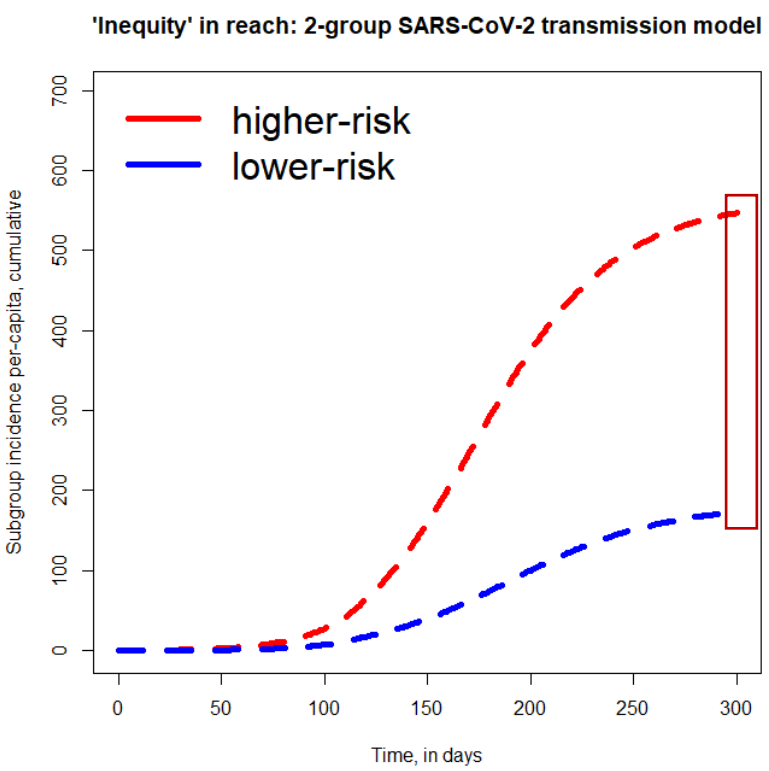
base-case

Cumulative Incidence Rate Ratio: 2.94



everyone ↓ contact rates by 25%

Cumulative Incidence Rate Ratio: 3.16



higher-risk neighbourhoods can only reduce their contact rates by 10%,
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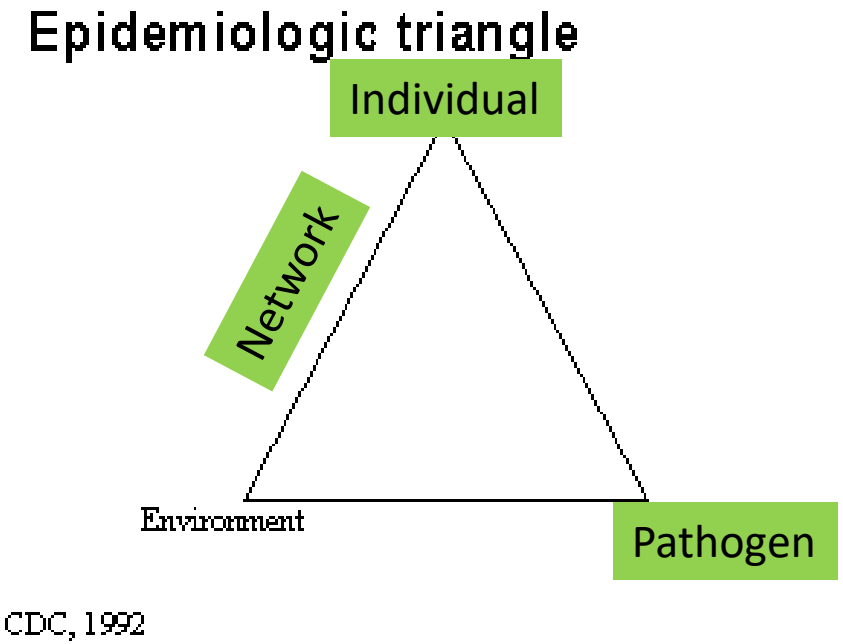
Mishra et al, in preparation

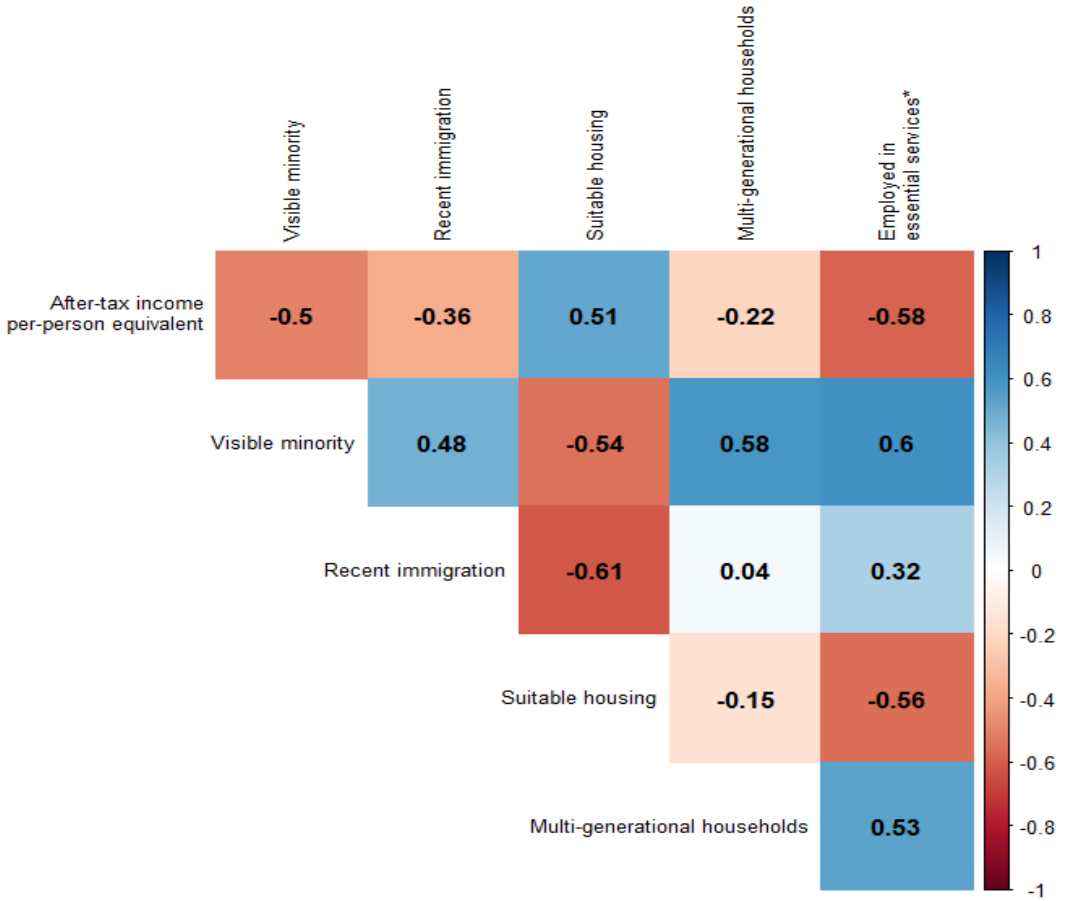
Mechanistic pathways?



CDC, 1992

structural & social inequalities → influence population-level causal pathways at every part of the triangle

Traditional social determinants of health & structural (mechanistic)



"Traditional" social determinants of health:

- Income
- Proxies of systemic racism

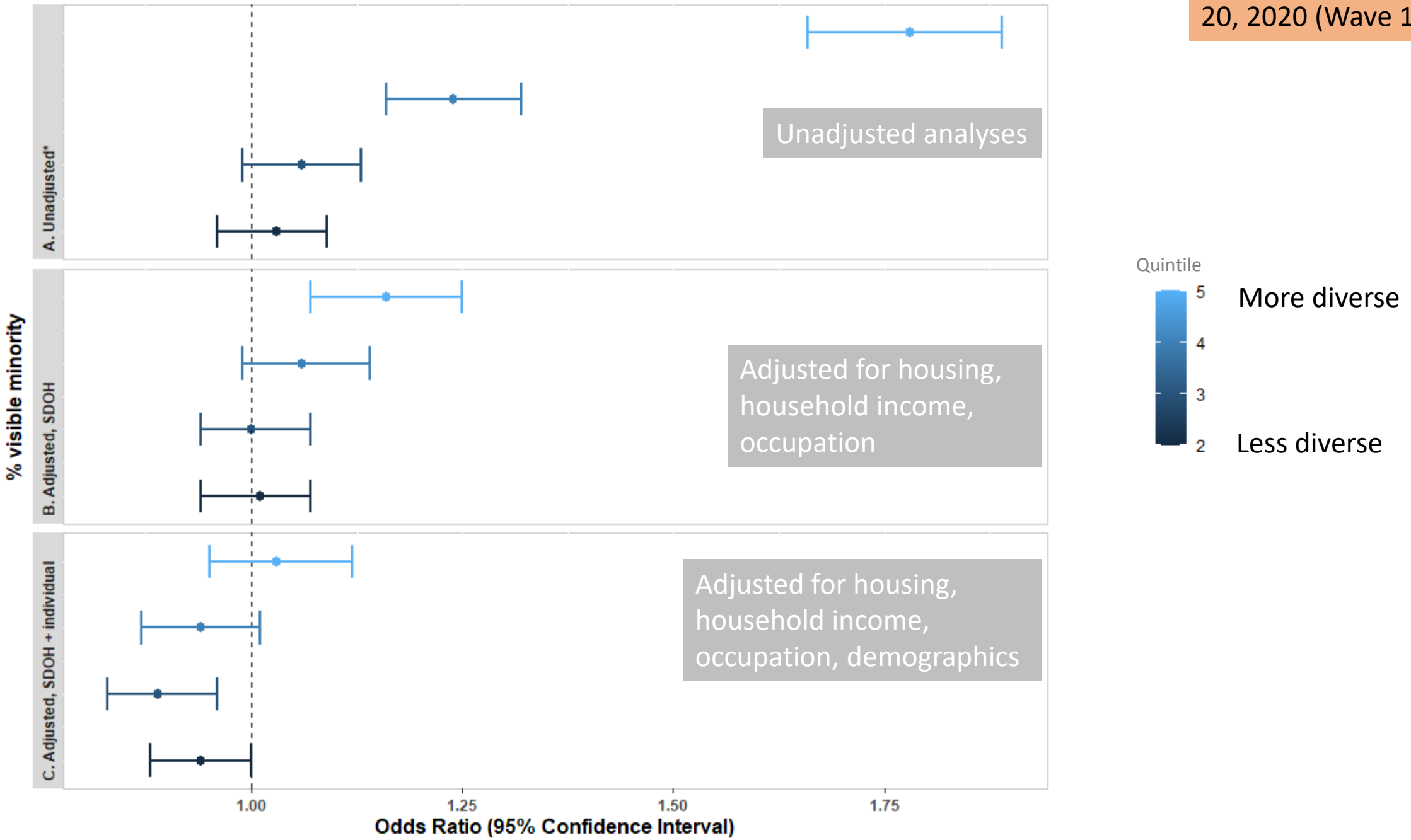
"Structural" (mechanistic):

- Essential services
- Multigenerational households
- Household size
- Suitable housing (proxy for housing density)

https://pubmed.ncbi.nlm.nih.gov/34320380/

attenuation of association after accounting for potential confounders

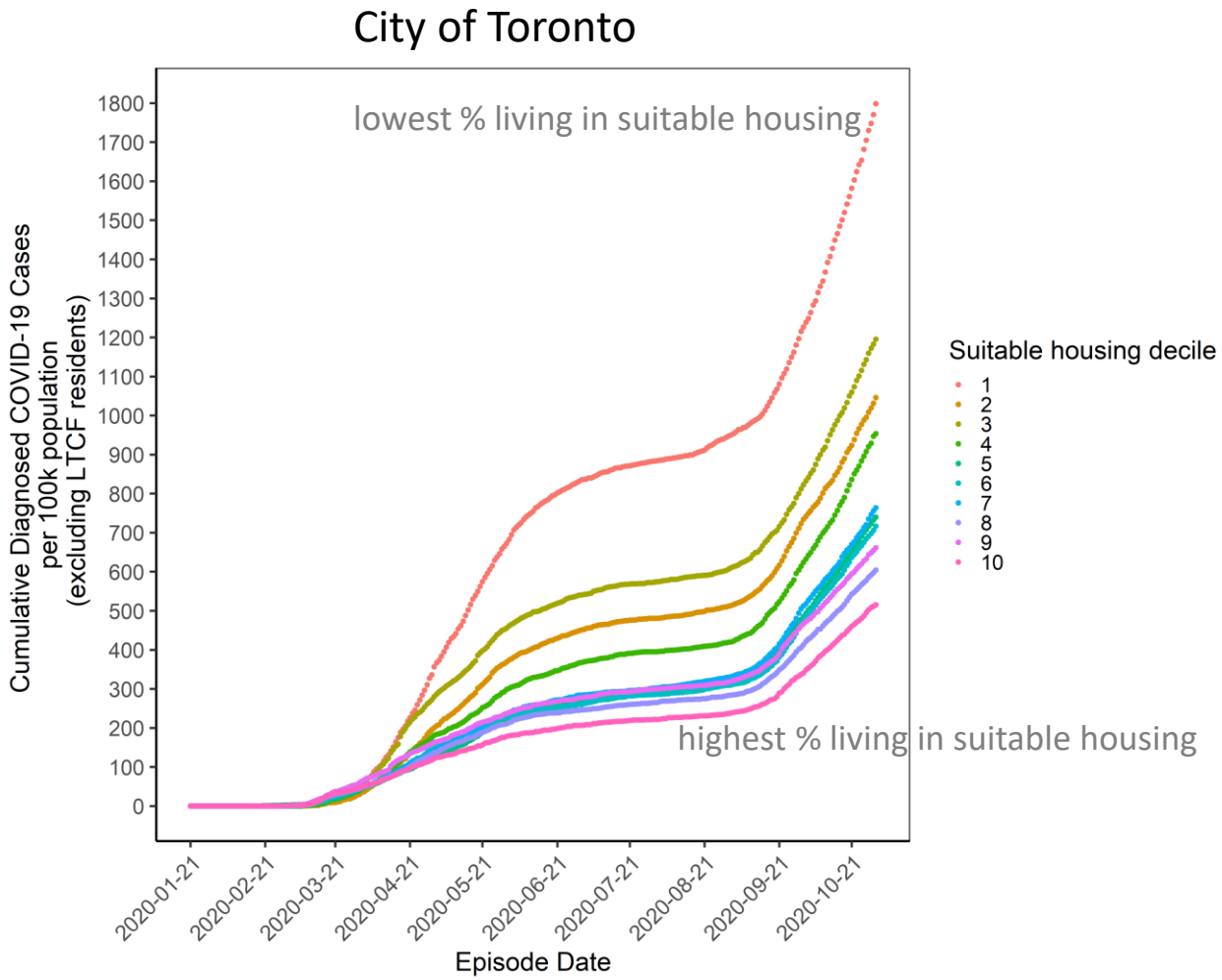
Ontario cases: March 1 – June 20, 2020 (Wave 1)



