

COVID-19 hospitalization, mortality and pre-mature mortality by a history of immigration in Ontario, Canada: a population-based cohort study



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Summary

Background Immigrants in high-income countries experienced inequities in COVID-19 severe outcomes. We examined hospitalization and death throughout the pandemic, and change during the vaccine era, in Ontario, Canada.

Methods We conducted a population-based study using linked immigration and health data, following two cohorts for 20 months from January 1, 2020 (pre-vaccine) and September 1, 2021 (vaccine era). We used multivariable Poisson generalized estimating equation regression to estimate adjusted rate ratios (aRR) with 95% confidence intervals (CI), accounting for age, sex and co-morbidities. We calculated age-standardized years of life lost (ASYRs) rates by immigrant category.

Findings Of 11,692,387 community-dwelling adults in the pre-vaccine era cohort and 11,878,304 community-dwelling adults in the vaccine era cohort, 21.6% and 21.4% of adults in each era respectively were immigrants. Females accounted for 57.9% and 57.8% of sponsored family, and 68.4% and 67.6% of economic caregivers, in each era respectively. Compared to other Ontarians in the pre-vaccine era cohort, hospitalization rates were highest for refugees (aRR [95% CI] 3.41 [3.39–3.44]) and caregivers (3.13 [3.07–3.18]), followed by sponsored family and other economic immigrants. Compared to other Ontarians, aRRs were highest for immigrants from Central America (5.00 [4.92–5.09]), parts of South Asia (3.95 [3.89–4.01]) and Jamaica (3.56 [3.51–3.61]) with East Asians having lower aRRs. Mortality aRRs were similar to hospitalization aRRs. In the vaccine era, all aRRs were attenuated and most were similar to or lower than other Ontarians, with refugees and a few regions maintaining higher rates. In the pre-vaccine era ASYRs were higher for all immigrant groups. ASYRs dropped in the vaccine era with only refugees continuing to have higher rates.

Interpretation Immigrants, particularly refugees, experienced greater premature mortality. aRRs for most immigrant groups dropped substantially after high vaccine coverage was achieved. Vaccine outreach and improvements in the social determinants of health are needed.

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Research in context

Evidence before this study

To identify quantitative research examining COVID-19 hospitalization and mortality among immigrant populations, we searched MEDLINE, EMBASE, and Web of Science for articles published in any language between January 1, 2020 to July 1, 2023 using a combination of key terms related to: (1) Im/migrants and/or refugees (2) hospitalization/mortality/pre-mature mortality, and (3) COVID-19 and SARS-CoV-2. This search yielded 248 articles in MEDLINE, 622 in EMBASE and 218 in Web of Science. From this search we identified fifteen relevant population-based studies published in high-income countries. These studies included mostly data from only the first wave with five studies examining COVID-19 hospitalization and eleven mortality (COVID-19 specific or all-cause [pandemic vs. pre-pandemic]). These studies found that immigrants overall and from certain countries/regions of origin experienced greater risk or a disproportionate burden of these outcomes compared to non-immigrants. We separately identified a review published by the Organization for Economic Co-Operation and Development which described that immigrants in high-income countries experienced greater risk of COVID-19 hospitalization and mortality due to employment in frontline jobs, exposure to unsafe working conditions, residence in higher density neighborhoods, multi-generational housing, and a lack of accessible quality healthcare. A limited number of second

wave studies suggested that increased risks among immigrants persisted beyond the first wave.

Added value of this study

In Canada as of 2021, 23% of the population was foreign-born, with one of the most diverse immigrant populations in the world. About half of Canada's foreign-born population resides in Ontario, the country's most populous province (~15 million people). To our knowledge our study has the largest population of adult immigrants in the literature to date. In addition, ours is the only study to examine severe outcomes occurring throughout the duration of the pandemic until the end of April 2023, to examine premature mortality due to COVID-19 and examine risks of severe outcomes by detailed immigration categories and highly disaggregated regions of birth representing immigrants from across the globe.

Implications of all the available evidence

Refugees and immigrants from specific countries/regions of birth may continue to benefit from structurally, culturally and linguistically appropriate public health prevention efforts including COVID-19 boosters. Policies supporting access to decent work and safe workplaces for immigrants and refugees in Canada and many other high-income countries are also needed to mitigate inequities in future pandemics.

Introduction

The COVID-19 pandemic has heightened our awareness of the critical importance of the social determinants of health and the structural conditions (systemic racism, neoliberal labour market conditions) which shape them. Immigration is an under-recognized structural determinant of health.¹ An August 2022 review described that immigrants in high-income countries experienced lower rates of SARS-CoV-2 testing, higher SARS-CoV-2 incidence and greater risk of COVID-19 hospitalization and mortality due to employment in frontline jobs, exposure to unsafe working conditions, residence in higher density neighborhoods, multi-generational housing, and a lack of accessible quality healthcare.² Population-based studies in high-income countries,^{3–18} mostly from the first wave, found that immigrants overall^{3,4,6,7,11} and from certain countries/regions of origin^{4,5,7–13,15–18} experienced greater risk or a disproportionate burden of COVID-19 hospitalization and mortality compared to non-immigrants. A limited number of studies found that increased risks persisted into the second wave.² Early evidence demonstrated that COVID-19 outcomes were associated with older age, male sex, race/ethnicity (i.e., South Asian, Black) and several co-morbidities including diabetes,

obesity, respiratory disease including asthma, recent cancer, kidney and liver disease and autoimmune conditions.^{19,20}

Permanent and temporary immigration to Canada is considered critical for the country's economic growth. To address labour shortages, the number of permanent residents admitted, typically 250,000–300,000 per year, has increased to 465,000 in 2023 and will go up to 500,000 in 2025. Each year about 50% of Canada's permanent residents settle in Ontario, the country's most populous province (15.5 million) where ~30% of the population is foreign-born.²¹ In the last forty years, 80% of permanent residents have self-identified as being a member of a racialized (non-white) group²¹ whose experiences of racism are considered a critical factor in SARS-CoV-2 risk and COVID-19 severe outcomes in many countries.²²

Permanent residents enter Canada under three main categories—economic (~60% of all permanent residents per year), sponsored family (~30%) and refugee (~10%). Economic immigrants, including the caregiver class (~10% of all economic immigrants), are generally selected based on a lack of pre-existing medical conditions, high levels of education/training and knowledge

of Canada's official languages as well as the ability to contribute to the economy. Entry criteria for sponsored family and refugees are generally not dependent on economic value. Economic caregivers enter as temporary foreign workers employed in the care of children or people with high medical needs. A survey of 631 Filipino caregivers from across Canada who became permanent residents described that many remained in care work; some retrained as personal support workers, or transitioned to low-wage jobs (e.g., sales).²³ Given the frontline nature of their employment, particularly in long-term care homes and other health care settings,²⁴ the impact of the COVID-19 pandemic on the caregiver class is particularly salient.

Despite the World Health Organization declaring the COVID-19 pandemic over recently (May 2023), most studies on severe outcomes among immigrants include data from only the first wave and do not overlap with the availability of COVID-19 vaccines, limiting our understanding of the cumulative impact of these outcomes among immigrants, and whether vaccines mitigated these impacts. We recently demonstrated²⁵ that immigrants overall had similar two-dose COVID-19 vaccine coverage as other residents of Ontario with some significant variability by region of birth, but much lower three-dose coverage overall and across almost all regions of birth. It is unclear how COVID-19 severe outcomes among immigrants in Canada or elsewhere were impacted by COVID-19 vaccine coverage. Our objective was to examine rates of COVID-19 hospitalization, mortality and pre-mature mortality among adults in Ontario, Canada, by immigration category and region of birth, before and after widespread availability of COVID-19 vaccines. We had four aims. First, we compared the rates of COVID-19 hospitalization and mortality among refugees, economic caregivers and sponsored family to those of other Ontario residents. Second, we compared the rates of COVID-19 hospitalization and mortality of regions and countries of birth for which immigrants were more likely to be members of racialized groups (based on the Canadian census) to those of other Ontario residents and immigrants from Europe, United States, Oceania and others who were more likely to be white. Third, we compared COVID-19 hospitalization and mortality rate ratios from the vaccine era to the pre-vaccine era. Finally, we compared rates of age-adjusted years of life lost for refugees and caregivers to those of other economic immigrants and other Ontarians.

Methods

Population and setting

We conducted a population-based cohort study of all community-dwelling residents of Ontario, Canada who were ≥ 18 years old, residents of Ontario and eligible for publicly funded, single-payer health insurance on their cohort initiation date. We examined separate cohorts in

the pre-vaccine and vaccine eras. The pre-vaccine era cohort was followed from January 1, 2020 to August 31, 2021, and the vaccine era cohort was followed from September 1, 2021 to April 30, 2023, allowing a maximum of 20 months of follow-up each. We excluded residents < 65 years old who had no contact with the healthcare system in the 9 years prior to the index date and residents ≥ 65 years old who had no contact in the previous 3 years as they were likely not living in Ontario on their cohort initiation date. See [Supplementary Fig. S1a and b](#) for exclusions and cohort selection. We followed the RECORD²⁶ reporting guidelines.

Data sources

Ontario's health system provides access to most medically necessary health-care services. We linked demographic and healthcare administrative databases held at ICES to identify the populations of interest and operationalize outcomes, exposures and covariates. ICES is an independent, non-profit research institute whose legal status under Ontario's health information privacy law allows it to collect and analyze health care and demographic data, without consent, for health system evaluation. Details of the databases used in this study and associated study measures are described in [Supplementary Tables S1 and S2](#), respectively.

Immigrants and refugees were identified using the Ontario portion of the Immigration, Refugees and Citizenship Canada (IRCC) Permanent Resident Database. The healthcare registry (Ontario Health Insurance Program [OHIP] Registered Persons Database [RPDB]) includes information on all Ontario residents who have been eligible for healthcare since 1990. The overall linkage rate between the IRCC database and the OHIP-RPD was 87.0% for both the pre-vaccine and vaccine era cohorts (see [Supplementary Fig. S1a and b](#)). There were few differences in characteristics between immigrants who linked to the healthcare registry compared to those who were not, suggesting minimal linkage bias.²⁷ Study outcomes were captured by Public Health Ontario's Case and Contact Management (CCM) database, a central data repository for mandatory reporting of diseases of public health significance (including COVID-19) to the Ministry of Health by all of Ontario's public health units. Select co-morbidities were based on OHIP physician billing claims and Canadian Institutes for Health Information (CIHI) databases including the Discharge Abstract Database (DAD), Same Day Survey (SDS) Database, National Ambulatory Care Reporting System (NACRS). Neighborhood level characteristics were captured from the Statistics Canada Census.

