Research

Morbidity and mortality of newborns born to immigrant and nonimmigrant females residing in low-income neighbourhoods

Jennifer A. Jairam MSc, Simone N. Vigod MD MSc, Arjumand Siddiqi ScD, Jun Guan MSc, Alexa Boblitz MPH, Xuesong Wang MSc, Patricia O'Campo PhD, Joel G. Ray MD MSc

Cite as: *CMAJ* 2023 April 17;195:E537-47. doi: 10.1503/cmaj.221711

Abstract

Background: Living in low-income neighbourhoods and being an immigrant are each independently associated with adverse neonatal outcomes, but it is unknown if disparities exist in the neonatal period for children of immigrant and nonimmigrant females living in low-income areas. We sought to compare the risk of severe neonatal morbidity and mortality (SNMM) between newborns of immigrant and nonimmigrant mothers who resided in low-income neighbourhoods.

Methods: This population-based cohort study used administrative data for females residing in low-income urban neighbourhoods in Ontario, who had an in-hospital, singleton live birth at 20–42 weeks' gestation, from 2002 to 2019. We defined immigrant status as nonrefugee immigrant or nonimmigrant, further detailed by country of birth and duration of residence in Ontario. The primary outcome was a SNMM composite (with 16 diagnoses, including neonatal death and 7 neonatal procedures as indicators), arising within 0–27 days after birth. We estimated relative risks (RRs) and 95% confidence intervals (CIs) using modified Poisson regression with generalized estimating equations.

Results: Our cohort included 148 050 and 266 191 live births among immigrant and nonimmigrant mothers, respectively. Compared with newborns of nonimmigrant females, SNMM was less frequent among newborns of immigrant females (49.7 v. 65.6 per 1000 live births), with an adjusted RR of 0.76 (95% CI 0.74 to 0.79). The most frequent SNMM indicator was receipt of ventilatory support. Relative to neonates of nonimmigrant females, the risk of SNMM was highest among those of immigrants from Jamaica (adjusted RR 1.14, 95% CI 1.05 to 1.23) and Ghana (adjusted RR 1.20, 95% CI 1.05 to 1.38), and lowest among those of immigrants from China (adjusted RR 0.44, 95% CI 0.40 to 0.48). Among immigrants, the risk of SNMM declined with shorter duration of residence before the index birth.

Interpretation: Within low-income urban areas, newborns of immigrant females had an overall lower risk of SNMM than those of nonimmigrant females, with considerable variation by maternal birthplace and duration of residence. Initiatives should focus on improving preconception health and perinatal care within subgroups of females residing in low-income neighbourhoods.

Neonatal morbidity and mortality are important public health indicators used to monitor and evaluate neonatal health and quality of perinatal care.[1,2] The neonatal period, ranging from birth to 27 days thereafter, is the most vulnerable time for infant survival.[1] Around 75% of infant deaths occur during this period, largely from prematurity and other conditions that can often be prevented by timely obstetrical and neonatal care.[3,4]

In high-income countries, improvements in health care have resulted in a decline in neonatal mortality,[5,6] including in Canada, where the rate is 3.6 deaths per 1000 live births.[7] Accordingly, research and public health surveillance has increasingly focused on severe neonatal morbidity (SNM), which refers to a newborn who has survived a severe complication during birth or the neonatal period.[1,8,9] Identifying newborns at high risk of SNM is crucial as it has serious implications for the surviving child and their family.[10,11]

Limited research has examined SNM in high-income countries.[2,6,8,12–17] Studies have primarily focused on deriving and validating the criteria to define SNM,[1,3,10] quantifying the prevalence of SNM and identifying risk factors in African, Asian and Latin American regions.[11,18–27] Research is also lacking on a range of upstream social determinants of health inequity and their influence on SNM.[28,29] Living in a low-income area[12,30–35] and being an

immigrant[36–46] are each independently associated with adverse neonatal outcomes. However, studies about area-level income have only made comparisons across income groups (e.g., females living in low- v. high-income areas), rather than being confined to low-income areas, where the risk of adverse neonatal outcomes may be highest and where enhanced obstetric and neonatal care are most needed. Thus, these studies may not have effectively disentangled the influence of area-level income from that of being a new immigrant who may settle in a low-income area or a nonimmigrant female living in a low-income area.

This study builds on our previous work, in which we found that females residing in the lowest-income areas were at highest risk of having a newborn with concomitant preterm birth and severe small-for-gestational-age birth weight.[35] Furthermore, immigrant females had a slightly lower overall risk of severe maternal morbidity or mortality (SMMM) than nonimmigrant females, all of whom were residing within low-income areas.[47]

In this study, we sought to compare the risk of SNMM between newborns of immigrant and nonimmigrant females residing in low-income urban neighbourhoods. We further sought to evaluate risk of SNMM by maternal world region of birth and country of birth, and by duration of residence among immigrant females.