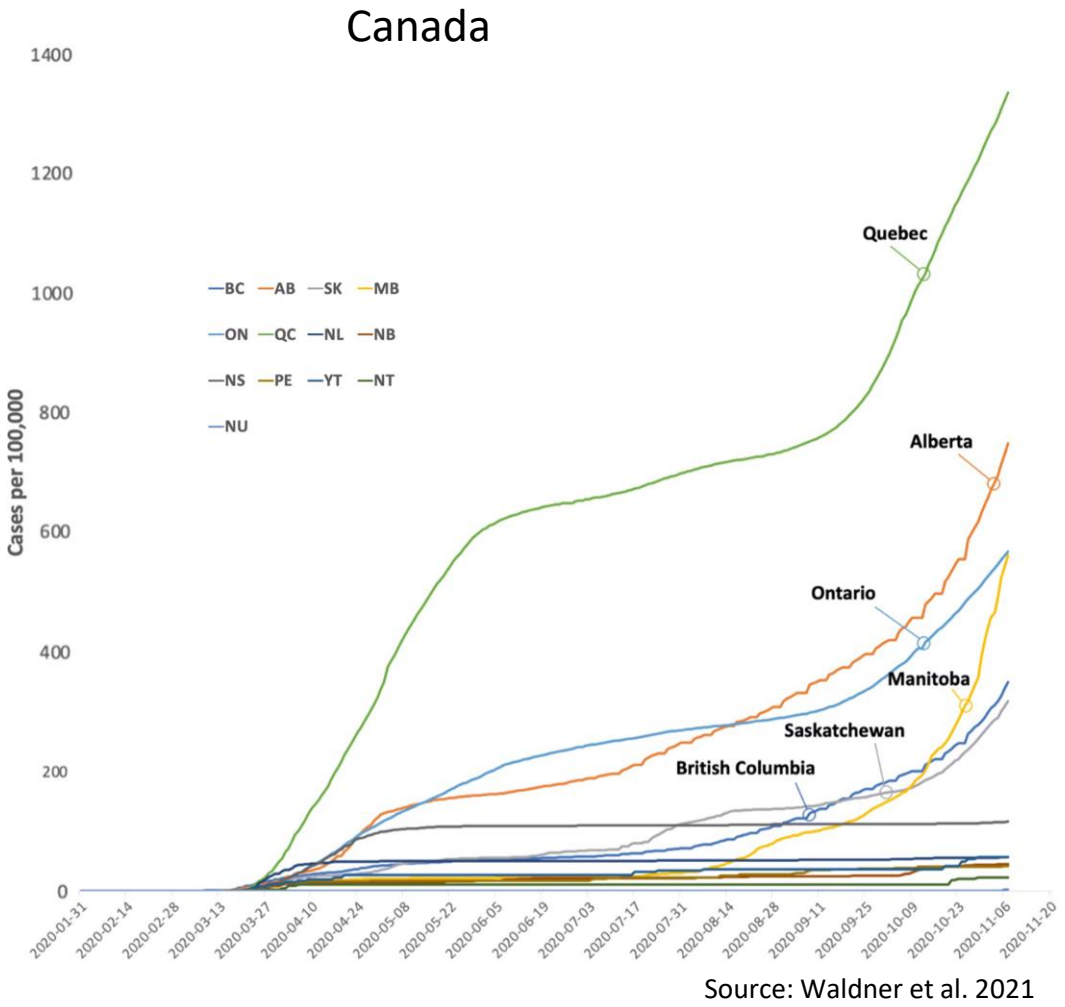
Sunderam et al. https://pubmed.ncbi.nlm.nih.gov/33906966/

*unadjusted accounts for variability by public health unit (fixed effect)

Epidemic curves by social & structural factors within a city



Epidemic curves by provinces within a country



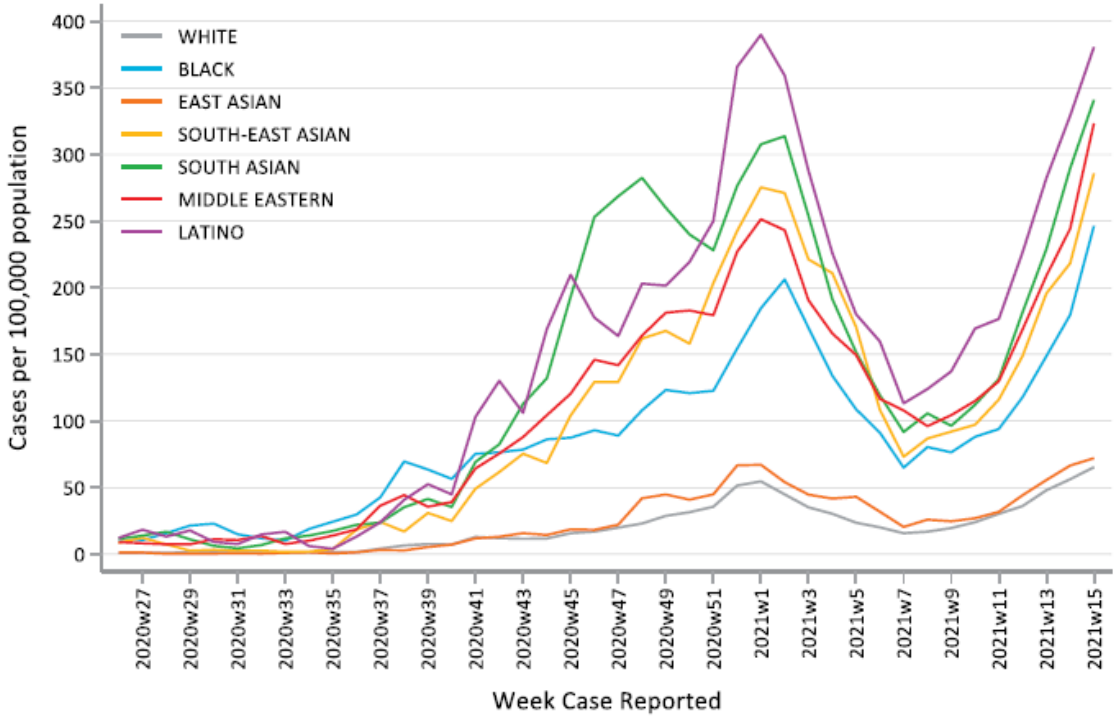
Source: Waldner et al. 2021

https://pubmed.ncbi.nlm.nih.gov/34320380/

Epidemic curves by self-identified race (as a proxy for systemic racism) within a province

Ontario

FIGURE 1. WEEKLY CASE COUNTS PER CAPITA BY RACE IN ONTARIO (JUNE 26, 2020 TO APRIL 21, 2021)

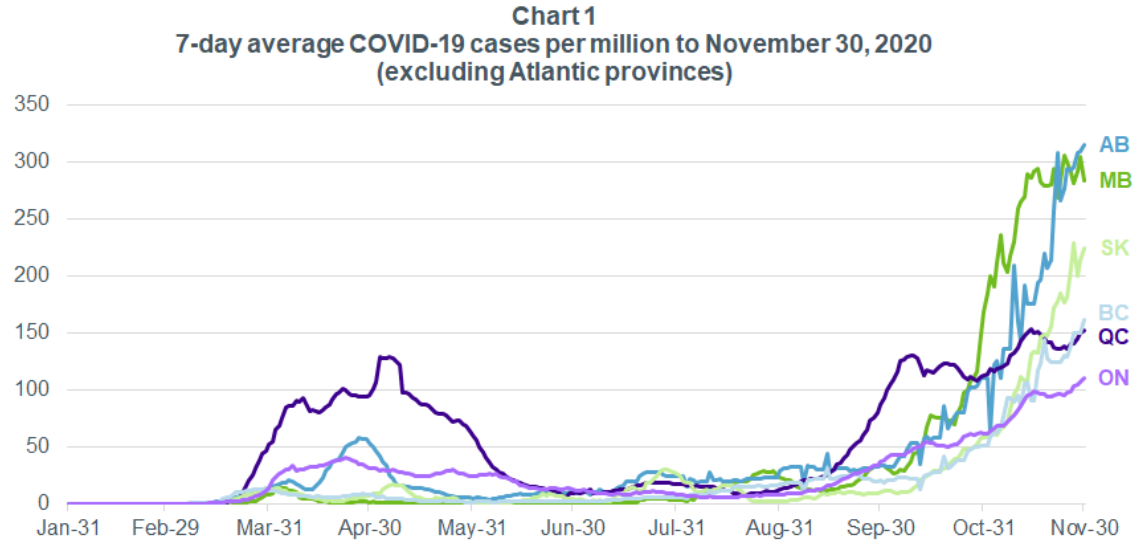


***Data source**: CCM plus and 2016 census population*

***Data note**: Missing race data for 43% of all cases (171,915/ 398,651). Weekly counts smoothed as a trailing 3-week average.*

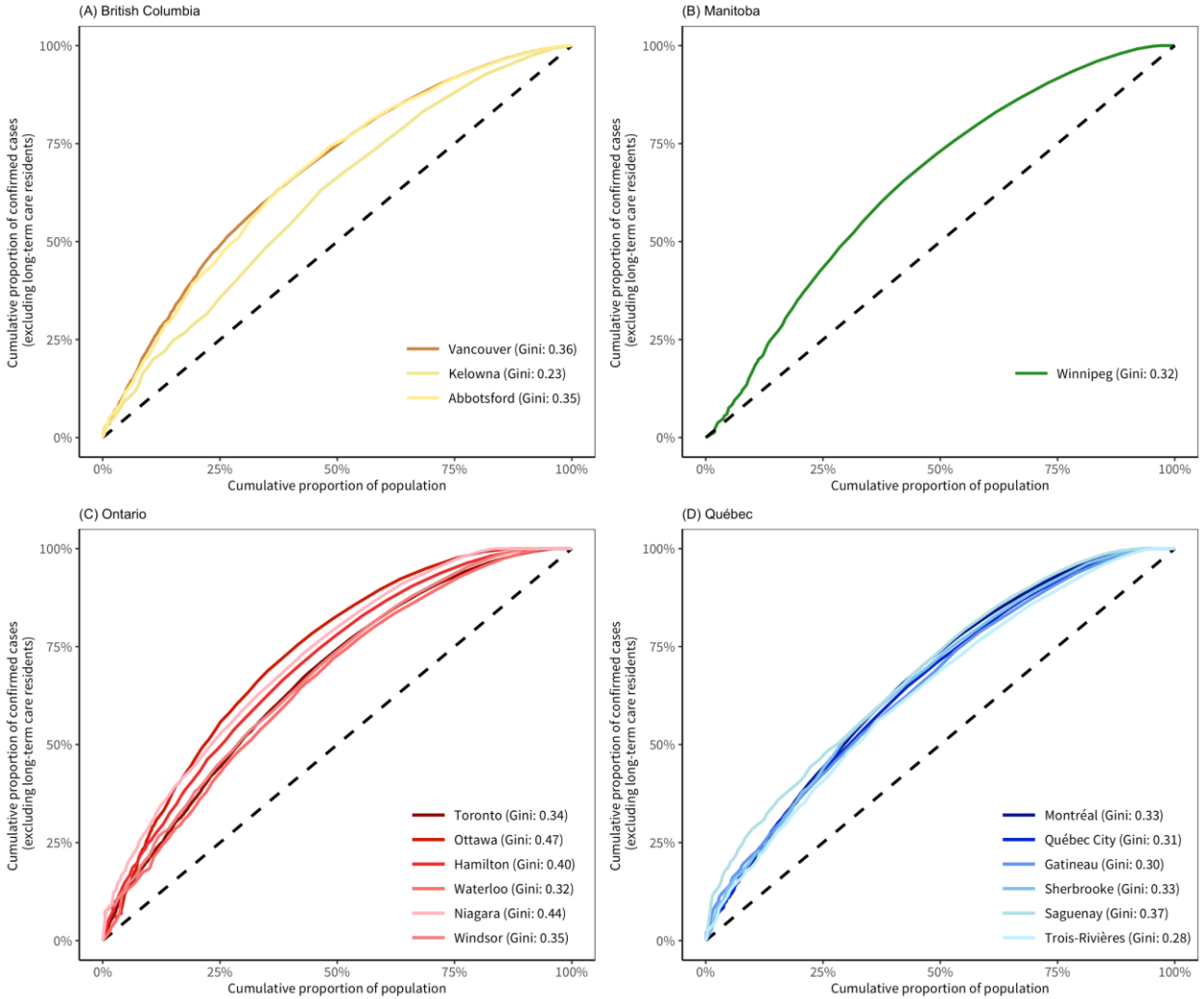
Epidemic curves by provinces within a country