Measures

Primary exposure

Persons with a history of immigration, receiving permanent residency between January 1, 1985 and September 30, 2020 (henceforth referred to as "immigrants"), were

categorized by their immigration pathway as available in the IRCC database (refugee, sponsored family, economic caregiver and other economic immigrants), and compared to all other residents in Ontario not identified in the IRCC database (“other Ontarians”). Immigration pathways delineate differences in how immigrants are selected and relate broadly to their types of employment and socio-economic status after arrival.

Secondary exposure

Twenty country/region of birth groupings were created (based on country of birth available in the IRCC database) to acknowledge some collective identity among countries within the groups as well as relate each to the proportion who self-identified as a member of a racialized or non-racialized group. We did this using data from the Statistics Canada 2016 Census on immigration status and racialized identity (i.e., “visible minority”, which does not include Indigenous identity) (see [Supplementary Fig. S2](#)). Briefly, immigrants from the US, Australia, Oceania and Europe predominately (>75%) self-identified as white whereas immigrants from all other regions predominately self-identified (>70%) as racialized. “Other Ontarians” were predominately (86.4%) white (see “Canada” place of birth in [Supplementary Fig. S2](#)) and were conceptualized as experiencing less marginalization than immigrants.

Outcomes

This study had three outcomes of interest—any COVID-19 hospitalization, COVID-19 mortality, and age-standardized years of life lost (ASYR) due to COVID. Residents were followed from the index date to the date of COVID-19 hospitalization, or mortality and were censored for migration out of the province, non-COVID death or at 20 months of follow-up.

Covariates

Covariates available for both immigrants and other Ontario residents (not identified in the IRCC database) included age, sex (male/female), rurality, neighborhood level characteristics and relevant co-morbidities. Neighborhood level socio-demographic characteristics were measured at the dissemination-area level (400–700 people), derived from the Statistics Canada census and categorized into quintiles. These characteristics included: average household income, the proportion employed in essential services, average household density, the proportion who self-identified as a member of a racialized (“visible minority”) group and the proportion with limited educational attainment. Relevant co-morbidities were asthma²⁸ and chronic obstructive pulmonary disease,²⁹ chronic kidney disease (see [Supplementary Table S3](#) for the list of diagnosis and billing codes), diabetes,³⁰ congestive heart failure,³¹ immunodeficiency conditions,³² inflammatory bowel disease,³³ liver disease³⁴ (see [Supplementary Table S4](#) for list of diagnosis and

billing codes) and cancer diagnosis in the previous five years. For immigrants only, we examined detailed immigration sub-categories and duration of residence.

Statistical analysis

For both cohorts, we calculated standardized differences (SD) to assess balance in measured covariates compared to other Ontario residents; groups were considered balanced when SDs ≤ 0.1 . We also calculated COVID-19 hospitalization and mortality rates per 100,000 person-years of follow-up, stratified by immigration category and country/region of birth.

We conducted multivariable Poisson generalized estimating equation (GEE) regression to estimate hospitalization and mortality rate ratios (aRR) with 95% confidence intervals (CI), by immigration category and country/region of birth with the reference being “other Ontarians”, separately by cohort. We adjusted all models for age, sex, and select co-morbidities (i.e., asthma/chronic obstructive pulmonary disorder; chronic kidney disease; diabetes; congestive heart failure; immunocompromised; inflammatory bowel disease; liver disease; cancer in the last five years). These were chosen based on known risk factors,^{19,20} the data available and fulfilled the usual criteria for confounders.³⁵ Since the development of some co-morbid conditions may be a consequence of social disadvantage and are also important risk factors for severe COVID-19 outcomes, we conceptualized these as partially mediating as well as confounding the relationship between the immigration variables and COVID-19 outcomes. We present models with and without co-morbidity adjustment to acknowledge this causal pathway. Neighborhood sociodemographic variables were not used to adjust estimates in multivariable models since they are more a direct consequence of immigration and racialized status and were likely in the causal pathway.

We used methods adapted from the Global Burden of Disease Study³⁶ to calculate crude potential years of life lost (PYLL) and age-standardized potential years of life lost (ASYR) with 95% confidence intervals³⁷ due to COVID-19 by immigration category in each cohort. We used standard life expectancy values by age published by the World Health Organization in 2017 along with population weights at each age based on the eligible study population in Ontario as of the index date of each cohort.

All statistical analyses were conducted in SAS 9.4.

Research ethics

The use of the data in this project is authorized under section 45 of Ontario’s Personal Health Information Protection Act (PHIPA) and does not require review by a Research Ethics Board.

Role of the funding source

The funders had no role in the study design, data collection, data analysis, interpretation or writing of this report.

Characteristic	Persons with a history of Immigration (1985–2020)				Other Ontario residents	Standardized differences ^a (vs. Other ON residents)			
	Refugees	Sponsored family	Economic caregiver	All other economic		Refugees	Sponsored family	Economic caregiver	All other economic
N (% of total population)	458,867 (3.9%)	887,191 (7.6%)	100,298 (0.9%)	1,090,561 (9.3%)	9,155,470 (78.3%)				
Censoring reason									
Death	2944 (0.6%)	8251 (0.9%)	205 (0.2%)	3397 (0.3%)	140,495 (1.5%)				
Left province	2281 (0.5%)	4008 (0.5%)	491 (0.5%)	7586 (0.7%)	87,552 (1.0%)				
Follow-up Time (years)									
Mean ± SD	1.66 ± 0.11	1.65 ± 0.12	1.66 ± 0.10	1.66 ± 0.11	1.64 ± 0.17				
Median (IQR)	2 (2–2)	2 (2–2)	2 (2–2)	2 (2–2)	2 (2–2)				
Age (years) ^b									
Mean ± SD	45.34 ± 15.34	48.86 ± 16.75	41.34 ± 12.80	44.01 ± 14.27	49.00 ± 18.93	0.21	0.01	0.47	0.3
Median (IQR)	45 (33–57)	46 (36–60)	42 (32–50)	44 (32–55)	49 (32–64)	0.2	0.01	0.46	0.27
Age group (years) ^b									
18–29	75,112 (16.4%)	86,011 (9.7%)	19,619 (19.6%)	188,889 (17.3%)	1,711,530 (18.7%)	0.06	0.26	0.02	0.04
30–39	104,861 (22.9%)	220,680 (24.9%)	21,851 (21.8%)	271,518 (24.9%)	1,588,237 (17.3%)	0.14	0.19	0.11	0.19
40–49	92,299 (20.1%)	203,183 (22.9%)	31,171 (31.1%)	222,215 (20.4%)	1,345,416 (14.7%)	0.14	0.21	0.4	0.15
50–59	99,730 (21.7%)	151,018 (17.0%)	20,422 (20.4%)	232,343 (21.3%)	1,582,853 (17.3%)	0.11	0.01	0.08	0.1
60–69	59,934 (13.1%)	97,136 (10.9%)	6230 (6.2%)	138,033 (12.7%)	1,442,545 (15.8%)	0.08	0.14	0.31	0.09
70–79	18,967 (4.1%)	78,674 (8.9%)	918 (0.9%)	32,949 (3.0%)	964,556 (10.5%)	0.25	0.06	0.42	0.3
80+	7964 (1.7%)	50,489 (5.7%)	87 (0.1%)	4614 (0.4%)	520,333 (5.7%)	0.21	0	0.34	0.31
Sex									
Female	216,894 (47.3%)	513,663 (57.9%)	68,562 (68.4%)	524,272 (48.1%)	4,665,549 (51.0%)	0.07	0.14	0.36	0.06
Male	241,973 (52.7%)	373,528 (42.1%)	31,736 (31.6%)	566,289 (51.9%)	4,489,921 (49.0%)	0.07	0.14	0.36	0.06
Immigration sub-category									
Government assisted refugee & Blended visa office referred	86,401 (18.8%)	n/a	n/a	n/a	n/a				
Privately sponsored refugee	108,488 (23.6%)	n/a	n/a	n/a	n/a				
Protected persons (successful asylum-seekers)	169,102 (36.9%)	n/a	n/a	n/a	n/a				
Dependents of protected persons	52,519 (11.4%)	n/a	n/a	n/a	n/a				
Other refugees	42,357 (9.2%)	n/a	n/a	n/a	n/a				
Spouse	n/a	540,201 (60.9%)	n/a	n/a	n/a				
Child	n/a	78,618 (8.9%)	n/a	n/a	n/a				
Parent	n/a	245,570 (27.7%)	n/a	n/a	n/a				
Other	n/a	22,802 (2.6%)	n/a	n/a	n/a				
Entrepreneur	n/a	n/a	n/a	67,382 (6.2%)	n/a				
Skilled	n/a	n/a	n/a	428,995 (39.3%)	n/a				
Caregiver	n/a	n/a	100,298 (100.0%)	n/a	n/a				
Family	n/a	n/a	n/a	163,500 (15.0%)	n/a				
Other	n/a	n/a	n/a	430,684 (39.5%)	n/a				

(Table 1 continues on next page)