Methods

Study design and setting

We conducted this retrospective, population-based cohort study in Ontario, the most populous and ethnically diverse province in Canada. Ontario receives about 53% of all female immigrants entering Canada,[48] many of whom originate from nations where rates of SNMM are relatively high,[10] and many reside in low-income urban areas upon arrival.[48] We report our findings according to the Reporting of Studies Conducted using Observational Routinely Collected Data (RECORD) checklist.[49]

Participants

We included all in-hospital, singleton live births at 20–42 weeks' gestation, from 2002 to 2019. We limited the cohort to births to females aged 15–50 years who had a valid Ontario Health Insurance Plan (OHIP) number and who resided in urban neighbourhoods of the lowest income quintile as of the index birth date (Appendix 1, Table S1, available at www.cmaj.ca/lookup/doi/10.1503/cmaj.221711/tab-related-content).

Data sources

We used administrative data at ICES, an independent, nonprofit 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 and improvement. Data sets used for this study are valid and reliable sources for perinatal research, described in Appendix 1, Table S2.[50–54] These deidentified data sets are linked using unique encoded identifiers and analyzed at ICES.

All live births were identified in the MOMBABY database, which captures labour and delivery records for about 98% of Ontario births.[50–52] Maternal immigrant status was determined using the Immigration, Refugees and Citizenship Canada Permanent Residents database (Appendix 1, Table S2).[53,54] Neighbourhood income quintile was categorized using Statistics Canada's Postal Code Conversion File Plus (PCCF+, version 7B), based on the female's residential postal code at the time of the index birth.[55]

Exposures

The primary exposure was maternal immigrant status before the index birth, defined according to a female's birthplace and migration status. Henceforth, we refer to nonrefugee immigrants as "immigrants," and females born in Canada as "nonimmigrants." We excluded refugees or other special-status immigrants, and females concomitantly classified as both a nonimmigrant and immigrant. We also omitted immigrants who did not have a landing date, or those whose landing date either preceded their own date of birth or was after the index delivery date (Appendix 1, Table S1).

We defined 3 secondary exposures, namely world region of birth, country of birth and, for immigrant females, duration of residence in Ontario. We categorized world region of birth according to a modified version of the United Nations classification scheme (i.e., Canada, Caribbean, East Asia and Pacific, Latin America, Middle East and North Africa, South Asia, Sub-Saharan Africa, and Western Nations and Europe).[56–58] We identified country of birth for those who had immigrated from the 20 countries contributing the greatest number of births in Ontario during the study period. For immigrant females, we calculated duration of residence as a continuous variable, defined by the number of years between their landing date in Ontario and the index birth date.

Outcomes

The primary outcome was a composite of SNM and all-cause neonatal mortality (SNMM). We measured SNMM in our study using the English-version Neonatal Adverse Outcomes Indicator (E-NAOI), defined as the presence of 1 or more E-NAOI components arising in the index birth admission and up to 27 days thereafter.[8] The E-NAOI consists of 16 neonatal diagnoses (including neonatal death) and 7 procedures that relate to different body systems.[8] The components are equally weighted. They are recorded using diagnostic codes (e.g., seizures) from the Canadian version of the *International Classification of Diseases and Related Health Problems, 10th Revision* (ICD-10-CA) and procedural codes (e.g., resuscitation, ventilatory support) from the Canadian Classification of Health Interventions (Appendix 1, Table S1).[8] The E-NAOI has shown good concurrent validity as a population measure of SNM, and predictive validity for infant death and hospital readmission in the first year of life.[8]

A secondary outcome was the number of SNMM indicators (i.e., E-NAOI components) that were present at the index birth admission and up to 27 days thereafter, categorized as 0 (referent), 1, 2 or 3 or more indicators.[59] For this secondary outcome, neonatal death and neonatal diagnoses or procedures were not mutually exclusive categories (e.g., we classified a newborn who died after having a seizure as having an SNMM score of 2).

Statistical analysis

Given ICES privacy and security requirements, ICES staff (A.B. and J.G.) generated the study cohort. One author (J.A.J.) completed the analyses using SAS version 9.4 (SAS Institute).

We compared means and proportions between immigrant and nonimmigrant females and their newborns for birth characteristics using standard differences, with a value greater than 0.10 considered to be a clinically meaningful difference.[60]

We used modified Poisson regression with generalized estimating equations (GEEs) to estimate relative risks (RRs), absolute risk differences and 95% confidence intervals (CIs) for the main outcome of SNMM (i.e., the presence of ≥ 1 E-NAOI components v. none), comparing newborns of immigrant and nonimmigrant females.[61–63] We used this modelling approach to analyze the risk of SNMM for maternal world region of birth and country of birth, with females born in Canada as the referent. Generalized estimating equations, with an exchangeable correlation structure, accounted for correlation among females who had more than 1 live birth during the study period.[64] We adjusted RRs and absolute risk differences for maternal age (15–19 yr, 20–29 yr, 30–39 yr, 40–50 yr),[21,24] parity (0, 1, 2, ≥ 3)[65] and any newborn structural congenital anomaly (yes or no),[1] each determined in the index birth admission.