Canada



https://www.wellesleyinstitute.com/publications/tracking-covid-19/

In each city: ≈50% of cases in 25% of population



Xia & Ma et al. https://www.medrxiv.org/content/10.1101/2021.07.23.21261039v1

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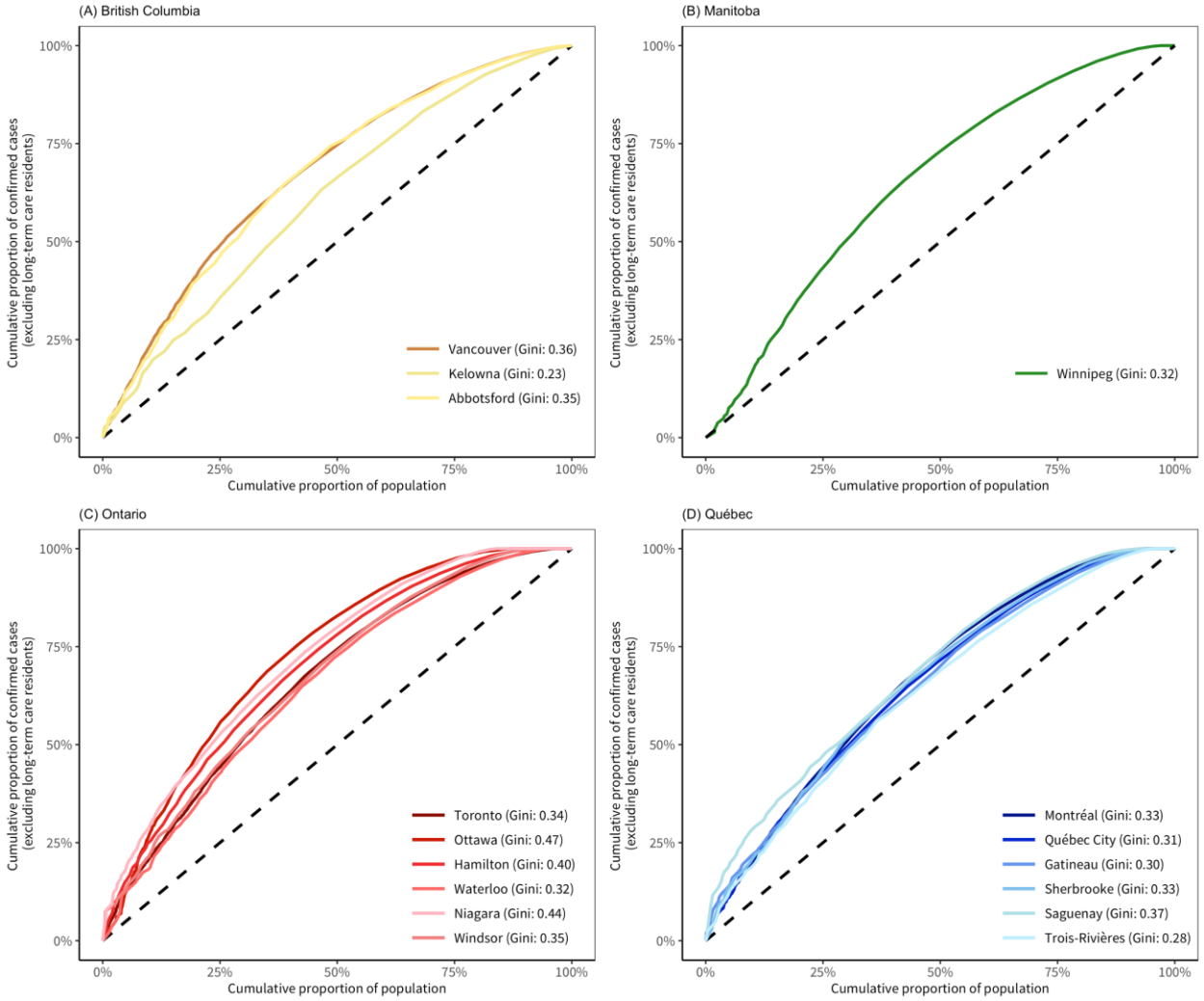
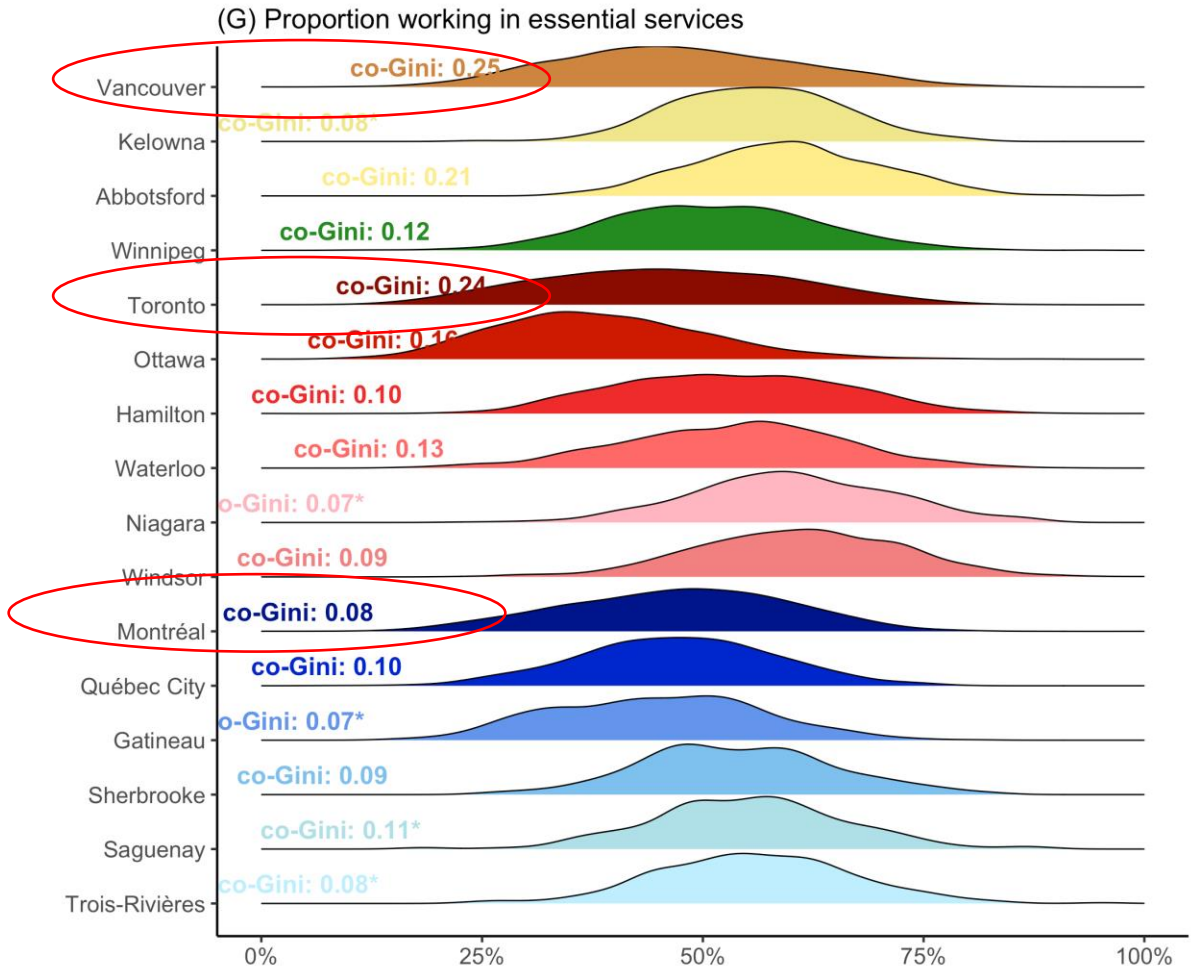


...social/structural determinant of spatial concentration varied between cities....

Essential workers:
Vancouver: Gini 0.25
Toronto: Gini 0.24
Montreal: Gini 0.08



Xia & Ma et al. https://www.medrxiv.org/content/10.1101/2021.07.23.21261039v1

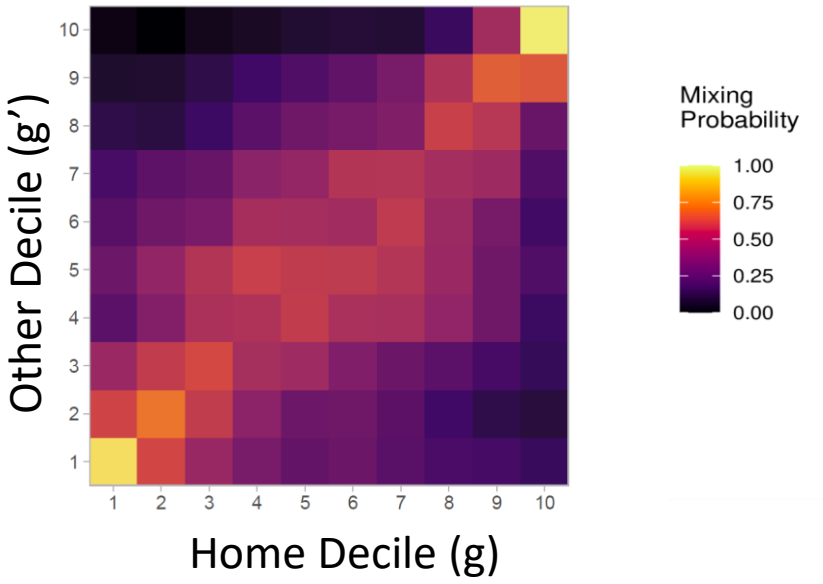
Mixing by social/structural determinants

1) Relative “like with like” with respect to “mixing” by area-level social determinants:

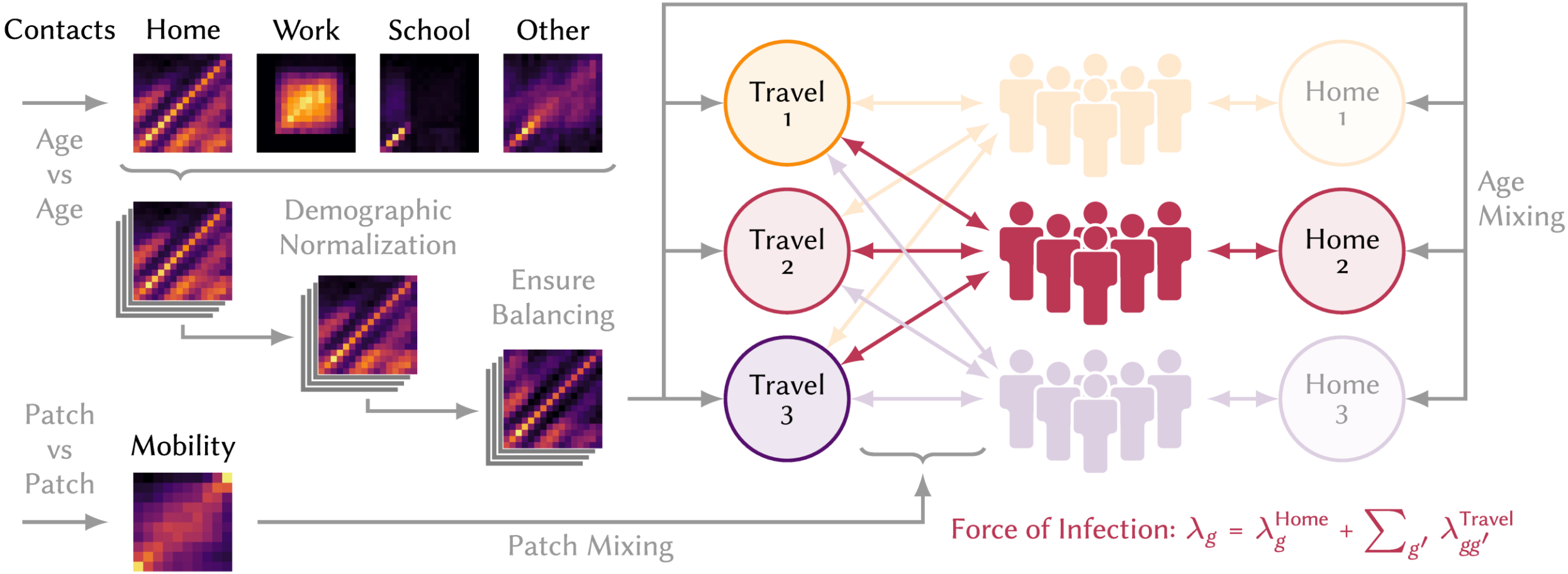
- e.g. we tend to travel to similar income neighbourhoods as us

2) More movement from lower income → higher income than from higher income → lower income

Non-household contacts between neighbourhoods

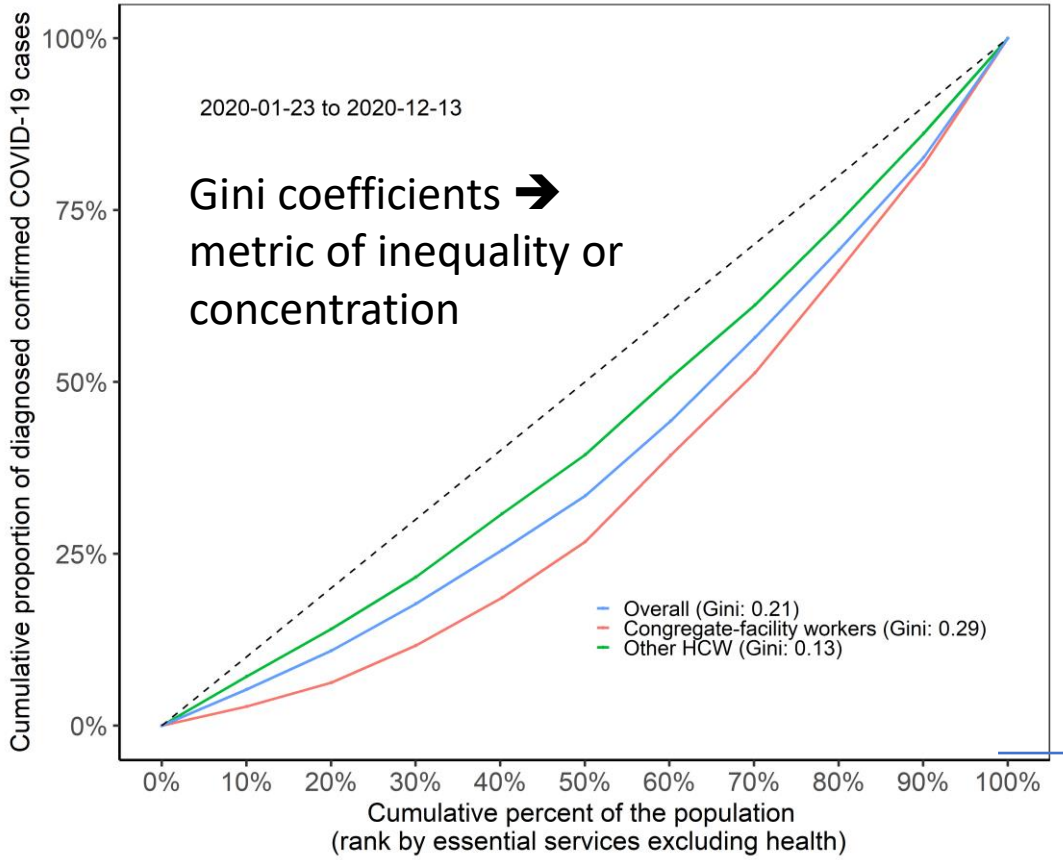


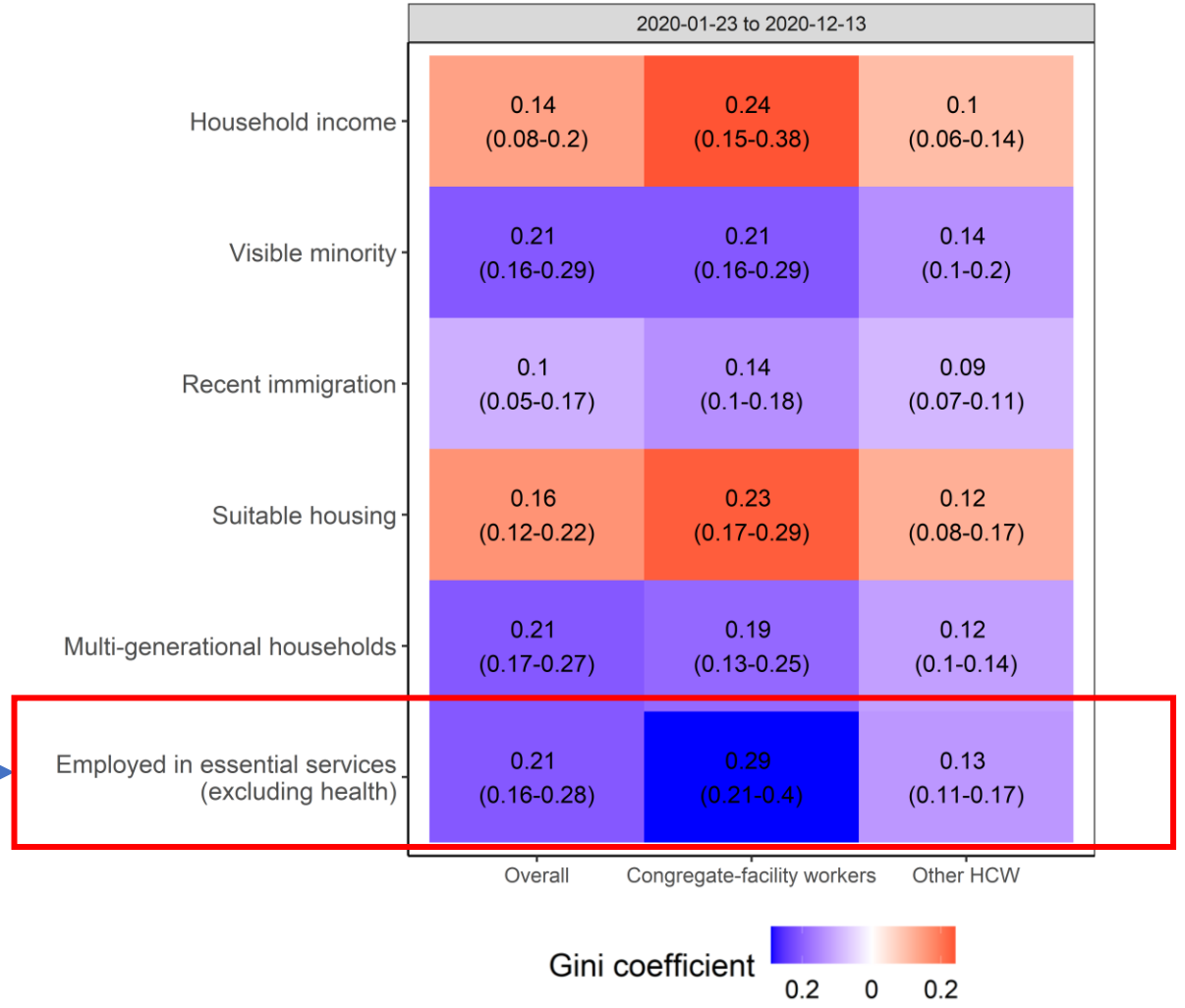
Methods to generate networks re: who contacts whom using area-level "patches" with survey data + cell phone data



Knight et al. https://www.medrxiv.org/content/10.1101/2021.09.29.21264319v1

Congregate facilities & their overlap with neighbourhoods of where staff live





Ma et al, in preparation

Was (is) there a prevention gap?