Characteristic	Persons with a history of Immigration (1985–2020)				Other Ontario residents	Standardized differences ^a (vs. Other ON residents)			
	Refugees	Sponsored family	Economic caregiver	All other economic		Refugees	Sponsored family	Economic caregiver	All other economic
(Continued from previous page)									
Region/Country of Birth ^c									
Jamaica	2499 (0.5%)	58,104 (6.5%)	935 (0.9%)	14,324 (1.3%)	n/a				
Other Caribbean and Bermuda	12,794 (2.8%)	40,600 (4.6%)	856 (0.9%)	21,304 (2.0%)	n/a				
East Africa	46,339 (10.1%)	18,540 (2.1%)	284 (0.3%)	15,658 (1.4%)	n/a				
Other Africa	21,155 (4.6%)	21,748 (2.5%)	275 (0.3%)	28,604 (2.6%)	n/a				
South America	25,798 (5.6%)	61,456 (6.9%)	946 (0.9%)	38,766 (3.6%)	n/a				
Central America	21,245 (4.6%)	19,051 (2.1%)	179 (0.2%)	10,890 (1.0%)	n/a				
Iran	19,268 (4.2%)	16,162 (1.8%)	46 (0.0%)	44,462 (4.1%)	n/a				
Other West & Central Asia & Middle East	73,615 (16.0%)	33,819 (3.8%)	397 (0.4%)	75,435 (6.9%)	n/a				
North Africa	9607 (2.1%)	9161 (1.0%)	123 (0.1%)	24,486 (2.2%)	n/a				
Philippines	1456 (0.3%)	58,525 (6.6%)	90,422 (90.2%)	63,262 (5.8%)	n/a				
Other Southeast Asia	15,404 (3.4%)	36,020 (4.1%)	325 (0.3%)	12,714 (1.2%)	n/a				
China	26,258 (5.7%)	97,356 (11.0%)	1337 (1.3%)	131,940 (12.1%)	n/a				
Hong Kong	2377 (0.5%)	13,552 (1.5%)	180 (0.2%)	36,770 (3.4%)	n/a				
Other East Asia	2344 (0.5%)	14,309 (1.6%)	176 (0.2%)	38,769 (3.6%)	n/a				
India	7183 (1.6%)	142,389 (16.0%)	1050 (1.0%)	206,040 (18.9%)	n/a				
Sri Lanka	44,318 (9.7%)	34,483 (3.9%)	239 (0.2%)	15,096 (1.4%)	n/a				
Pakistan	18,085 (3.9%)	40,503 (4.6%)	137 (0.1%)	76,094 (7.0%)	n/a				
Other South Asia	31,394 (6.8%)	18,097 (2.0%)	256 (0.3%)	27,317 (2.5%)	n/a				
North America & Australasia & Oceania	3286 (0.7%)	33,660 (3.8%)	91 (0.1%)	18,729 (1.7%)	n/a				
Europe	74,308 (16.2%)	119,413 (13.5%)	2009 (2.0%)	189,787 (17.4%)	n/a				
Not stated	134 (0.0%)	243 (0.0%)	35 (0.0%)	114 (0.0%)	n/a				
Duration of residence									
0 to ≤ 10 years	133,280 (29.0%)	272,793 (30.7%)	48,415 (48.3%)	289,257 (26.5%)	n/a				
>10 to ≤ 20 years	139,432 (30.4%)	278,798 (31.4%)	38,915 (38.8%)	420,643 (38.6%)	n/a				
>20 years	186,155 (40.6%)	335,600 (37.8%)	12,968 (12.9%)	380,661 (34.9%)	n/a				
Household Income Quintile ^d									
1 (lowest)	161,102 (35.1%)	216,952 (24.5%)	43,230 (43.1%)	205,945 (18.9%)	1,650,545 (18.0%)	0.39	0.16	0.57	0.02
2	100,297 (21.9%)	200,171 (22.6%)	24,445 (24.4%)	216,534 (19.9%)	1,770,693 (19.3%)	0.06	0.08	0.12	0.01
3	84,384 (18.4%)	196,252 (22.1%)	15,276 (15.2%)	233,337 (21.4%)	1,826,420 (19.9%)	0.04	0.05	0.12	0.04
4	69,937 (15.2%)	159,833 (18.0%)	10,064 (10.0%)	236,128 (21.7%)	1,872,511 (20.5%)	0.14	0.06	0.29	0.03
5 (highest)	41,665 (9.1%)	111,428 (12.6%)	7186 (7.2%)	194,551 (17.8%)	2,005,344 (21.9%)	0.36	0.25	0.43	0.1
Suppressed/missing	1482 (0.3%)	2555 (0.3%)	97 (0.1%)	4066 (0.4%)	29,957 (0.3%)	0	0.01	0.05	0.01
Employment in Essential Services Quintile ^d									
1 (lowest)	68,570 (14.9%)	162,276 (18.3%)	13,325 (13.3%)	333,987 (30.6%)	1,914,667 (20.9%)	0.16	0.07	0.2	0.22
2	99,581 (21.7%)	201,248 (22.7%)	18,335 (18.3%)	291,437 (26.7%)	1,987,582 (21.7%)	0	0.02	0.09	0.12
3	90,281 (19.7%)	169,370 (19.1%)	21,850 (21.8%)	188,338 (17.3%)	1,846,398 (20.2%)	0.01	0.03	0.04	0.07

(Table 1 continues on next page)

Characteristic	Persons with a history of Immigration (1985-2020)				Other Ontario residents	Standardized differences ^a (vs. Other ON residents)			
	Refugees	Sponsored family	Economic caregiver	All other economic		Refugees	Sponsored family	Economic caregiver	All other economic
(Continued from previous page)									
4	93,756 (20.4%)	176,553 (19.9%)	25,394 (25.3%)	155,941 (14.3%)	1,760,317 (19.2%)	0.03	0.02	0.15	0.13
5 (highest)	105,014 (22.9%)	174,820 (19.7%)	21,266 (21.2%)	116,256 (10.7%)	1,597,270 (17.4%)	0.14	0.06	0.1	0.2
Suppressed/missing	1665 (0.4%)	2924 (0.3%)	128 (0.1%)	4602 (0.4%)	49,236 (0.5%)	0.03	0.03	0.07	0.02
Household Density Quintile ^d									
1 (lowest)	74,235 (16.2%)	113,737 (12.8%)	16,192 (16.1%)	180,012 (16.5%)	1,864,729 (20.4%)	0.11	0.2	0.11	0.1
2	57,513 (12.5%)	89,387 (10.1%)	14,550 (14.5%)	101,065 (9.3%)	1,786,052 (19.5%)	0.19	0.27	0.13	0.29
3	43,405 (9.5%)	72,363 (8.2%)	12,812 (12.8%)	84,495 (7.7%)	1,362,639 (14.9%)	0.17	0.21	0.06	0.23
4	104,355 (22.7%)	183,592 (20.7%)	29,433 (29.3%)	220,707 (20.2%)	2,201,530 (24.0%)	0.03	0.08	0.12	0.09
5 (highest)	177,560 (38.7%)	425,024 (47.9%)	27,170 (27.1%)	499,249 (45.8%)	1,886,472 (20.6%)	0.4	0.6	0.15	0.55
Suppressed/missing	1799 (0.4%)	3088 (0.3%)	141 (0.1%)	5033 (0.5%)	54,048 (0.6%)	0.03	0.04	0.07	0.02
Racialized population ("Visible Minority") Quintile ^{d,e}									
1 (lowest)	7447 (1.6%)	23,933 (2.7%)	1439 (1.4%)	21,801 (2.0%)	1,766,992 (19.3%)	0.6	0.55	0.61	0.58
2	18,143 (4.0%)	41,875 (4.7%)	3571 (3.6%)	42,519 (3.9%)	1,836,579 (20.1%)	0.51	0.48	0.53	0.51
3	49,124 (10.7%)	86,552 (9.8%)	9515 (9.5%)	105,317 (9.7%)	1,844,487 (20.1%)	0.26	0.29	0.3	0.3
4	124,146 (27.1%)	197,566 (22.3%)	25,167 (25.1%)	280,116 (25.7%)	1,928,056 (21.1%)	0.14	0.03	0.1	0.11
5 (highest)	258,345 (56.3%)	534,347 (60.2%)	60,478 (60.3%)	636,207 (58.3%)	1,730,332 (18.9%)	0.84	0.93	0.93	0.89
Suppressed/missing	1662 (0.4%)	2918 (0.3%)	128 (0.1%)	4601 (0.4%)	49,024 (0.5%)	0.03	0.03	0.07	0.02
Limited educational attainment quintile ^d									
1 (lowest)	62,779 (13.7%)	149,119 (16.8%)	18,726 (18.7%)	307,696 (28.2%)	1,923,114 (21.0%)	0.19	0.11	0.06	0.17
2	86,645 (18.9%)	170,083 (19.2%)	19,605 (19.5%)	263,970 (24.2%)	1,970,362 (21.5%)	0.07	0.06	0.05	0.06
3	96,033 (20.9%)	193,677 (21.8%)	20,273 (20.2%)	224,052 (20.5%)	1,912,605 (20.9%)	0	0.02	0.02	0.01
4	97,042 (21.1%)	189,090 (21.3%)	21,642 (21.6%)	170,075 (15.6%)	1,772,311 (19.4%)	0.04	0.05	0.06	0.1
5 (highest)	114,705 (25.0%)	182,298 (20.5%)	19,924 (19.9%)	120,166 (11.0%)	1,527,895 (16.7%)	0.21	0.1	0.08	0.16
Suppressed/missing	1663 (0.4%)	2924 (0.3%)	128 (0.1%)	4602 (0.4%)	49,183 (0.5%)	0.03	0.03	0.07	0.02
Rurality									
Urban	453,627 (98.9%)	869,584 (98.0%)	99,364 (99.1%)	1,072,153 (98.3%)	7,969,623 (87.0%)	0.47	0.43	0.49	0.44
Rural	3772 (0.8%)	15,081 (1.7%)	839 (0.8%)	14,379 (1.3%)	1,160,029 (12.7%)	0.49	0.43	0.49	0.46
Missing	1468 (0.3%)	2526 (0.3%)	95 (0.1%)	4029 (0.4%)	25,818 (0.3%)	0.01	0	0.04	0.02
Co-morbidities									
Asthma & Chronic obstructive pulmonary disease	53,206 (11.6%)	90,267 (10.2%)	5063 (5.0%)	95,050 (8.7%)	2,116,502 (23.1%)	0.31	0.35	0.54	0.4
Chronic kidney disease (incl chronic dialysis)	9191 (2.0%)	24,470 (2.8%)	1229 (1.2%)	15,363 (1.4%)	240,034 (2.6%)	0.04	0.01	0.1	0.09
Diabetes	63,072 (13.7%)	129,619 (14.6%)	8655 (8.6%)	117,493 (10.8%)	1,057,899 (11.6%)	0.07	0.09	0.1	0.02
Congestive heart failure	99,097 (21.6%)	224,006 (25.2%)	18,048 (18.0%)	205,084 (18.8%)	2,503,838 (27.3%)	0.13	0.05	0.22	0.2
Immunocompromised	5072 (1.1%)	6236 (0.7%)	363 (0.4%)	5594 (0.5%)	90,813 (1.0%)	0.01	0.03	0.08	0.06