For the outcome of the number of SNMM indicators, we calculated odds ratios (ORs) using multinomial logistic regression with a robust error variance and GEE, comparing newborns of immigrant and nonimmigrant females. We adjusted ORs for the same variables as the main analysis.

In an immigrant-only analysis, after conducting multivariable fractional polynomial regression,[66] we observed a nonlinear (quadratic) relation between maternal duration of residence and the risk of SNMM. Accordingly, we used a modified Poisson regression GEE model with a restricted cubic spline function to estimate adjusted RRs and 95% CIs of SNMM by declining duration of residence, compared with residing in Ontario 20 years or longer before the index birth.[67] We adjusted RRs for the same variables as the main analysis, as well as world region of birth[16] and other variables documented at arrival to Canada, including immigration class (economic, sponsored family),[46] highest level of education (secondary school or less; trade certificate or diploma, or some university; university degree; graduate degree)[27] and self-reported English and/or French language ability (yes or no).[16,68]

For the first sensitivity analysis, we removed gestational age at birth less than 32 weeks and a birth weight less than 1500 g from the SNMM composite for the main model, as neither are disease states, per se. The second analysis stratified the previous model by gestational age (births occurring < 32 or ≥ 32 weeks' gestation), since birth before 32 weeks' gestation is a major contributor to morbidity and mortality.[5,69] The third analysis expanded the cohort to live births and stillbirths born at 20 weeks' gestation or later, and compared SNM or perinatal mortality in the index birth admission and up to 27 days thereafter for newborns of immigrant and nonimmigrant females.

Ethics approval

Ethics approval was received from the University of Toronto Research Ethics Board (no. 00040721).

Results

Of the 2 374 755 births during the study period, 414 241 were singleton live births to 312 124 females residing in a lowest-income (quintile 1) urban neighbourhood at the time of the index birth (Figure 1). Among these live births, 148 050 were to immigrant females and 266 191 were to nonimmigrant females (Table 1).

Immigrant females were older than nonimmigrant females (30.6 yr v. 27.9 yr) and more likely to be parous, and their newborns had a lower mean birthweight (Table 1). Mean gestational age at birth, and proportions of preterm births and structural congenital anomalies, did not differ appreciably (Table 1).

Most immigrants had originated from South Asia (n = 52 428, 35.4%) and the East Asia and Pacific region (n = 35 276, 23.8%); 111 626 (75.4%) immigrants had resided in Ontario for less than 10 years (Table 1). Additional characteristics are presented in Table 1.

Indicators of SNMM

The 5 most frequent SNMM indicators were the same among newborns of immigrant and nonimmigrant females. These were ventilatory support, receipt of intravenous fluids, gestational age at birth of less than 32 weeks, birth weight of less than 1500 g and respiratory distress syndrome (Appendix 1, Table S3).

Immigrant status and SNMM

The rate of SNMM (the presence of ≥ 1 E-NAOI components v. none) was significantly lower among newborns of immigrant (49.7 per 1000 live births) than nonimmigrant (65.6 per 1000 live births) females, equivalent to an adjusted RR of 0.76 (95% CI 0.74 to 0.79) and an adjusted absolute risk difference of −15.2 cases per 1000 live births (95% CI −16.6 to −13.8) (Table 2).

Compared with their nonimmigrant counterparts, the newborns of immigrant females had lower odds of having 1 SNMM indicator (adjusted OR 0.74, 95% CI 0.71 to 0.76), 2 indicators (adjusted OR 0.68, 95% CI 0.64 to 0.73) and 3 or more indicators (adjusted OR 0.82, 95% CI 0.78 to 0.86) (Table 3).

Maternal birthplace and SNMM

Relative to newborns of nonimmigrants, the risk of SNMM was lower for newborns of immigrant females from South Asia (adjusted RR 0.72, 95% CI 0.69 to 0.75), Middle East and North Africa (adjusted RR 0.70, 95% CI 0.65 to 0.76), East Asia and Pacific (adjusted RR 0.67, 95% CI 0.64 to 0.71), Latin America (adjusted RR 0.79, 95% CI 0.73 to 0.87), and Western Nations and Europe (adjusted RR 0.77, 95% CI 0.71 to 0.83) (Table 4). Conversely, the risk was higher for those of immigrant females from the Caribbean (adjusted RR 1.12, 95% CI 1.04 to 1.19).