3 examples:

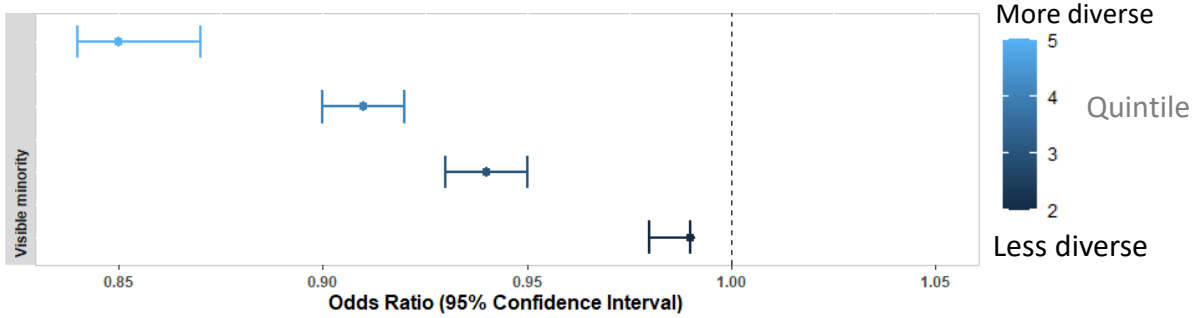
effective isolation (testing)

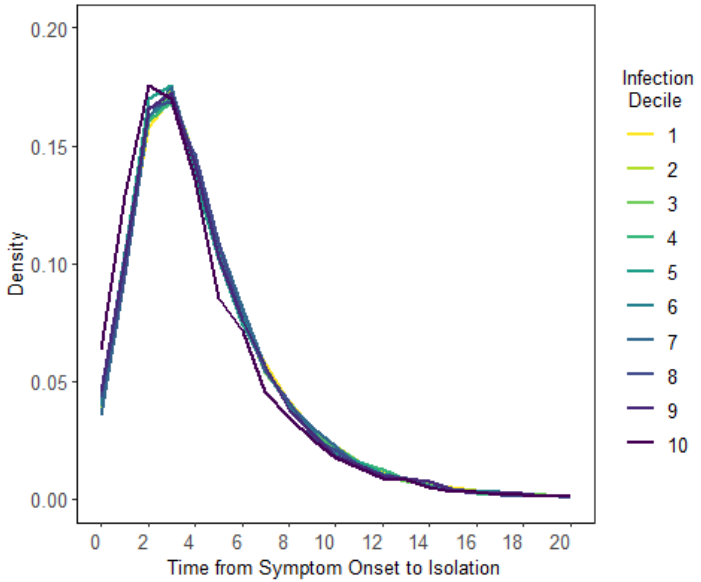
contacts/mixing

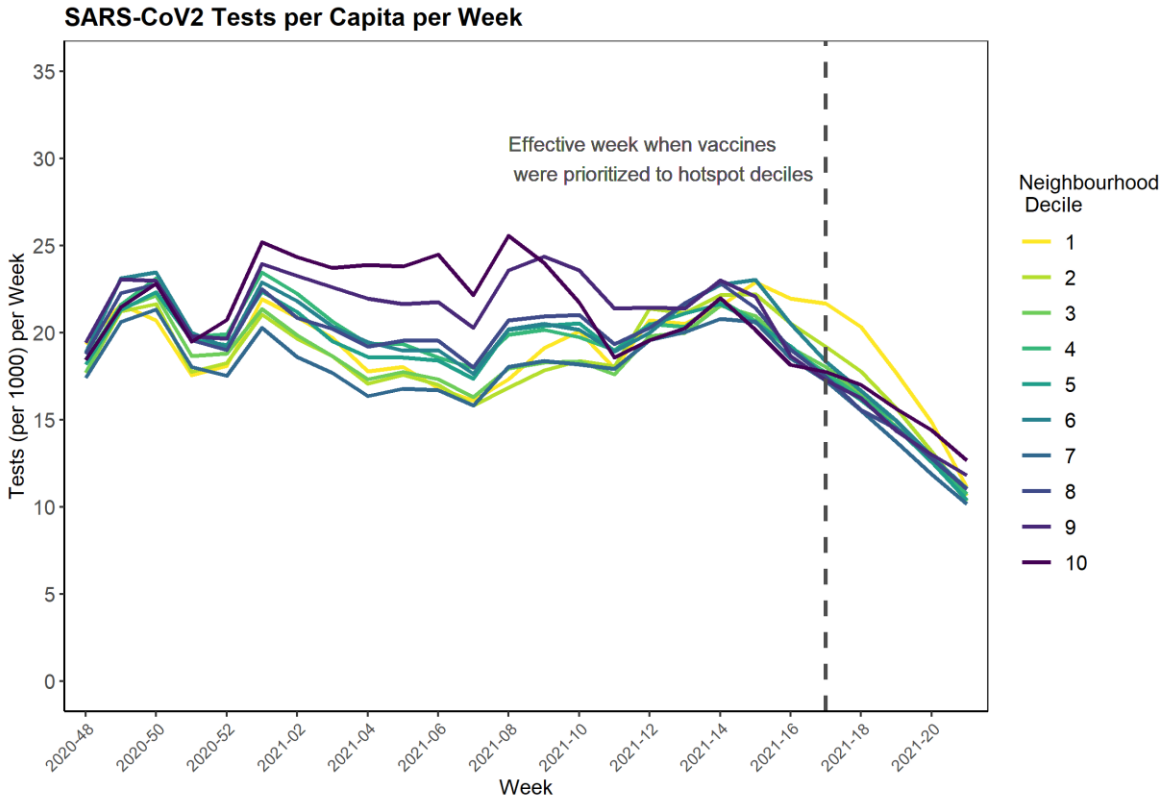
vaccination coverage

access to or uptake of effective isolation *via* testing → lowest in the hardest hit neighbourhoods but distribution in time from symptom onset to isolation was similar

Ever tested (wave 1)



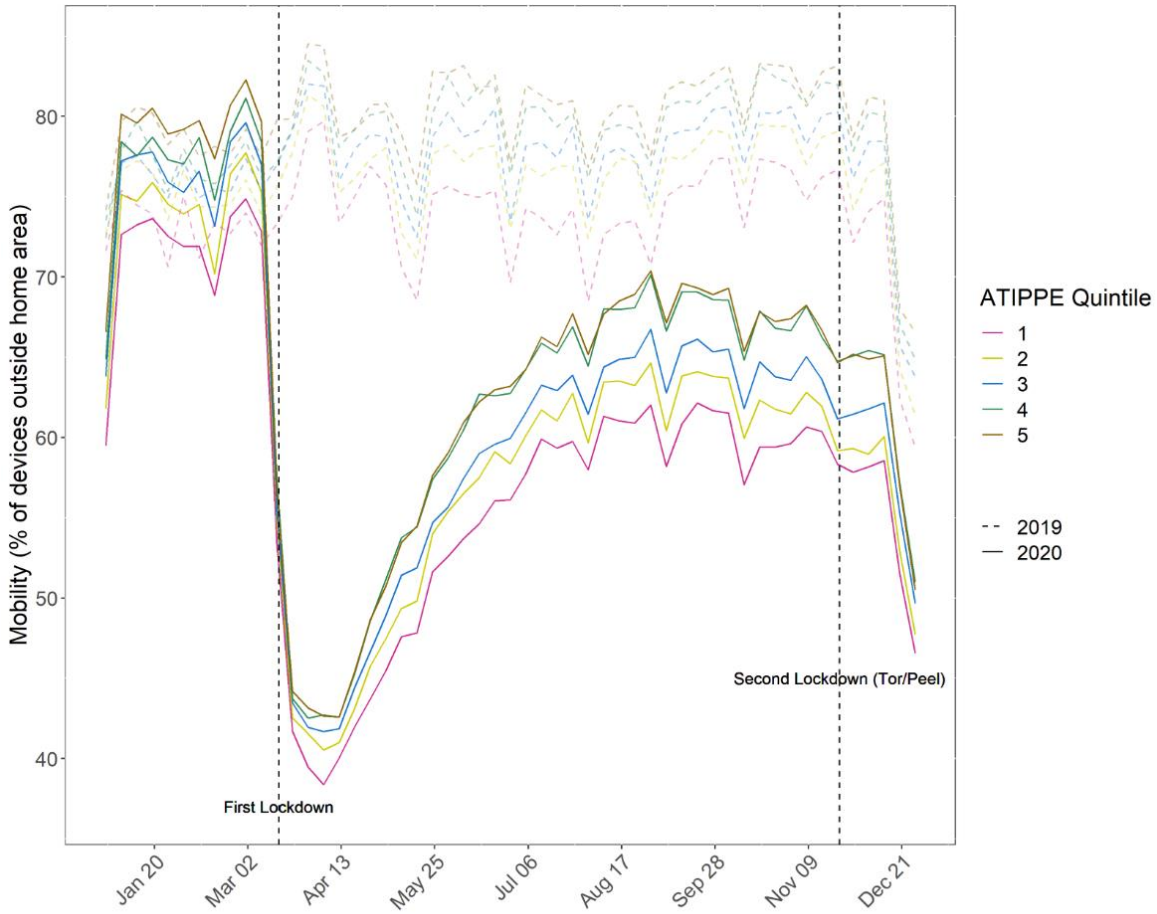




Note: Forward sortation areas were ranked into neighbourhood deciles according to COVID-19 cases counts as of March 28, 2021. Long-term care home residents were excluded from the population. One test per person per day was included. If there were multiple tests per person per day, the first positive was included , otherwise, the first negative test was included. If an individual tested positive, all future tests were excluded.

Hamilton et al, in preparation

…lower income neighbourhoods ↓mobility <u>almost as much*</u> as higher income

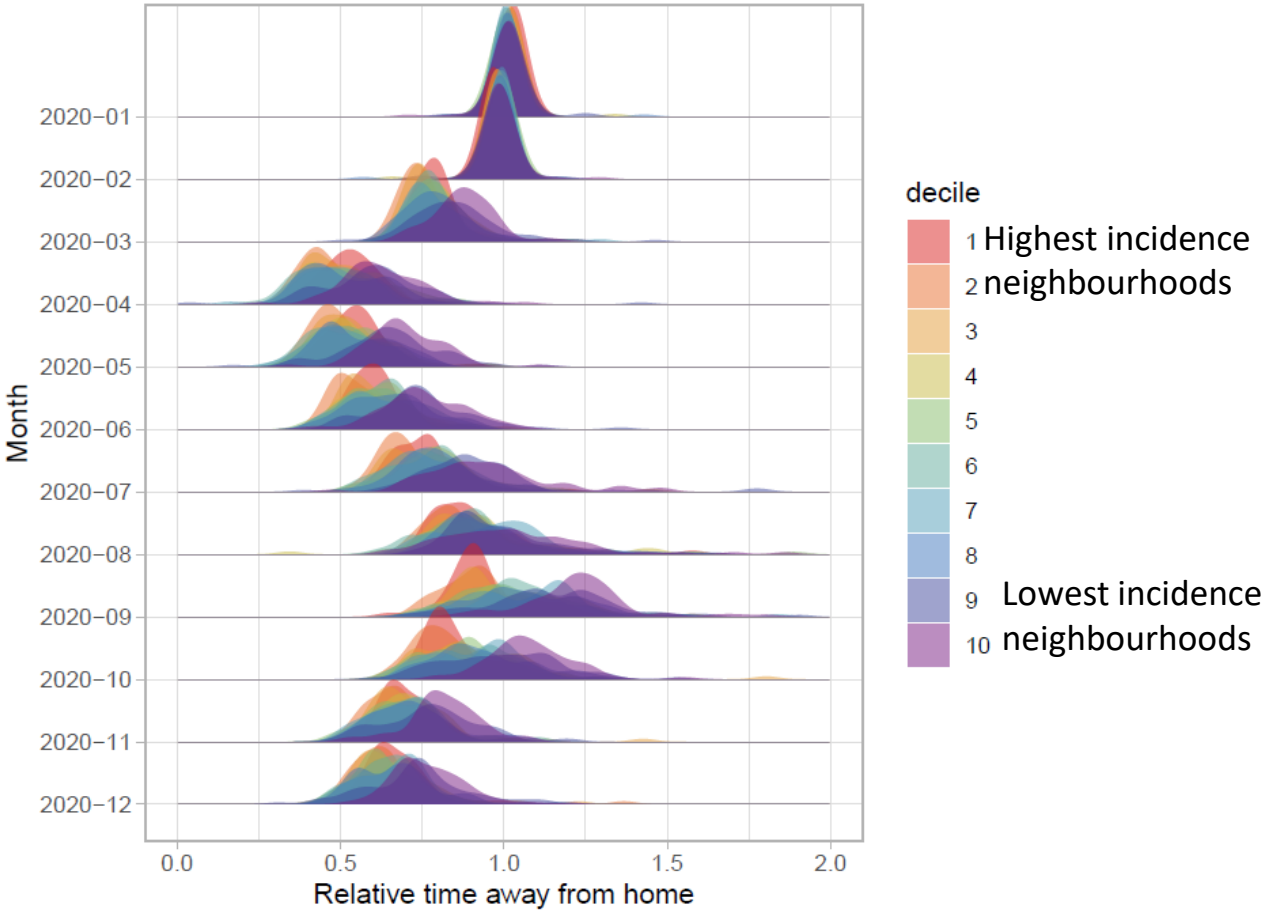


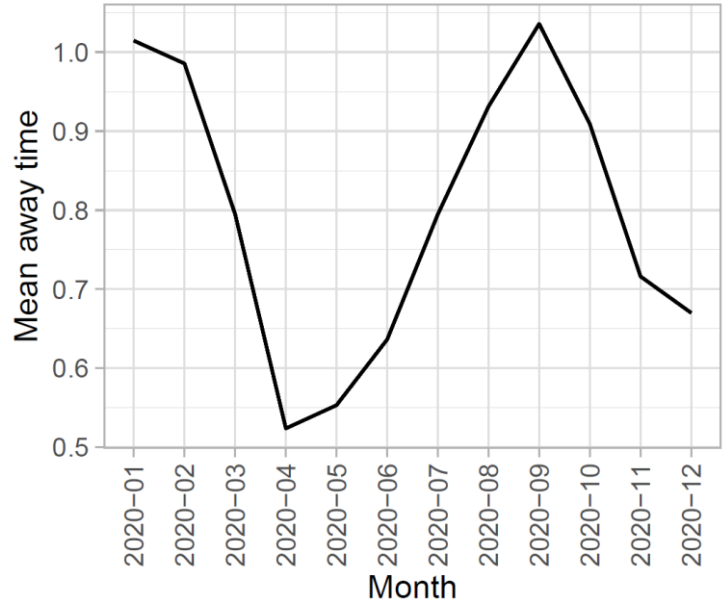
Greater Toronto Area: mobility metric (% of devices that went outside the home location) stratified by income quintile (measured at the level of the census tract)