(Table 1 continues on next page)

Characteristic	Persons with a history of Immigration (1985–2020)				Other Ontario residents	Standardized differences ^a (vs. Other ON residents)			
	Refugees	Sponsored family	Economic caregiver	All other economic		Refugees	Sponsored family	Economic caregiver	All other economic
(Continued from previous page)									
Inflammatory bowel disease	4191 (0.9%)	7917 (0.9%)	374 (0.4%)	7972 (0.7%)	154,987 (1.7%)	0.07	0.07	0.13	0.09
Advanced liver disease	3487 (0.8%)	5585 (0.6%)	321 (0.3%)	5886 (0.5%)	74,086 (0.8%)	0.01	0.02	0.07	0.03
Cancer (<5 yrs)	6032 (1.3%)	13,462 (1.5%)	1184 (1.2%)	13,361 (1.2%)	212,929 (2.3%)	0.08	0.06	0.09	0.08

^aSD = standardized difference if > 0.1 indicates important differences vs. other Ontario residents. ^bAge as of Jan 1, 2020. ^cRegion/country of birth reporting categories based on those reported in Statistics Canada 2016 long-form microdata file for which “visible minority” status (racialization in the Canadian context) is also reported. Racial or ethnic categories not collected in Canadian immigration data. ^dMeasured at the neighborhood/dissemination area (DA) level. ^eDefined using “visible minority” as per Statistics Canada categories.

Table 1: Pre-vaccine Era cohort (index date January 1, 2020)—characteristics and socio-demographics by immigration category in Ontario (ON), Canada (n, % of column unless otherwise indicated).

Results

Descriptive characteristics

Of 11,692,387 community-dwelling adults in the pre-vaccine era cohort (Table 1) and 11,878,304 community-dwelling adults in the vaccine era cohort (Table 2), 21.6% and 21.4% of adults in each era respectively were immigrants. Compared to other Ontario residents (pre-vaccine and vaccine eras, respectively—average age 49.0 and 49.1 years old; proportion female 51% and 50.7%), refugees (45.3 and 46.3 years old), economic caregivers (41.3 and 42.2 years old), and all other economic immigrants (44.0 and 45.1 years old) were younger. In terms of sex, a greater proportion of sponsored family (57.9% and 57.8%) and economic caregivers (68.4% and 67.6%) were females. Refugees, sponsored family and economic caregivers were more likely to live in the lowest income neighborhoods (pre-vaccine era—35.1%, 24.5%, 43.1% respectively vs. 18% among other Ontario residents), and about three times more immigrants in all immigration categories (~60%) compared to ~19% of all other Ontarians lived in the highest neighborhood racialized population quintile. In both cohorts, there were no study subjects with missing data for age, sex or co-morbidities.

Outcomes by immigration category

Unless otherwise indicated, all data presented are fully adjusted rate ratios (aRR) with 95% CI.

Pre-vaccine era cohort

Refugees and sponsored family had the highest crude rates (per 100,000 PY) of COVID-19 hospitalization (306 and 248, respectively) and mortality (44 and 50, respectively) followed by economic caregivers (hospitalization 188; mortality 16), other Ontarians (hospitalization 115; mortality 27) and other economic immigrants (hospitalization 115; mortality 15). Refugees (adjusted rate ratio (aRR), 3.41 [95% CI 3.39–3.44]), sponsored family (aRR, 2.28 [2.27–2.29]), economic caregivers (3.13 [3.07–3.18]), and other economic immigrants (1.51 [1.50–1.52]) were more likely to be hospitalized due to COVID-19 compared to other Ontarians (Fig. 1;

Supplementary Table S5 for all model estimates). COVID-19 mortality aRRs were of similar magnitude (Fig. 2; Supplementary Table S6 for all model estimates).

Vaccine era cohort

Compared to the pre-vaccine era cohort, absolute COVID-19 hospitalization and mortality rates dropped by approximately half or more within each immigration category, (e.g., refugee—hospitalization 167, mortality 29) while for other Ontarians, the hospitalization rate almost doubled (hospitalization 200) and the mortality rate increased (34). After adjustment (Figs. 1 and 2), only refugees continued to have a higher rate of COVID-19 hospitalization (aRR = 1.31 [95% CI 1.30–1.33]) and COVID-19 mortality (1.65 [1.63–1.67]). Persons in all other immigrant categories experienced significantly lower rates (other economic immigrants—hospitalization 0.67 (0.66–0.67); mortality 0.65 (0.64–0.66); economic caregivers—hospitalization 0.60 (0.57–0.62); sponsored family—hospitalization 0.91 (0.90–0.92)) or no difference in rates (economic caregivers: mortality 0.98 (0.93–1.03); sponsored family—mortality 1.00 (1.00–1.01)) compared to other Ontarians.

For both eras, adjustment for age and sex alone were not appreciably different (Figs. 1 and 2).

Outcomes by country/region of birth

Immigrants who did not state their country of birth were excluded (pre-vaccine era N = 526, vaccine era N = 520; 0.0% of each immigrant category).

Pre-vaccine era cohort

Immigrants from almost all regions had higher COVID-19 hospitalization (Fig. 3) and mortality (Fig. 4) aRRs when compared to other Ontarians (see Supplementary Tables S7 and S8 for all model estimates) except immigrants from East Asia and Iran who had lower rates or for whom there was no difference in rates (Hong Kong). Hospitalization aRRs were highest for immigrants from Central America (aRR = 5.00 [95%

Characteristic	Persons with a history of Immigration (1985–2020)				Other Ontario residents	Standardized Differences ^a (vs. Other ON residents)			
	Refugees	Sponsored family	Economic caregiver	All other economic		Refugees	Sponsored family	Economic caregiver	All other economic
N (% of total population)	461,125 (3.9%)	875,185 (7.4%)	102,825 (0.9%)	1,097,825 (9.2%)	9,341,344 (78.6%)				
Censoring reason									
Death	3132 (0.7%)	8537 (1.0%)	202 (0.2%)	3678 (0.3%)	156,804 (1.7%)				
Left province	1885 (0.4%)	3525 (0.4%)	655 (0.6%)	7138 (0.7%)	99,719 (1.1%)				
Follow-up Time (years)									
Mean ± SD	1.65 ± 0.10	1.65 ± 0.11	1.65 ± 0.08	1.65 ± 0.10	1.64 ± 0.16				
Median (IQR)	2 (2–2)	2 (2–2)	2 (2–2)	2 (2–2)	2 (2–2)				
Age (years) ^b									
Mean ± SD	46.29 ± 15.49	49.69 ± 16.46	42.18 ± 13.27	45.10 ± 14.45	49.11 ± 19.06	0.16	0.03	0.42	0.24
Median (IQR)	46 (34–58)	47 (37–60)	43 (32–52)	45 (33–56)	49 (32–64)	0.14	0.04	0.4	0.21
Age group (years) ^b									
18–29	73,657 (16.0%)	72,411 (8.3%)	22,525 (21.9%)	170,268 (15.5%)	1,872,070 (20.0%)	0.11	0.34	0.05	0.12
30–39	97,332 (21.1%)	201,527 (23.0%)	17,068 (16.6%)	272,591 (24.8%)	1,533,256 (16.4%)	0.12	0.17	0	0.21
40–49	92,046 (20.0%)	211,598 (24.2%)	31,195 (30.3%)	215,457 (19.6%)	1,347,558 (14.4%)	0.15	0.25	0.39	0.14
50–59	99,858 (21.7%)	160,547 (18.3%)	22,718 (22.1%)	235,129 (21.4%)	1,535,871 (16.4%)	0.13	0.05	0.14	0.13
60–69	67,572 (14.7%)	100,799 (11.5%)	7905 (7.7%)	156,186 (14.2%)	1,485,818 (15.9%)	0.03	0.13	0.26	0.05
70–79	22,151 (4.8%)	76,634 (8.8%)	1291 (1.3%)	42,186 (3.8%)	1,018,998 (10.9%)	0.23	0.07	0.41	0.27
80+	8509 (1.8%)	51,669 (5.9%)	123 (0.1%)	6008 (0.5%)	547,773 (5.9%)	0.21	0	0.34	0.31
Sex									
Female	218,166 (47.3%)	506,244 (57.8%)	69,487 (67.6%)	527,740 (48.1%)	4,740,182 (50.7%)	0.07	0.14	0.35	0.05
Male	242,959 (52.7%)	368,941 (42.2%)	33,338 (32.4%)	570,085 (51.9%)	4,601,162 (49.3%)	0.07	0.14	0.35	0.05
Immigration sub-category									
Government assisted refugee & Blended visa office referred	87,237 (18.9%)	n/a	n/a	n/a	n/a				
Privately sponsored refugee	108,883 (23.6%)	n/a	n/a	n/a	n/a				
Protected persons (successful asylum-seekers)	167,762 (36.4%)	n/a	n/a	n/a	n/a				
Dependents of protected persons	54,446 (11.8%)	n/a	n/a	n/a	n/a				
Other refugees	42,797 (9.3%)	n/a	n/a	n/a	n/a				
Spouse	n/a	541,862 (61.9%)	n/a	n/a	n/a				
Child	n/a	79,695 (9.1%)	n/a	n/a	n/a				
Parent	n/a	231,011 (26.4%)	n/a	n/a	n/a				
Other	n/a	22,617 (2.6%)	n/a	n/a	n/a				
Entrepreneur	n/a	n/a	n/a	65,791 (6.0%)	n/a				
Skilled	n/a	n/a	n/a	443,482 (40.4%)	n/a				
Caregiver	n/a	n/a	102,825 (100.0%)	n/a	n/a				
Family	n/a	n/a	n/a	162,141 (14.8%)	n/a				
Other	n/a	n/a	n/a	426,411 (38.8%)	n/a				
Region/Country of Birth ^c									
Jamaica	2557 (0.6%)	58,413 (6.7%)	943 (0.9%)	14,367 (1.3%)	n/a				
Other Caribbean and Bermuda	12,857 (2.8%)	40,459 (4.6%)	850 (0.8%)	21,282 (1.9%)	n/a				
East Africa	46,564 (10.1%)	18,453 (2.1%)	285 (0.3%)	15,620 (1.4%)	n/a				
Other Africa	21,457 (4.7%)	21,819 (2.5%)	270 (0.3%)	29,392 (2.7%)	n/a				
South America	25,646 (5.6%)	60,798 (6.9%)	935 (0.9%)	38,595 (3.5%)	n/a				
Central America	21,199 (4.6%)	19,092 (2.2%)	183 (0.2%)	10,836 (1.0%)	n/a				
Iran	19,123 (4.1%)	15,728 (1.8%)	46 (0.0%)	44,181 (4.0%)	n/a				

(Table 2 continues on next page)

Characteristic	Persons with a history of Immigration (1985–2020)				Other Ontario residents	Standardized Differences ^a (vs. Other ON residents)			
	Refugees	Sponsored family	Economic caregiver	All other economic		Refugees	Sponsored family	Economic caregiver	All other economic
(Continued from previous page)									
Other West & Central Asia & Middle East	75,712 (16.4%)	33,701 (3.9%)	451 (0.4%)	77,144 (7.0%)	n/a				
North Africa	9665 (2.1%)	9040 (1.0%)	126 (0.1%)	25,083 (2.3%)	n/a				
Philippines	1465 (0.3%)	57,835 (6.6%)	92,870 (90.3%)	63,361 (5.8%)	n/a				
Other Southeast Asia	15,307 (3.3%)	35,715 (4.1%)	333 (0.3%)	12,685 (1.2%)	n/a				
China	26,160 (5.7%)	93,590 (10.7%)	1343 (1.3%)	130,503 (11.9%)	n/a				
Hong Kong	2356 (0.5%)	13,487 (1.5%)	185 (0.2%)	36,493 (3.3%)	n/a				
Other East Asia	2279 (0.5%)	14,105 (1.6%)	186 (0.2%)	37,928 (3.5%)	n/a				
India	7135 (1.5%)	139,365 (15.9%)	1051 (1.0%)	212,490 (19.4%)	n/a				
Sri Lanka	44,053 (9.6%)	33,841 (3.9%)	243 (0.2%)	15,217 (1.4%)	n/a				
Pakistan	18,439 (4.0%)	40,591 (4.6%)	144 (0.1%)	77,145 (7.0%)	n/a				
Other South Asia	31,558 (6.8%)	18,095 (2.1%)	268 (0.3%)	27,742 (2.5%)	n/a				
North America & Australasia & Oceania	4102 (0.9%)	33,553 (3.8%)	95 (0.1%)	19,282 (1.8%)	n/a				
Europe	73,359 (15.9%)	117,271 (13.4%)	1977 (1.9%)	188,366 (17.2%)	n/a				
Not stated	132 (0.0%)	234 (0.0%)	41 (0.0%)	113 (0.0%)	n/a				
Duration of Residence									
0 to ≤ 10 years	114,922 (24.9%)	234,232 (26.8%)	41,179 (40.0%)	242,803 (22.1%)	n/a				
>10 to ≤ 20 years	141,775 (30.7%)	271,925 (31.1%)	46,634 (45.4%)	385,857 (35.1%)	n/a				
>20 years	204,428 (44.3%)	369,028 (42.2%)	15,012 (14.6%)	469,165 (42.7%)	n/a				
Household Income Quintile ^d									
1 (lowest)	156,447 (33.9%)	207,313 (23.7%)	41,519 (40.4%)	188,141 (17.1%)	1,722,272 (18.4%)	0.36	0.13	0.5	0.03
2	96,616 (21.0%)	188,839 (21.6%)	27,867 (27.1%)	218,151 (19.9%)	1,848,570 (19.8%)	0.03	0.04	0.17	0
3	87,806 (19.0%)	194,875 (22.3%)	15,694 (15.3%)	238,059 (21.7%)	1,847,356 (19.8%)	0.02	0.06	0.12	0.05
4	73,626 (16.0%)	163,866 (18.7%)	10,858 (10.6%)	244,076 (22.2%)	1,882,581 (20.2%)	0.11	0.04	0.27	0.05
5 (highest)	45,162 (9.8%)	118,087 (13.5%)	6692 (6.5%)	205,992 (18.8%)	2,003,730 (21.5%)	0.33	0.21	0.44	0.07
Suppressed/missing	1468 (0.3%)	2205 (0.3%)	195 (0.2%)	3406 (0.3%)	36,835 (0.4%)	0.01	0.03	0.04	0.01
Employment in Essential Services Quintile ^d									
1 (lowest)	69,911 (15.2%)	159,709 (18.2%)	12,872 (12.5%)	335,036 (30.5%)	1,945,145 (20.8%)	0.15	0.06	0.22	0.22
2	101,963 (22.1%)	202,282 (23.1%)	18,679 (18.2%)	298,662 (27.2%)	2,033,589 (21.8%)	0.01	0.03	0.09	0.13
3	91,327 (19.8%)	168,168 (19.2%)	22,541 (21.9%)	190,726 (17.4%)	1,884,768 (20.2%)	0.01	0.02	0.04	0.07
4	93,193 (20.2%)	172,070 (19.7%)	26,003 (25.3%)	153,873 (14.0%)	1,795,895 (19.2%)	0.02	0.01	0.15	0.14
5 (highest)	102,556 (22.2%)	168,702 (19.3%)	22,538 (21.9%)	112,621 (10.3%)	1,626,875 (17.4%)	0.12	0.05	0.11	0.21
Suppressed/missing	2175 (0.5%)	4254 (0.5%)	192 (0.2%)	6907 (0.6%)	55,072 (0.6%)	0.02	0.01	0.06	0.01
Household Density Quintile ^d									
1 (lowest)	73,231 (15.9%)	111,477 (12.7%)	16,272 (15.8%)	175,099 (15.9%)	1,888,403 (20.2%)	0.11	0.2	0.11	0.11
2	57,424 (12.5%)	88,909 (10.2%)	14,942 (14.5%)	100,335 (9.1%)	1,813,773 (19.4%)	0.19	0.26	0.13	0.3
3	44,274 (9.6%)	72,406 (8.3%)	13,094 (12.7%)	85,440 (7.8%)	1,384,816 (14.8%)	0.16	0.21	0.06	0.22
4	106,170 (23.0%)	183,615 (21.0%)	30,476 (29.6%)	226,407 (20.6%)	2,240,067 (24.0%)	0.02	0.07	0.13	0.08
5 (highest)	177,719 (38.5%)	414,375 (47.3%)	27,837 (27.1%)	503,229 (45.8%)	1,954,400 (20.9%)	0.39	0.58	0.14	0.55
Suppressed/missing	2307 (0.5%)	4403 (0.5%)	204 (0.2%)	7315 (0.7%)	59,885 (0.6%)	0.02	0.02	0.07	0
Racialized population ("Visible Minority") Quintile ^{d,e}									
1 (lowest)	8735 (1.9%)	26,134 (3.0%)	1640 (1.6%)	24,517 (2.2%)	1,811,121 (19.4%)	0.59	0.54	0.61	0.57
2	20,608 (4.5%)	45,489 (5.2%)	4032 (3.9%)	48,049 (4.4%)	1,866,611 (20.0%)	0.49	0.46	0.51	0.49

(Table 2 continues on next page)

Characteristic	Persons with a history of Immigration (1985–2020)				Other Ontario residents	Standardized Differences* (vs. Other ON residents)			
	Refugees	Sponsored family	Economic caregiver	All other economic		Refugees	Sponsored family	Economic caregiver	All other economic
(Continued from previous page)									
3	51,718 (11.2%)	90,082 (10.3%)	10,099 (9.8%)	112,256 (10.2%)	1,855,220 (19.9%)	0.24	0.27	0.29	0.27
4	126,237 (27.4%)	197,786 (22.6%)	25,359 (24.7%)	287,917 (26.2%)	1,957,624 (21.0%)	0.15	0.04	0.09	0.12
5 (highest)	251,656 (54.6%)	511,449 (58.4%)	61,503 (59.8%)	618,181 (56.3%)	1,795,928 (19.2%)	0.79	0.88	0.91	0.83
Suppressed/missing	2171 (0.5%)	4245 (0.5%)	192 (0.2%)	6905 (0.6%)	54,840 (0.6%)	0.02	0.01	0.06	0.01
Limited educational attainment quintile ^d									
1 (lowest)	64,529 (14.0%)	147,911 (16.9%)	18,166 (17.7%)	310,644 (28.3%)	1,958,735 (21.0%)	0.18	0.1	0.08	0.17
2	89,276 (19.4%)	170,637 (19.5%)	20,010 (19.5%)	270,167 (24.6%)	2,011,027 (21.5%)	0.05	0.05	0.05	0.07
3	97,889 (21.2%)	193,815 (22.1%)	20,892 (20.3%)	226,664 (20.6%)	1,958,911 (21.0%)	0.01	0.03	0.02	0.01
4	96,164 (20.9%)	183,338 (20.9%)	22,408 (21.8%)	167,242 (15.2%)	1,803,437 (19.3%)	0.04	0.04	0.06	0.11
5 (highest)	111,092 (24.1%)	175,232 (20.0%)	21,157 (20.6%)	116,202 (10.6%)	1,554,212 (16.6%)	0.19	0.09	0.1	0.18
Suppressed/missing	2175 (0.5%)	4252 (0.5%)	192 (0.2%)	6906 (0.6%)	55,022 (0.6%)	0.02	0.01	0.06	0.01
Rurality									
Urban	455,294 (98.7%)	856,760 (97.9%)	101,709 (98.9%)	1,078,979 (98.3%)	8,139,392 (87.1%)	0.46	0.42	0.48	0.44
Rural	4384 (1.0%)	16,253 (1.9%)	925 (0.9%)	15,483 (1.4%)	1,168,513 (12.5%)	0.47	0.42	0.48	0.45
Missing	1447 (0.3%)	2172 (0.2%)	191 (0.2%)	3363 (0.3%)	33,439 (0.4%)	0.01	0.02	0.03	0.01
Co-morbidities									
Asthma & Chronic obstructive pulmonary disease	58,422 (12.7%)	97,421 (11.1%)	6088 (5.9%)	105,316 (9.6%)	2,197,532 (23.5%)	0.28	0.33	0.51	0.38
Chronic kidney disease (incl chronic dialysis)	10,088 (2.2%)	25,990 (3.0%)	1455 (1.4%)	17,718 (1.6%)	250,424 (2.7%)	0.03	0.02	0.09	0.07
Diabetes	69,978 (15.2%)	141,157 (16.1%)	11,458 (11.1%)	134,376 (12.2%)	1,102,840 (11.8%)	0.1	0.12	0.02	0.01
Congestive heart failure	111,563 (24.2%)	243,081 (27.8%)	22,118 (21.5%)	230,390 (21.0%)	2,598,423 (27.8%)	0.08	0	0.15	0.16
Immunocompromised	4788 (1.0%)	5567 (0.6%)	343 (0.3%)	4939 (0.4%)	74,942 (0.8%)	0.02	0.02	0.06	0.04
Inflammatory bowel disease	5394 (1.2%)	10,097 (1.2%)	517 (0.5%)	10,455 (1.0%)	178,154 (1.9%)	0.06	0.06	0.13	0.08
Advanced liver disease	3205 (0.7%)	4924 (0.6%)	292 (0.3%)	5488 (0.5%)	68,250 (0.7%)	0	0.02	0.06	0.03
Cancer (<5 yrs)	6741 (1.5%)	14,176 (1.6%)	1399 (1.4%)	14,679 (1.3%)	217,777 (2.3%)	0.06	0.05	0.07	0.07