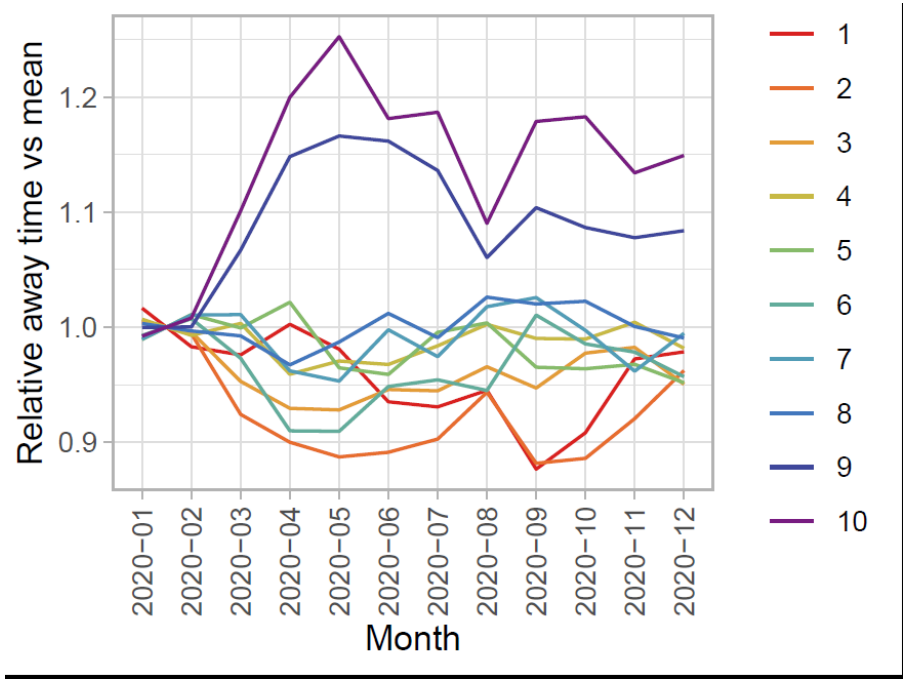
*in contrast to data from the United States and Chile using similar mobility metrics from cellular device/apps

Wang S et al, in preparation

…hardest-hit neighbourhoods (hotspots) ↓mobility more* than less-affected neighbourhoods (non-hotspots)

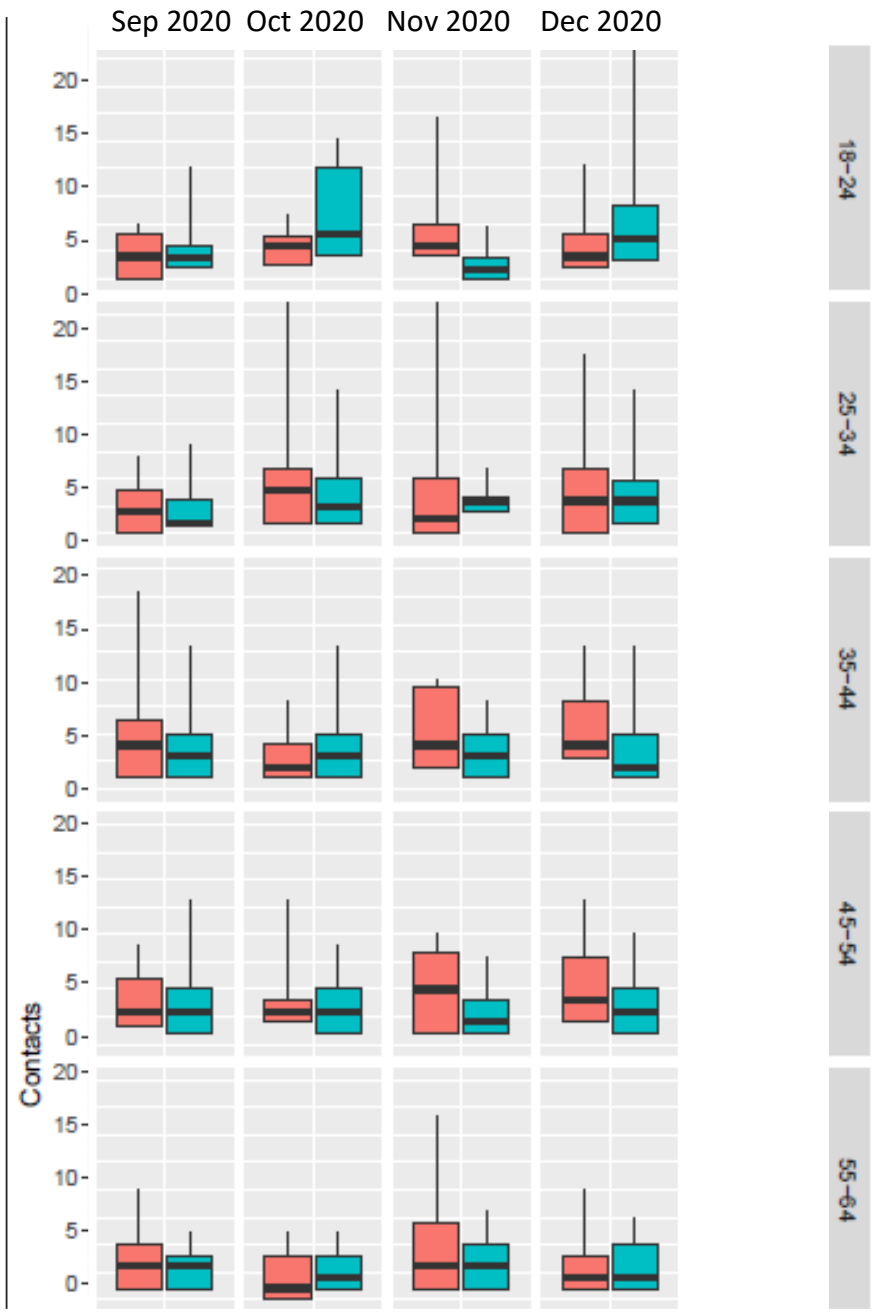


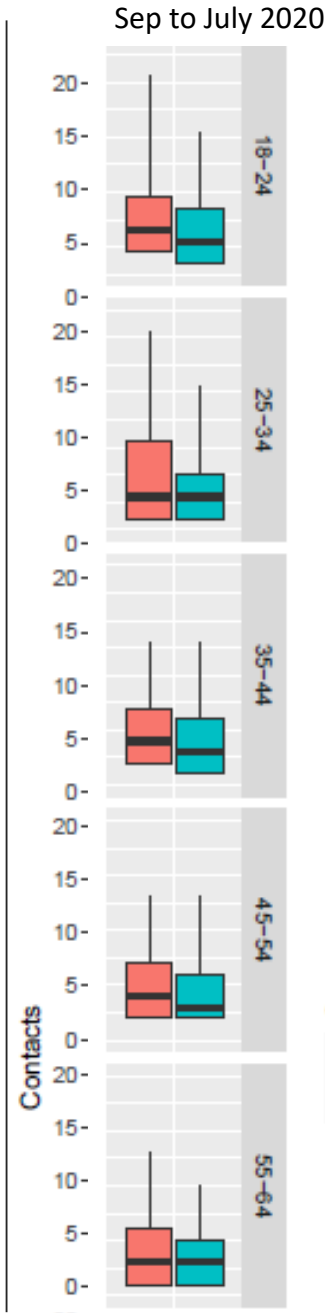


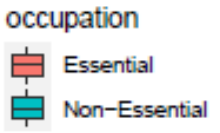


Ontario: mobility metric (relative time devices went outside the home location) stratified by incidence-deciles (measured at the level of the forward sortation area)

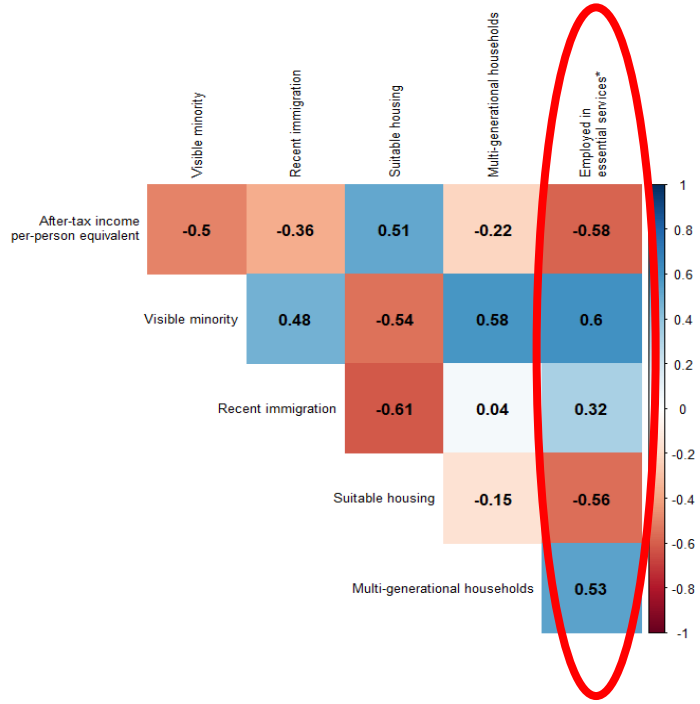
Knight et al. https://www.medrxiv.org/content/10.1101/2021.09.29.21264319v1







Intra-pandemic (British Columbia): on average, 1 additional non-household contact per day among essential workers vs. non-essential workers

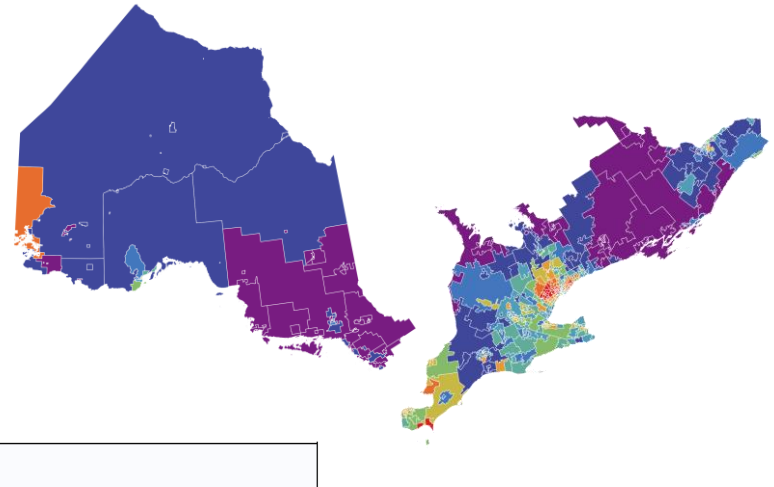


Source: BCMix Study. Adu & Janjua et al.

if devices left home decile→ probability of visiting with other decile remained relatively stable

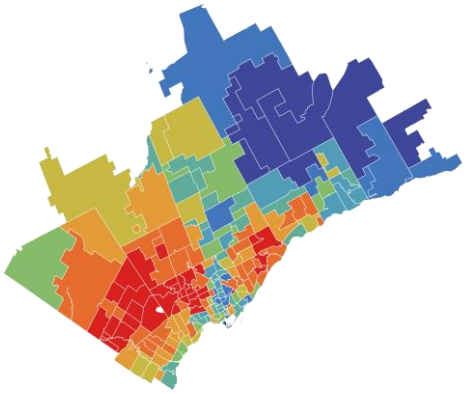
Knight et al. https://www.medrxiv.org/content/10.1101/2021.09.29.21264319v1

1st dose vaccine coverage: access to (reach of) vaccinations by March 22, 2021 in Ontario



As of March 22, 2021, excluding residents of long-term care homes (Ontario-wide)

	Neighbourhood Risk (1 = high incidence of COVID-19 infections, 10 = low incidence of COVID-19 infections)										
	1	2	3	4	5	6	7	8	9	10	**Overall**
80+	38.1%	44.8%	45.0%	50.5%	51.0%	53.2%	49.5%	57.1%	47.6%	49.2%	***48.8%***
75-79	8.3%	10.0%	10.6%	12.1%	12.0%	13.9%	11.5%	14.7%	9.6%	8.9%	***11.1%***
70-74	2.9%	4.0%	4.8%	4.7%	5.2%	5.2%	5.1%	5.4%	3.9%	4.3%	***4.6%***
65-69	3.5%	4.6%	5.4%	5.5%	5.9%	5.7%	6.2%	6.0%	5.1%	5.4%	***5.4%***
60-64	15.3%	19.6%	19.9%	17.1%	18.7%	17.1%	16.6%	14.9%	11.2%	16.7%	***16.6%***
55-59	6.0%	7.7%	8.0%	8.5%	9.5%	9.1%	9.3%	9.2%	8.5%	10.2%	***8.7%***
50-54	4.8%	5.8%	5.7%	6.9%	7.5%	7.3%	7.6%	7.7%	8.2%	9.1%	***7.0%***
45-49	5.0%	5.9%	5.6%	6.6%	7.2%	6.9%	7.0%	7.3%	7.8%	9.1%	***6.8%***
40-44	4.4%	5.3%	5.3%	6.3%	6.7%	6.6%	6.7%	7.1%	7.3%	8.7%	***6.4%***
16-39	3.2%	4.0%	4.2%	4.9%	5.4%	5.1%	5.0%	5.5%	5.7%	6.8%	***4.9%***
Overall	***5.2%***	***6.9%***	***7.0%***	***7.6%***	***8.0%***	***8.2%***	***8.0%***	***8.5%***	***7.7%***	***9.3%***	***9.2%***