*SD = standardized difference if >0.1 indicates important differences vs. other Ontario residents. ^bAge as of Jan 1, 2020. ^cRegion/country of birth reporting categories based on those reported in Statistics Canada 2016 long-form microdata file for which “visible minority” status (racialization in the Canadian context) is also reported. Racial or ethnic categories not collected in Canadian immigration data. ^dMeasured at the neighborhood/dissemination area (DA) level. ^eDefined using “visible minority” as per Statistics Canada categories.

Table 2: Vaccine Era cohort (index date September 1, 2021)-characteristics and socio-demographics by immigration category in Ontario (ON), Canada (n, % of column unless otherwise indicated).

CI 4.92–5.09]), South Asia (other than India, Sri Lanka and Pakistan) (3.95 [3.89–4.01]), Jamaica (3.56 [3.51–3.61]) and East Africa (3.44 [3.39–3.50]) and were lowest for China (1.00 [0.98–1.02]) and other East Asia (0.82 [0.79–0.85]). COVID-19 mortality aRRs were of similar magnitude to hospitalization aRRs for all countries/regions except for immigrants from Iran who had a higher hospitalization rate (1.62 [1.58–1.66]) but a lower mortality rate (0.73 [0.70–0.76]) compared to other Ontarians.

Vaccine era cohort

COVID-19 hospitalization and mortality aRRs for immigrants from almost all regions of birth were dramatically attenuated compared to the pre-vaccine era

cohort, with most groups showing no difference or lower rates compared to other Ontarians. Attenuation of hospitalization rate ratios in the vaccine era was the smallest for immigrants from North America, Australasia, Oceania & Other and Europe. Immigrants from Jamaica (mortality 1.17 (1.14–1.21)), other Caribbean and Bermuda (mortality 1.33 (1.29–1.37)), East Africa (mortality 1.38 (1.34–1.42)), Central America (hospitalization 1.34 (1.30–1.38); mortality 2.37 (2.30–2.44)), Other West & Central Asia/Middle East (excluding Iran) (hospitalization 1.34 (1.32–1.36); mortality 1.54 (1.51–1.58)), North Africa (hospitalization 1.06 (1.02–1.10)), other Southeast Asia (mortality 1.12 (1.08–1.15), and Europe (hospitalization 1.40 (1.38–1.41); mortality 1.48 (1.46–1.50)) continued to

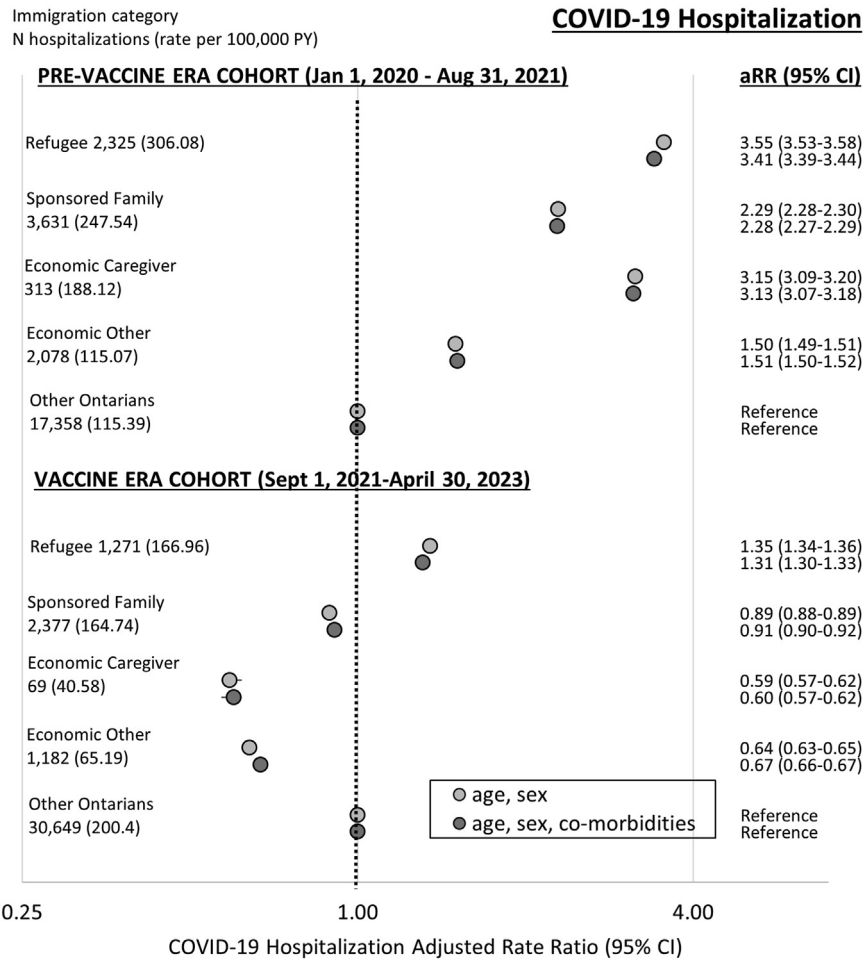


Fig. 1: COVID-19 hospitalization rate ratios (95% CI) by immigration category among persons with a history of immigration compared to all other Ontario residents in the pre-vaccine era cohort (January 1, 2020 to August 31, 2021) and the vaccine era cohort (September 1, 2021 to April 30, 2023). Adjusted rate ratios (aRR) and 95% Confidence Intervals (CI) adjusted for age and sex (light grey circles) and age, sex, co-morbidity adjustment (dark grey circles).

have significantly higher rate ratios for hospitalization and/or mortality.

For both eras, adjustment for age and sex alone were not appreciably different except for immigrants from Jamaica, other Caribbean and Bermuda and South Asia (excluding India, Sri Lanka, Pakistan) whose hospitalization aRRs became non-significant with the co-morbidity adjustment (Supplementary Tables S7 and S8).

Premature mortality

There were a total of 5496 COVID-19 deaths in the pre-vaccine era cohort (47/100,000) and 6006 COVID-19 deaths in the vaccine era cohort (51/100,000), of which 24% and 14% of COVID-19 deaths were to immigrants in each cohort respectively. In the pre-vaccine era cohort, rates of premature mortality, measured using

age-standardized years of life lost rates (ASYR, per 100,000), were higher for all immigration categories compared to other Ontario residents (Fig. 5, see Supplementary Table S9 for death counts and crude rates). ASYRs were approximately 3 times higher among refugees (ASYR [95% CI] = 2128 [1785, 2471]) and economic caregivers (1720 [1346, 2094]) to 70% higher for other economic immigrants (1023 [806, 1239]) compared to other Ontarians (602 [567, 638]). In the vaccine era cohort, ASYRs dropped significantly for all immigrant groups and increased slightly for other Ontario residents, with refugees (1281 [1015, 1547]) having higher rates of premature mortality compared to other Ontario residents (705 [666, 473]) and economic caregivers having lower rates (439 [299, 579]) (Fig. 5, see Supplementary Table S10 for death counts and crude rates).

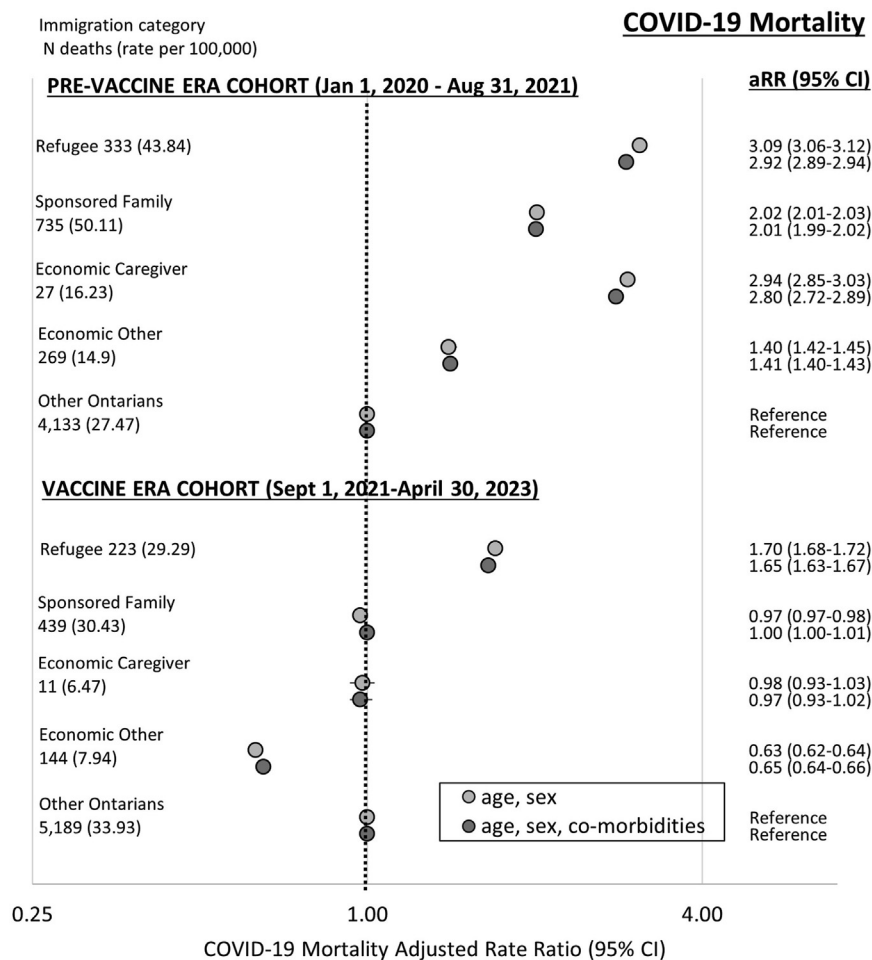


Fig. 2: COVID-19 mortality rate ratios (95% CI) by immigration category among persons with a history of immigration compared to all other Ontario residents in the pre-vaccine era cohort (January 1, 2020 to August 31, 2021) and the vaccine era cohort (September 1, 2021 to April 30, 2023). Adjusted rate ratios (aRR) and 95% Confidence Intervals (CI) adjusted for age and sex (light grey circles) and age, sex, co-morbidities (dark grey circles).