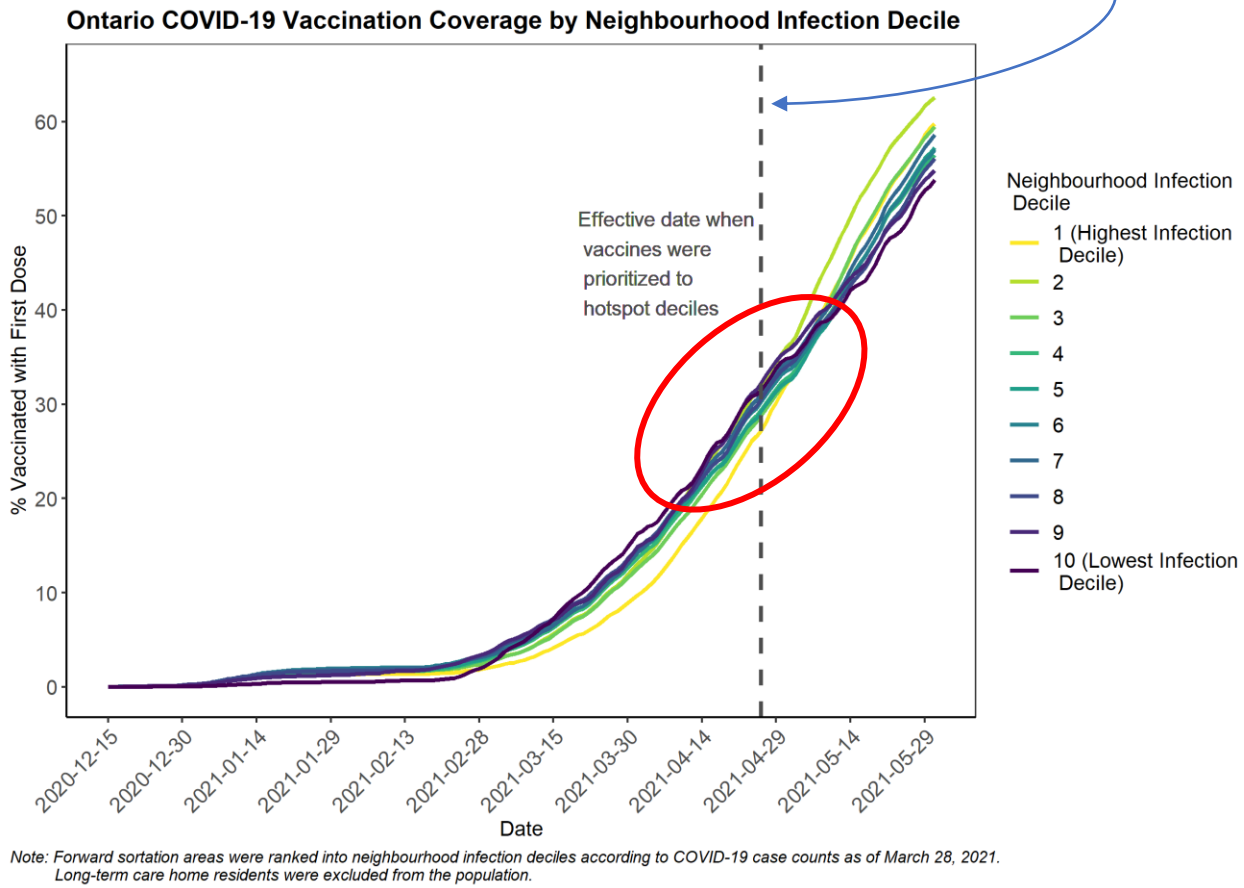
High-incidence neighbourhoods

Lower-incidence neighbourhoods

https://www.ices.on.ca/DAS/AHRQ/COVID-19-Dashboard

vaccination coverage: 1st dose

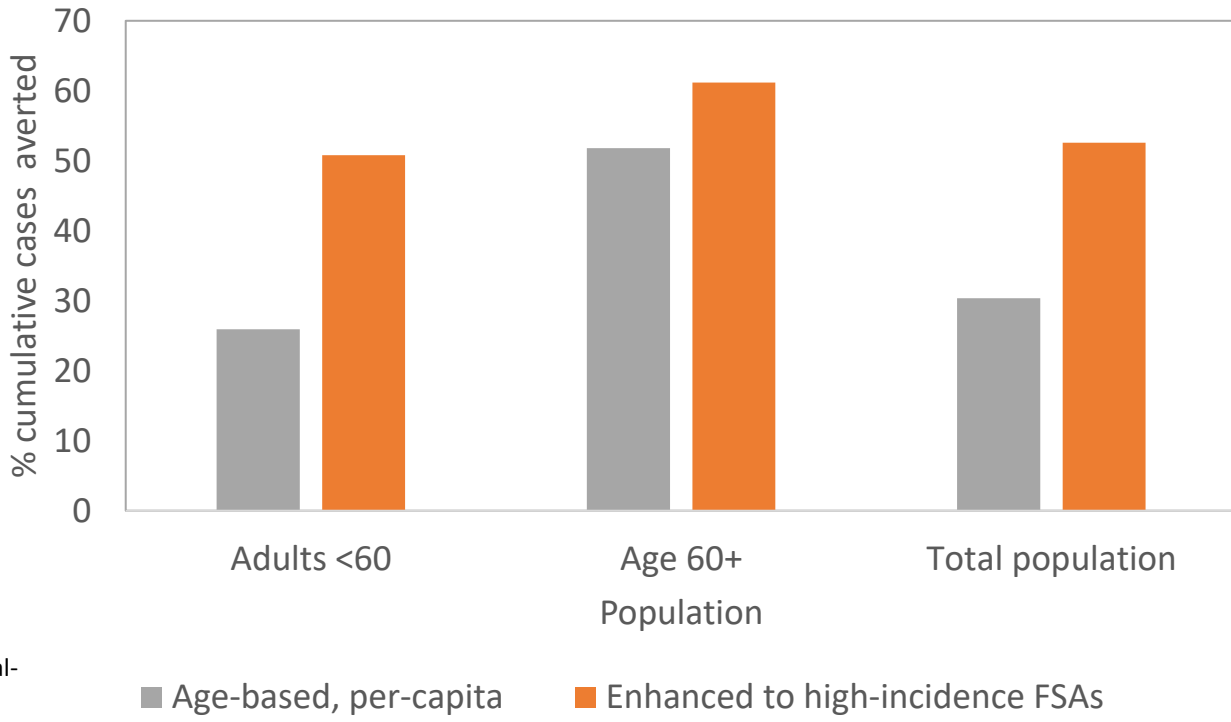
Hotspot vaccination policy for first-doses implemented in Ontario (50% allocation to 30% of population – top 3 deciles) vs. 50% allocation to top 2 deciles (modeled)



Note: Forward sortation areas were ranked into neighbourhood infection deciles according to COVID-19 case counts as of March 28, 2021. Long-term care home residents were excluded from the population.

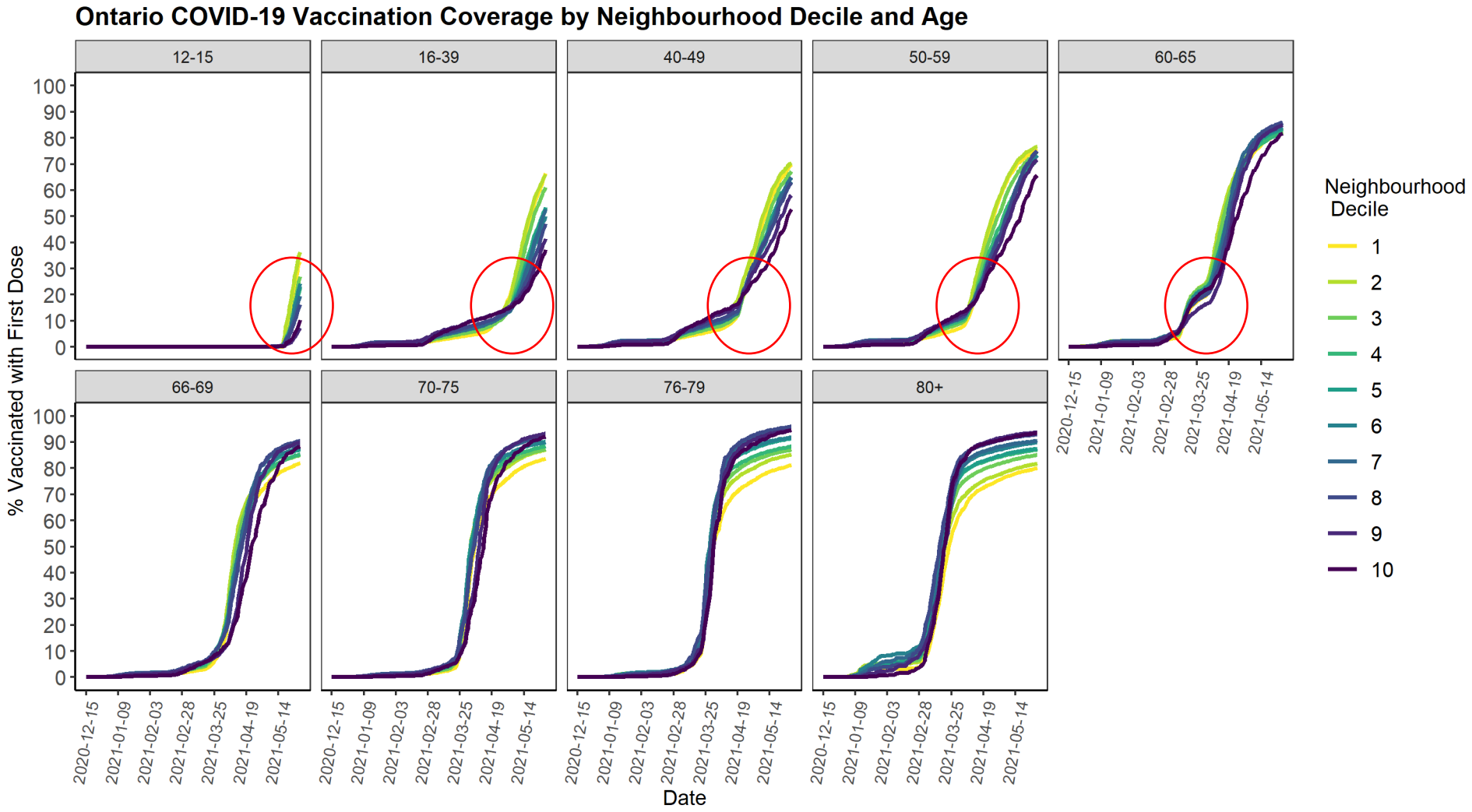
Number vaccinated per case averted

Potential impact at 60 days from March 24, 2021 of the roll-out of next 3 million doses over 30 days



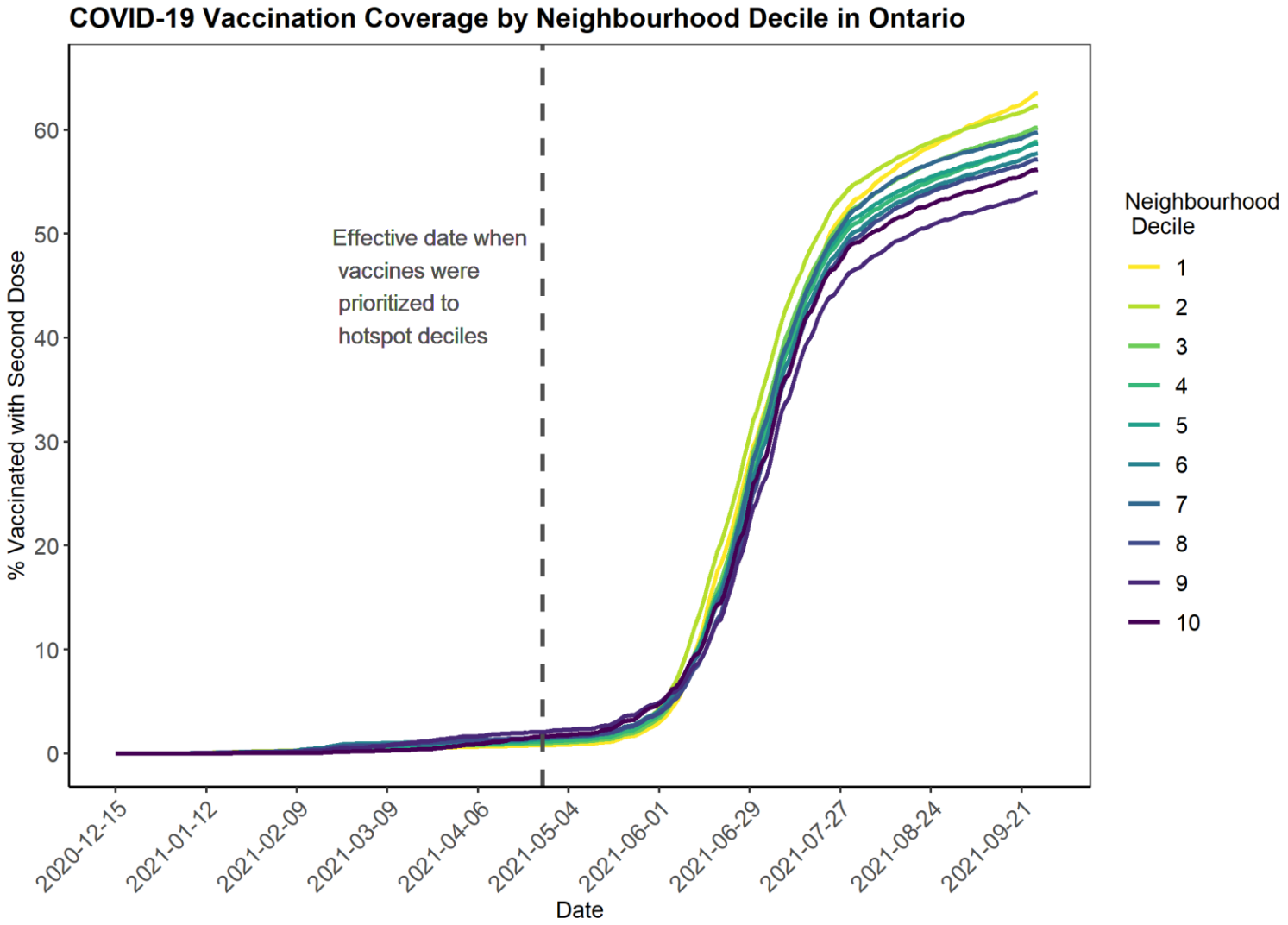
https://covid19-sciencetable.ca/sciencebrief/a-vaccination-strategy-for-ontario-covid-19-hotspots-and-essential-workers/

vaccination coverage: 1st dose



Hamilton et al, in preparation

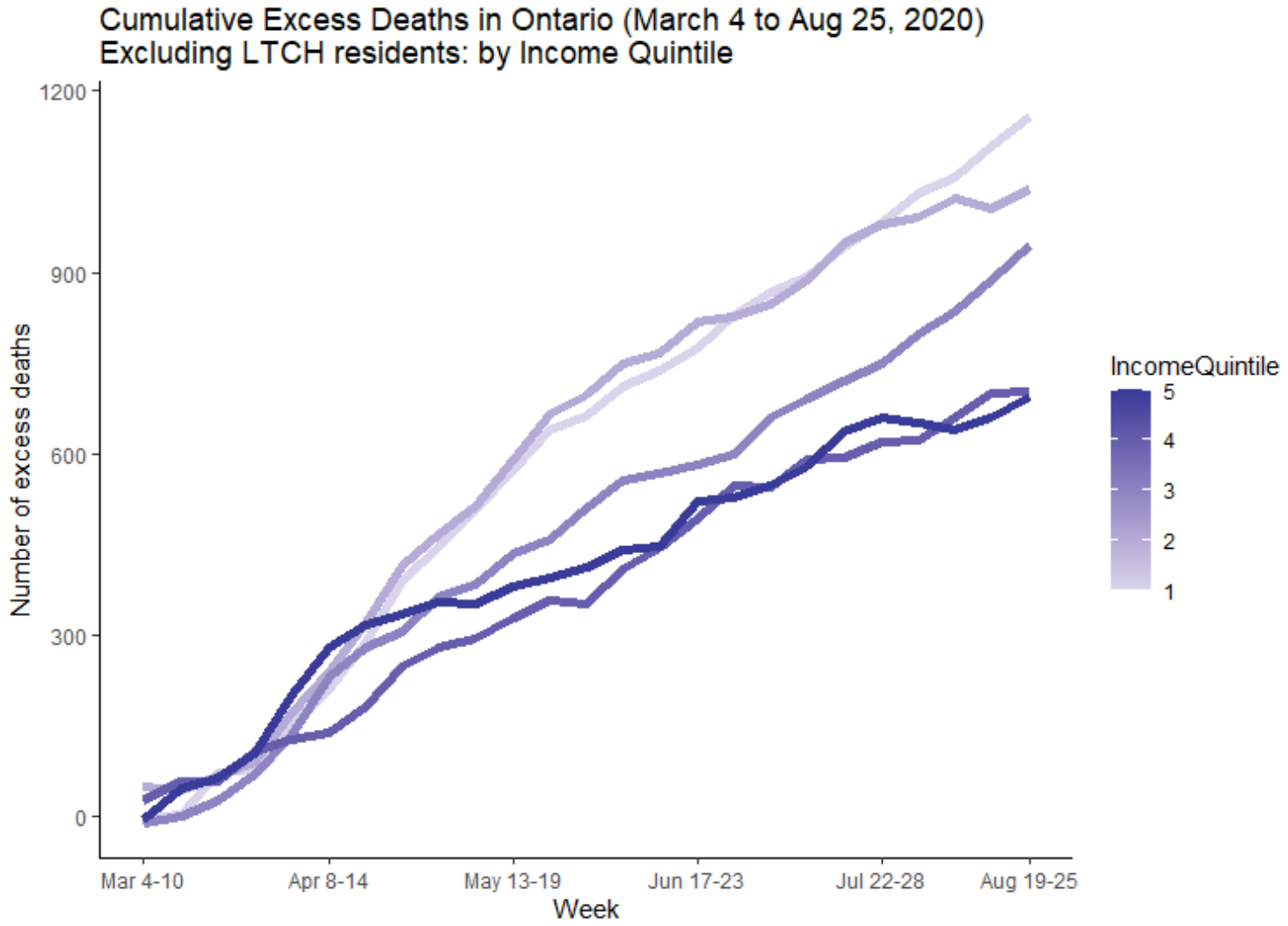
vaccination coverage: 2nd dose



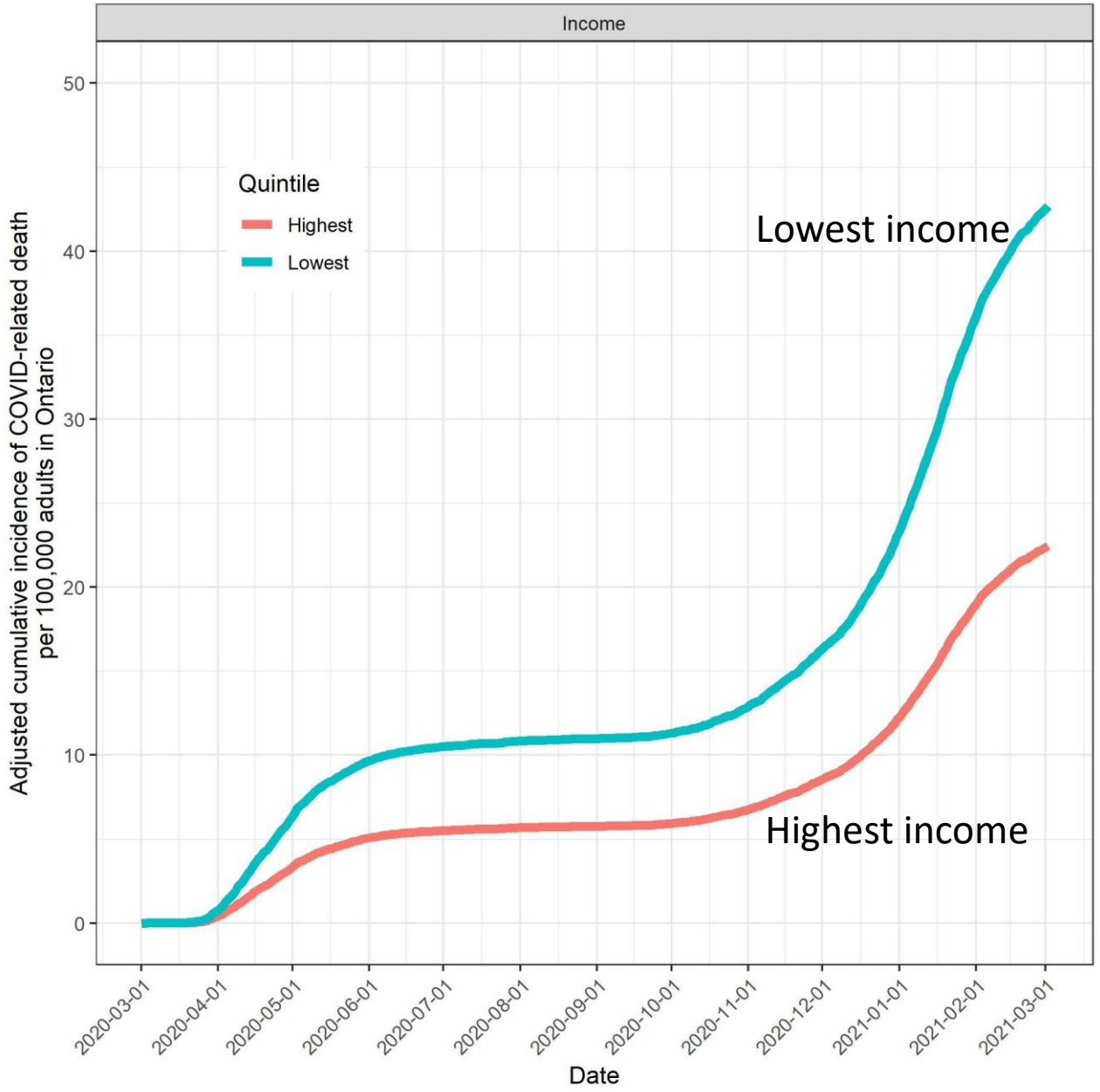
Note: Forward sortation areas were ranked into neighbourhood deciles according to COVID-19 cases counts as of March 28, 2021. Long-term care home residents were excluded from the population.

Hamilton et al, in preparation

Consequences: excess deaths in wave 1



Wang L et al, in preparation



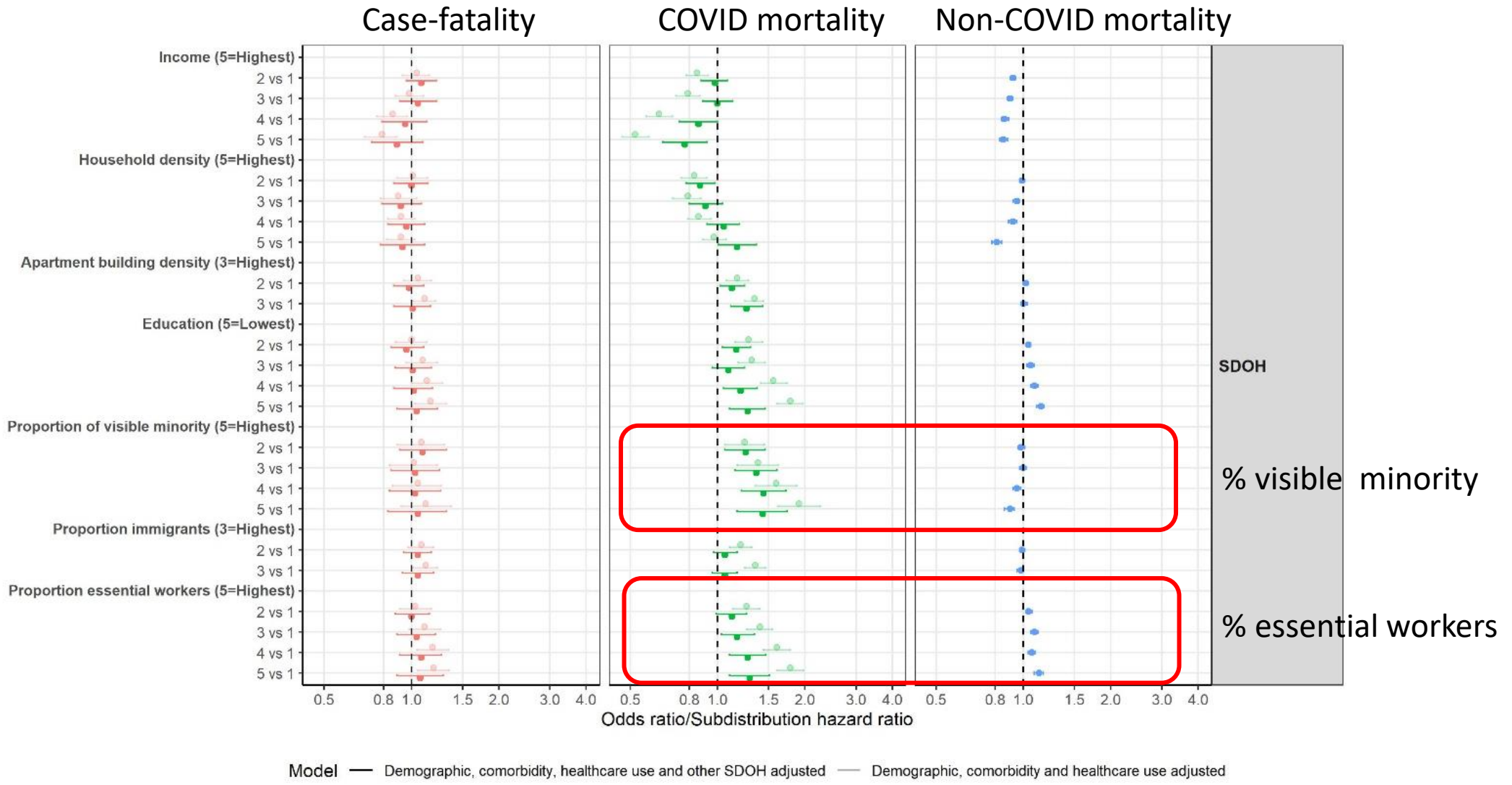
Consequences: cumulative (adjusted) marginal probability of COVID-death with non-COVID death as a competing risk

Persons living in lowest vs highest income neighbourhoods: 2x higher chance of acquiring & dying with COVID

Marginal cumulative incidence function estimated from Fine & Grey regression model adjusted for demographics including age, sex, rural/urban, public health unit, and baseline health conditions (a set of comorbidities, and prior hospitalization and outpatient visits).

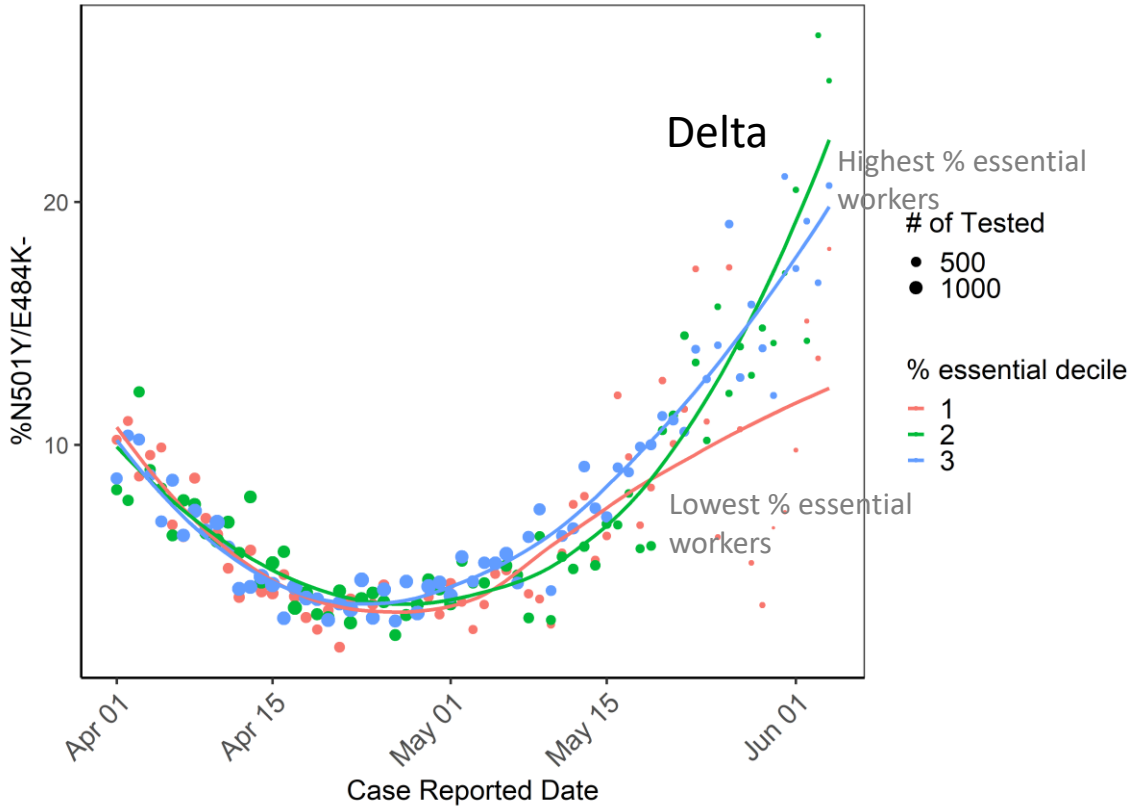
Wang L et al, in preparation

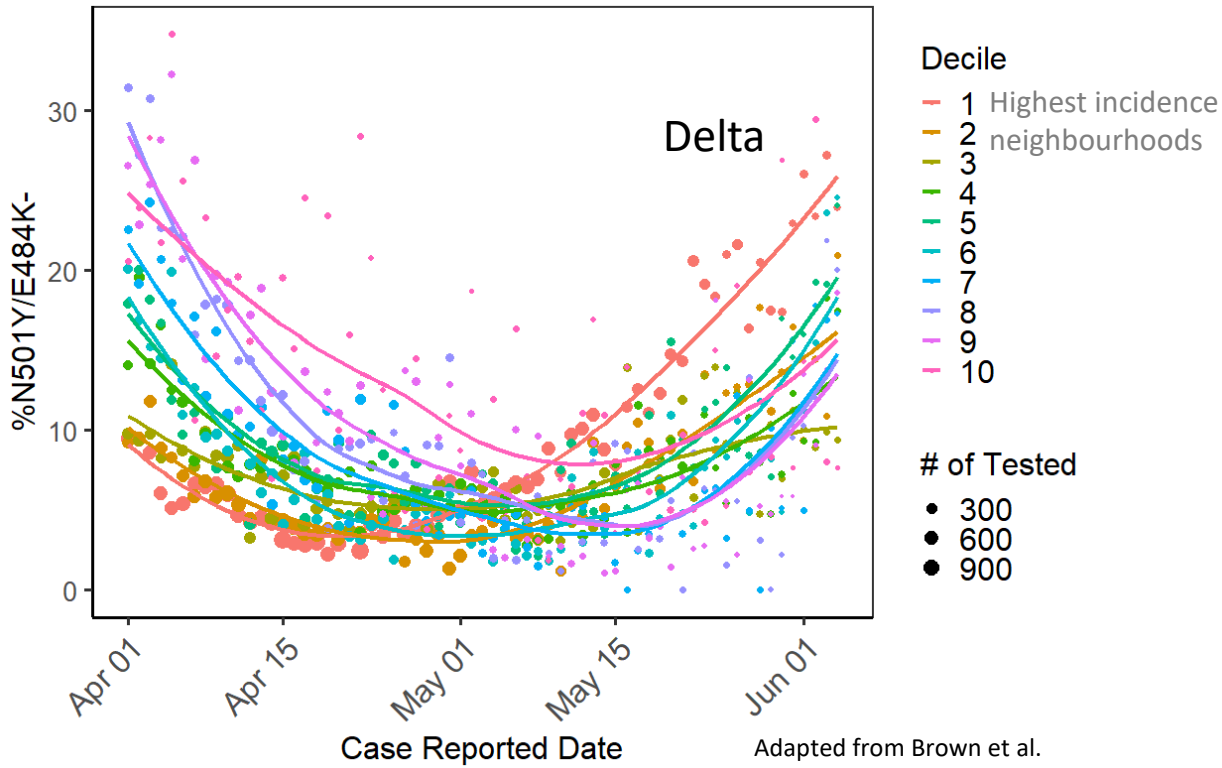
…with similar cumulative incidence of non-COVID mortality