Discussion

In this population-based study of all community-dwelling adults in Ontario, Canada, we found that prior to high population COVID-19 primary series vaccine coverage, immigrants experienced much higher rates of COVID-19 hospitalization and mortality compared to other Ontarians. With respect to our first aim, in the pre-vaccine era cohort refugees and economic caregivers were about 3 times more likely, and sponsored family were about 2 times more likely, to be hospitalized or die. Economic immigrants, with a similar distribution of neighborhood income as other Ontarians, were also 2 times more likely to be hospitalized or die. Addressing our second aim, rates of these outcomes varied substantially by region of birth with most immigrants born in regions who were more likely to be members of racialized groups experiencing 2–5

times higher rates of severe COVID-19 outcomes compared to other Ontarians, except for immigrants born in China, Hong Kong and other parts of East Asia who had similar or lower rates. After these East Asian regions, immigrants from Europe and North America/Australasia/Oceania had the lowest adjusted rate ratios. Relative to our third aim, high COVID-19 primary series vaccine coverage in Ontario²⁵ appeared to dramatically reduce the inequities experienced in the pre-vaccine era cohort. Hospitalization and mortality rate ratios dropped substantially for all immigration categories, except refugees, to rates similar to or lower than other Ontarians. Hospitalization and mortality rate ratios also dropped for most immigrant countries/regions of birth to levels similar to or lower than other Ontarians, but with significantly higher mortality rate ratios continuing for immigrants from Central America, other West &

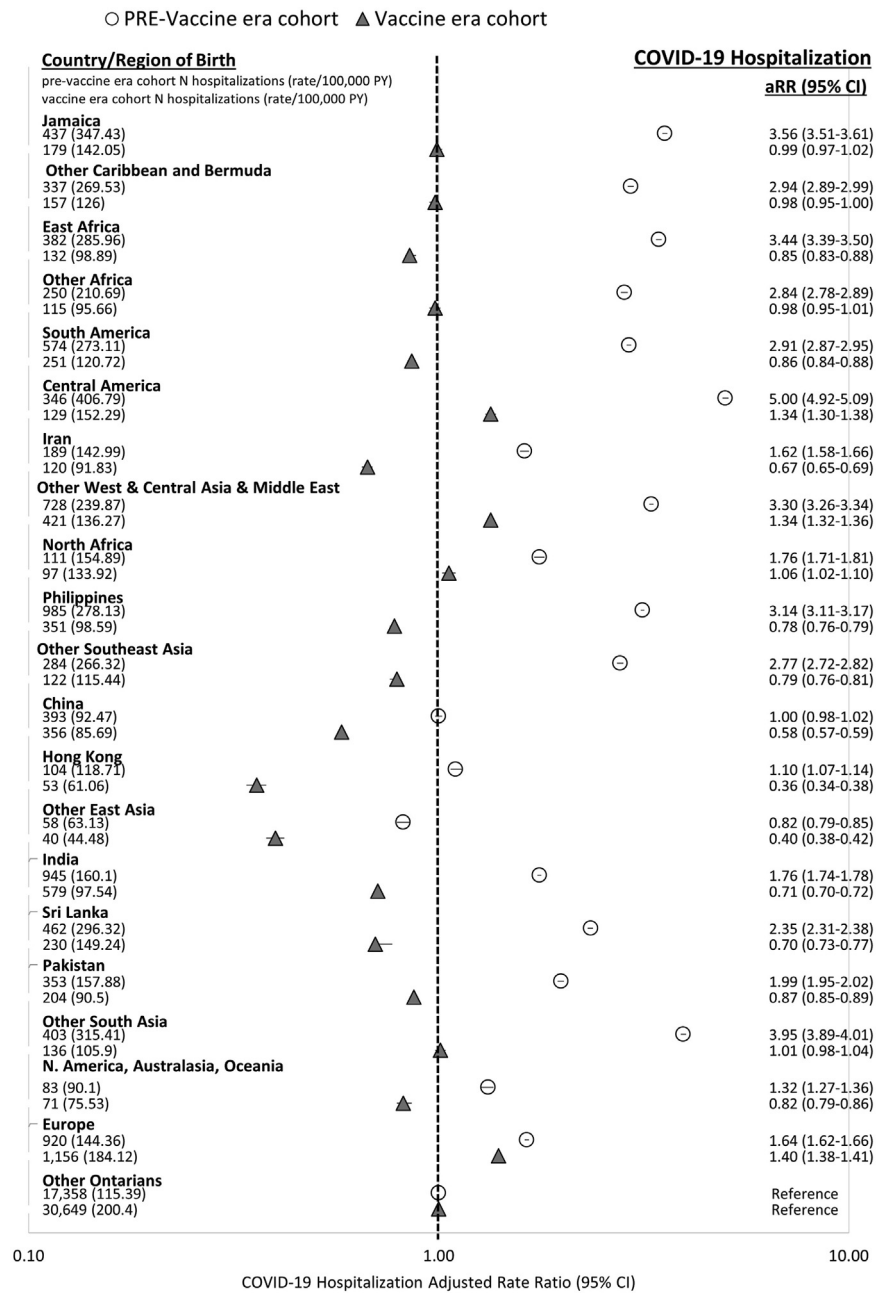


Fig. 3: COVID-19 hospitalization rate ratios (95% CI) by country/region of birth compared to all other Ontario residents; pre-vaccine era cohort (January 1, 2020 to August 31, 2021) and vaccine era cohort (September 1, 2021 to April 30, 2023). Adjusted rate ratios (aRR) and 95% Confidence Intervals (CI) adjusted for age, sex and co-morbidities.

Central Asia & the Middle East (excluding Iran), Jamaica, other Caribbean and Bermuda, East Africa, and Europe. While we did not test for rate differences between the vaccine and pre-vaccine era cohorts within immigration categories or regions of birth, we observe large drops in absolute rates for all groups except for other Ontarians and immigrants born in Europe for

whom absolute rates of these outcomes increased in the vaccine era relative to the pre-vaccine era. The availability of vaccines appeared to have the smallest impact on immigrants from Europe for whom the mortality aRR increased slightly in the vaccine era cohort. In relation to last aim, in the pre-vaccine era cohort we found refugees and economic caregivers experienced

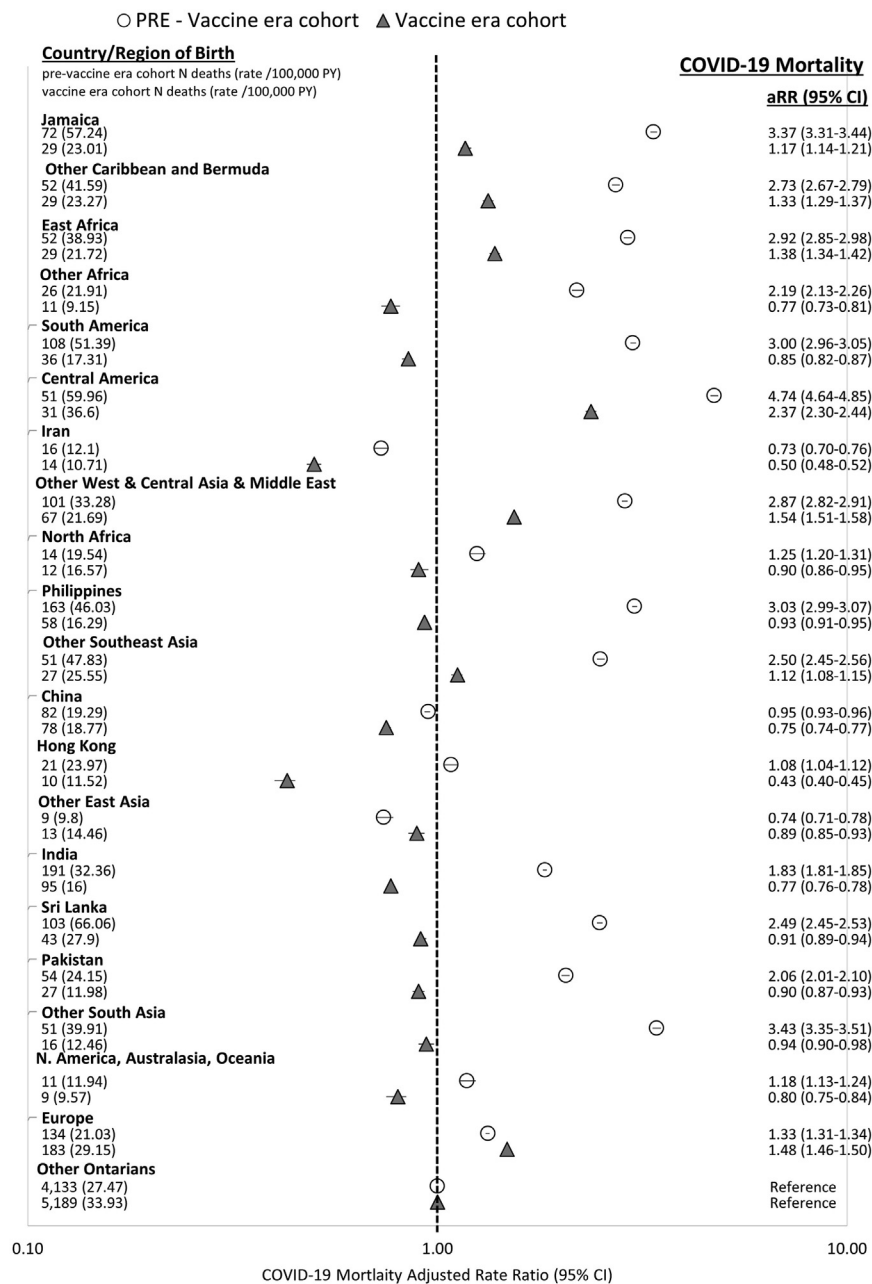


Fig. 4: COVID-19 mortality rate ratios (95% CI) by country/region of birth compared to all other Ontario residents; pre-vaccine era cohort (January 1, 2020 to August 31, 2021) and vaccine era cohort (September 1, 2021 to April 30, 2023). Adjusted rate ratios (aRR) and 95% Confidence Intervals (CI) adjusted for age, sex and co-morbidities.

the highest rates of age-standardized years of life lost due to premature death from COVID-19.

Our findings from the pre-vaccine era cohort are similar to those from other high-income countries. While most studies did not examine immigrants' employment characteristics, these are understood to be critical determinants of SARS-CoV-2 infection.² In

Canada, across all immigration classes^{23,38-40} immigrants are generally well-educated and/or skilled but experience structural and systematic barriers to their attainment of standard (full-time, permanent with single employer) and decent employment. The barriers to immigrants' decent employment include devaluation of foreign credentials and experience, employer

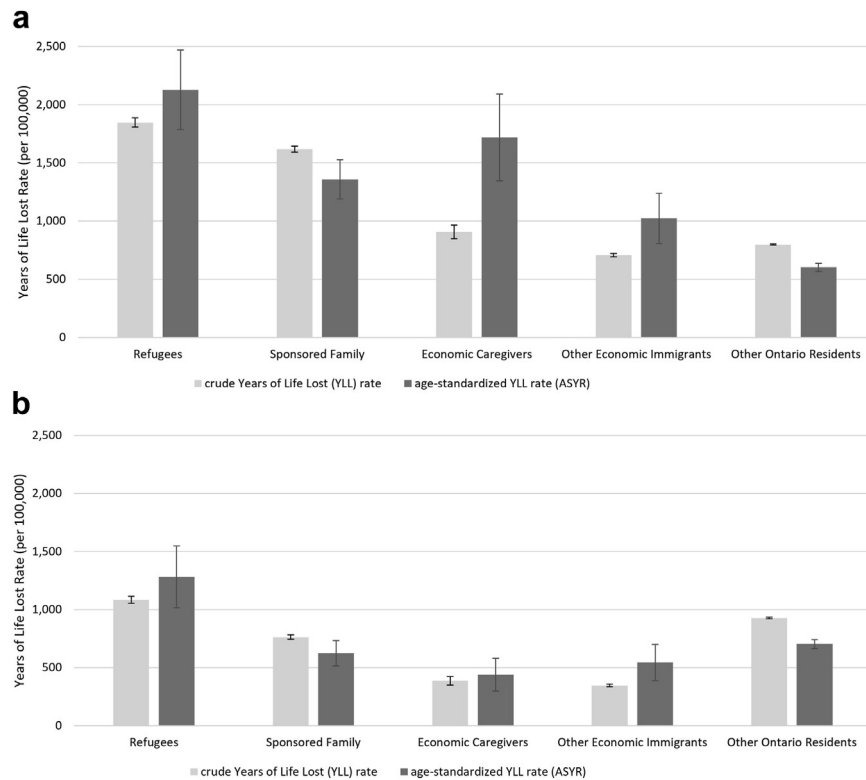


Fig. 5: Crude Years of Life Lost (YLL) rates and age-standardized years of life lost rates (ASYR) due to COVID-19 (per 100,000) among adult residents of Ontario, Canada by immigration category; pre-vaccine era cohort (January 1, 2020 to August 31, 2021) [panel a] and vaccine era cohort (September 1, 2021 to April 30, 2023) [panel b].

discrimination, lack of Canadian work experience and professional networks, and language barriers. Consequently, regardless of education or immigration class, many immigrants enter the Canadian labour market in non-standard jobs (e.g., temporary/part-time). Immigrants, particularly those from non-Western countries (most of whom are racialized), are over-represented in non-standard jobs in Canada and have difficulty leaving these jobs.⁴¹ Workers in non-standard jobs are not protected by labour laws, receive lower pay, have lower autonomy, less likely to have paid sick leave, at greater risk of workplace injury due to the lack of training and supervision, and less able to exercise their workplace rights. These circumstances increase the risk of SARS-CoV-2 exposure—directly through employment exposure and/or indirectly, as a consequence of lower incomes which increases the likelihood of, for example, needing to hold multiple jobs.

The systematic disadvantages faced by immigrants in the Canadian labour market are particularly striking when considering economic caregivers (65% female, 90% Philippine-born, 65% living in the two lowest income quintiles, with higher levels of education and training than non-immigrants²¹). They experienced 3 times the rate of COVID-19 hospitalization and

mortality compared to other Ontarians in our study. Previous studies found that immigrants entering Canada as caregivers are disproportionately employed as personal support workers or other care workers,²³ many of whom worked in long-term care homes during the pandemic under extremely challenging conditions.²⁴ In general, long-term care homes in Ontario are disproportionately staffed by immigrant women including those seeking asylum. The long-term care sector was devastated by COVID-19 infections and mortality in many high-income countries in the first six months of the pandemic, particularly in Canada, due to the susceptibility of the resident population, the lack of consistent infection control practices and staff absences. Employment in long-term care is precarious, and there have been renewed calls for structural reform including significantly improved working conditions.

The vaccine era cohort results of our study show a remarkable reduction, and often reversal, of excess risk experienced by immigrants. This is likely explained by the high level of hybrid immunity achieved in Canada during this time. High population-level primary series COVID-19 vaccine coverage among immigrants in Ontario was demonstrated in two recent studies by our team. We found equitable primary series coverage

among adult immigrants and other Ontario residents (72.6% vs. 76.4%, respectively) as of Sept 2021 with substantially lower coverage among immigrants from only a handful of regions of birth (i.e., Central Africa, Eastern Europe, the Caribbean).²⁵ The success of the primary series vaccine campaign in Ontario can be attributed to a number of factors, including a policy to prioritize vaccine distribution to high-risk neighborhoods, public health efforts to use data to guide equitable vaccination strategies, and numerous culturally appropriate community-led vaccination efforts. These successes demonstrate that immense challenges can be overcome when community needs and equity are both prioritized and adequately supported.

Among studies examining COVID-19 hospitalization and mortality among immigrants in high-income countries^{3–12,14–16} ours is the first to: i) include a follow-up period inclusive of the entire pandemic enabling us to examine the cumulative impact on immigrants, ii) examine premature mortality, iii) examine risks by immigration pathway, and iv) describe the impact of high population-level COVID-19 vaccine coverage on inequities in severe outcomes among immigrants. Our study has the largest population of adult immigrants in the literature to date.⁹ While studies report results by a limited number of country/regional of birth groupings, we report on 20 geographic groupings with large population sizes and representation from across the world. Despite these strengths, we acknowledge that analysis by regions of birth potentially masks relevant heterogeneity by country of birth. In addition, many baseline sociodemographic variables in our study (e.g., household density) were measured at the neighborhood-level whereas Swedish^{6,8,10} and Norwegian⁹ studies used individual-level measures and found greater risk among immigrants even after their adjustment. The variable sex was collected as a binary variable in administrative databases and does not reflect the spectrum of gender identity or expression. Acknowledging the critical importance of the intersection of race/ethnicity and occupation/employment on COVID-19 severe outcomes globally,²² we report results based on country/regional groupings which offered limited insights into racial inequities. We were unable to examine the combined influence of race, occupation, and immigration status in our study since race/ethnicity nor occupation are not routinely collected in Canadian health administrative data. Among American studies^{13,14,16} measuring race and immigration status, being foreign-vs. US-born conferred higher proportionate COVID-19 mortality,¹³ relative excess all-cause mortality¹⁶ and COVID-19 mortality risk¹⁴ among Latino^{13,14,16} and Black Americans.¹⁴ Methodological limitations include unmeasured confounding and residual confounding due to measurement error.

Conclusion

Immigrants, particularly refugees, in Ontario, Canada lost many more age-adjusted years of life in comparison to other residents of Ontario. Prior to the widespread availability of COVID-19 vaccines in Ontario, immigrants experienced substantially increased rates of severe outcomes which varied by immigration category and country/region of birth. High population COVID-19 vaccine primary series coverage in Ontario had a remarkable impact on reducing most inequities experienced in the pre-vaccine era. Refugees and those from specific countries/regions of birth may continue to benefit from targeted public health prevention efforts including COVID-19 boosters. Policies supporting access to decent work and safe workplaces for immigrants and refugees in Canada are needed to mitigate the impacts of future pandemics.

Contributors

SW, AG, BS, TS, HL, NS, SG conceived of and designed the study and along with HL and TS developed the methodological approach. SDOM, JS and SW conducted the literature search and synthesized the existing literature. HL conducted formal analysis and SW developed the figures and data visualization. SW and AG wrote the original draft and all authors contributed to the interpretation of the data. AG acquired funding. All authors revised it critically for important intellectual content, have approved the final version to be published and are accountable for all aspects of the work.

Data sharing statement

The dataset from this study is held securely in coded form at ICES. While legal data sharing agreements between ICES and data providers (e.g., healthcare organizations and government) prohibit ICES from making the dataset publicly available, access may be granted to those who meet pre-specified criteria for confidential access, available at <https://www.ices.on.ca/DAS> (email: das@ices.on.ca). The full dataset creation plan and underlying analytic code are available from the authors upon request, understanding that the computer programs may rely upon coding templates or macros that are unique to ICES and are therefore either inaccessible or may require modification.

Declaration of interests

The authors have no competing interests.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.lana.2024.100762>.

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