Wang L et al, in preparation

Consequences: emergence & propagation of variants of concern

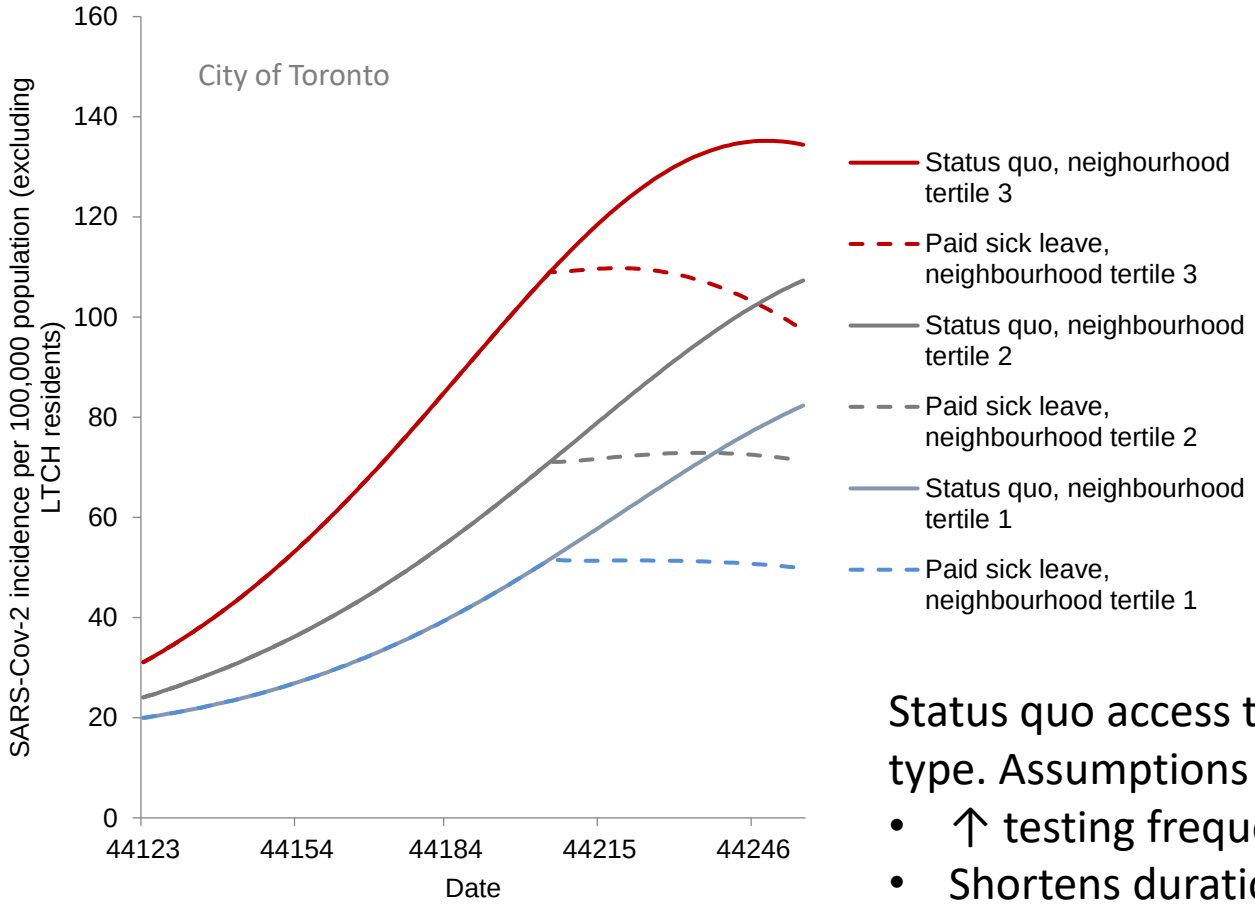




Adapted from Brown et al. https://www.medrxiv.org/content/10.1101/2021.06.22.21259349v1

Stein & Ma et al, in preparation

Implications: potential spillover benefit of addressing underlying social and/or structural inequalities



Neighbourhood strata 3: 58% work in essential services & 16% of households are multigenerational

Neighbourhood strata 2: 39% work in essential services & 7% of households are multigenerational

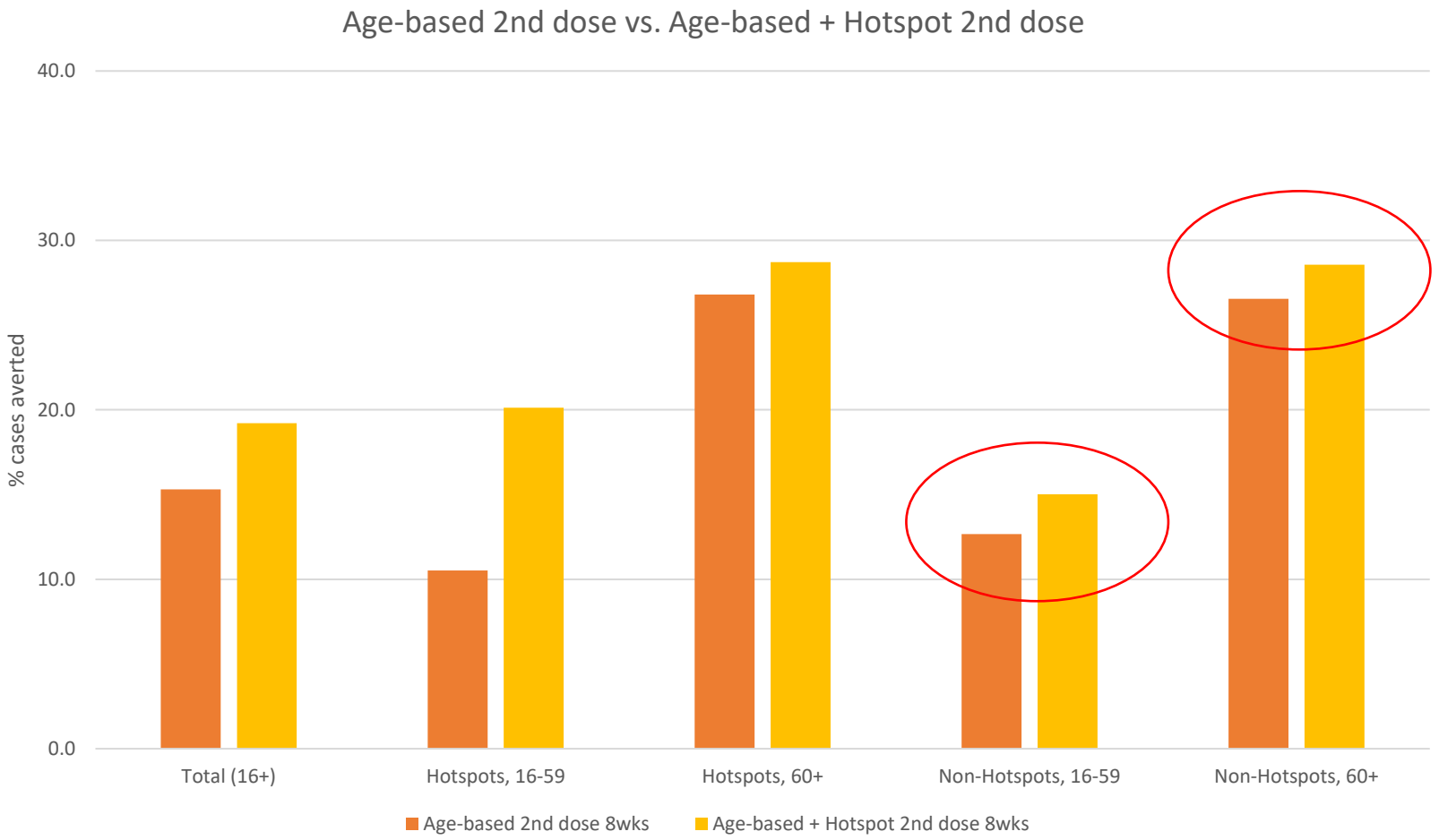
Neighbourhood strata 1: 21% work in essential services & 2% of households are multigenerational

Status quo access to paid sick leave weighted probability by income & occupation type. Assumptions re: mechanisms of effect via intervention

- ↑ testing frequency if symptomatic by 10-20%
- Shortens duration from symptomatic to isolation by 1-4 days
- Shortens duration from symptomatic to isolation by 1-4 days in same household

Mishra & Ma et al, in preparation

Implications: potential spillover benefit of prioritizing (resource allocation) & tailoring an intervention to reach communities experiencing disproportionate risks of acquisition and onward transmission



"spillover" protection:
≈42% of the additional cases averted are from preventing spillover into non-hotspots (i.e. indirect benefit *to* non-hotspots from 2nd-doses in hotspots)

1. Causes & (epidemic) consequences of heterogeneity in risks of acquisition & onward transmission & severity
2. Causes & (epidemic) consequences of heterogeneity in interventions → design → reach → effectiveness

For whom did we design (and implement) the public health response to COVID?

Implementation specifics → performative vs. actualized

"The promise of biomedical panaceas is deeply ingrained in the U.S. psyche, but COVID should have shown that **medical magic bullets lose their power when deployed in a profoundly unequal society**. There are other ways of thinking about preparedness. And there are reasons those ways were lost." *Ed Yong*

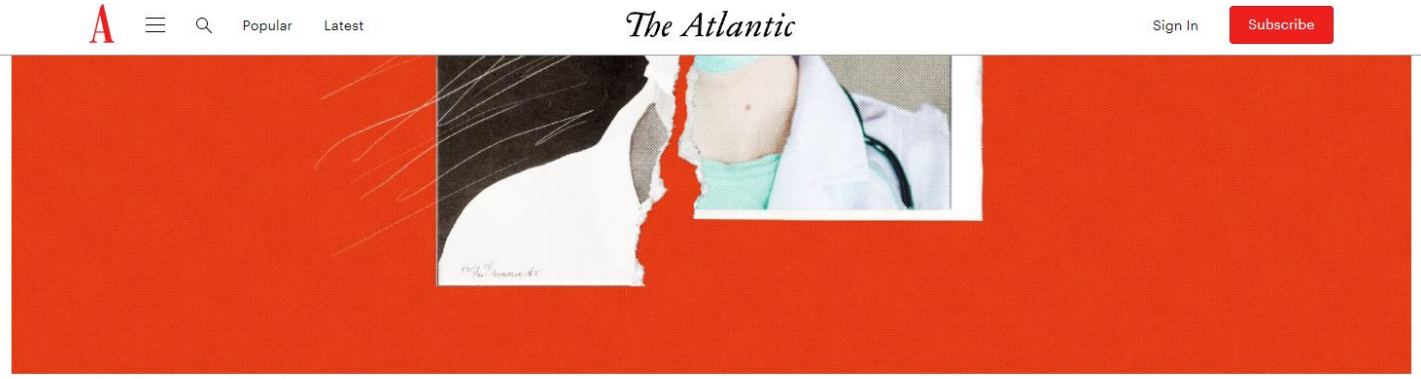


Photo illustrations by Ben Shmulevitch

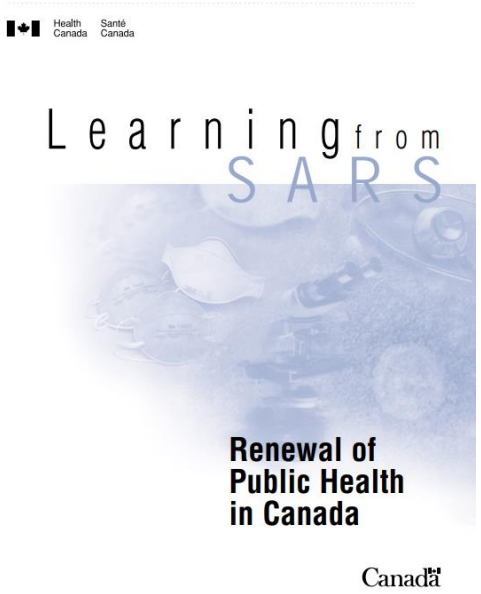
HEALTH

WE'RE ALREADY BARRELING TOWARD THE NEXT PANDEMIC

This one is far from over, but the window to prepare for future threats is closing fast.

By Ed Yong

https://www.theatlantic.com/health/archive/2021/09/america-prepared-next-pandemic/620238/



https://www.canada.ca/content/dam/phac-aspc/migration/phac-aspc/publicat/sars-sras/pdf/sars-e.pdf

Who was (is) at the table informing, designing, and implementing, the public health response to COVID?

…to public health emergencies?
…to emerging outbreaks & epidemics?

Heterogeneity in COVID-19 Research Group

Stefan Baral, Huiting Ma, Jesse Knight, Linwei Wang, Mackenzie Hamilton, Kristy Yiu, Beate Sander, Jeff Kwong

Gary Moloney, Andrew Calzavera, Rafal Kustra, Siyi Wang, Dariya Darvin, David Landsman, Adrienne Chan, Maria Sundaram, Sharon Straus, Stephen Hwang, Mohamed Djebli, Zain Chagla, Janet Smylie

Matheiu Maheu-Giroux, Yiqing Xia, Simon de Montigny, Marie-Claude Boily, Marc Brisson, Alan Katz, Tyler Williamson, Catherine Eastwood, David Vickers, Guosong Wu, Naveed Janjua, Michael Otterstater, Notice Ringa, Mel Krajden, Caroline Colijn, Kamran Khan, Isaac Bogoch, Allison McGeer

- Ontario COVID-19 Science Table, Peter Juni
- Ontario Community Health Partnership Profiles
- ICES
- MAP Centre for Urban Health Solutions, St. Michael's Hospital, Li Ka Shing Knowledge Institute
- Dalla Lana School of Public Health, University of Toronto

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