Newborns of females from Jamaica (adjusted RR 1.14, 95% CI 1.05 to 1.23) and Ghana (adjusted RR 1.20, 95% CI 1.05 to 1.38) had the highest risk of SNMM relative to their nonimmigrant counterparts, when data relating to the top 20 immigrant countries contributing to births were analyzed, while the lowest risk was among newborns of females from China (adjusted RR 0.44, 95% CI 0.40 to 0.48) (Table 5).

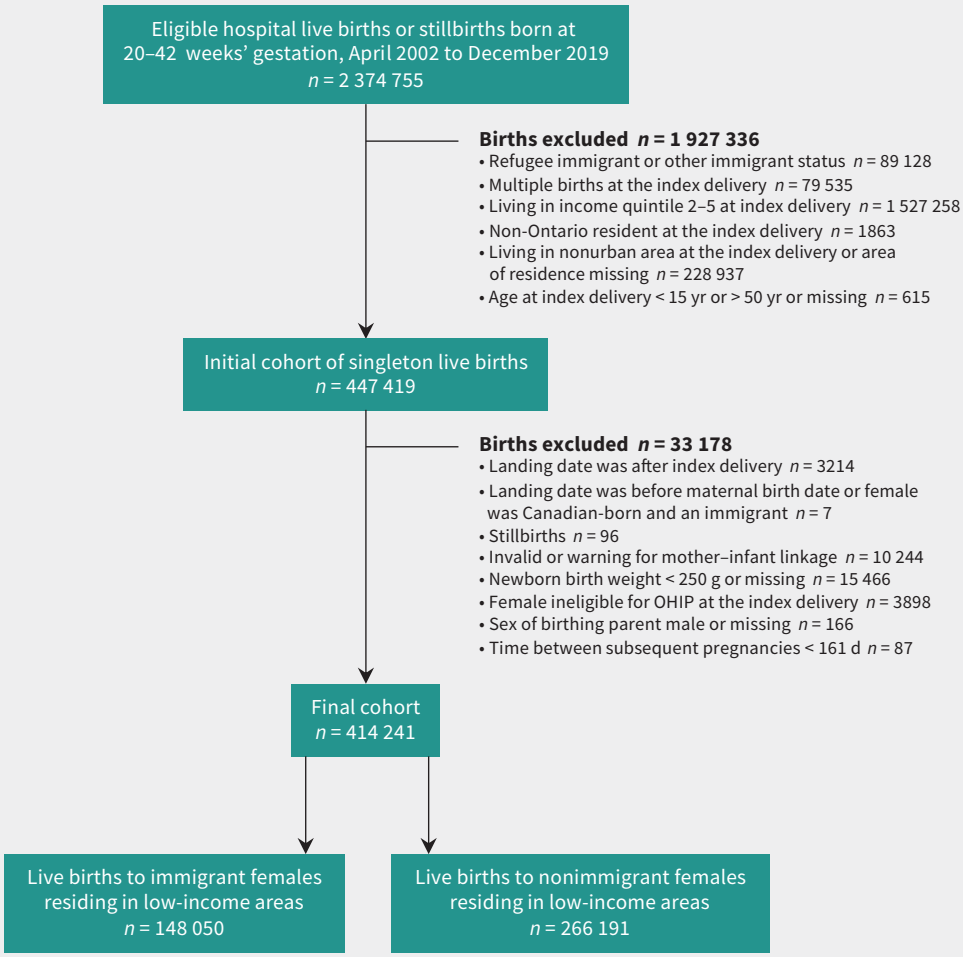

Figure 1: Flow diagram of cohort creation. Note: OHIP = Ontario Health Insurance Plan.

Maternal duration of residence and SNMM

The risk of SNMM declined among newborns of immigrants with shorter duration of residence in Ontario, relative to newborns of immigrants who had resided in Ontario for 20 years or more (Figure 2).

Sensitivity analyses

After removing the 2 nondiagnostic indicators (gestational age at birth < 32 weeks and birthweight < 1500 g) from the SNMM composite, the risk estimates were largely unchanged (Appendix 1, Table S4). Rates of SNMM were higher among newborns delivered before 32 weeks' gestation versus those born at or after 32 weeks' gestation (Appendix 1, Table S5). Within both gestational age strata, newborns of immigrant females had a lower risk of SNMM than those of nonimmigrant females, especially those born at or after 32 weeks' gestation (Appendix 1, Table S5). Inclusion of stillbirths and live births within the cohort did not materially change the risk estimates (Appendix 1, Table S6).

Interpretation

In this cohort of publicly insured females residing in low-income urban neighbourhoods in Ontario, newborns of immigrant females had an overall substantially lower risk of SNMM than newborns of nonimmigrant females. However, this association varied by maternal birthplace and duration of residence in Ontario. The risk of SNMM was higher among newborns of immigrants from the Caribbean world region; at a country level, those from Jamaica and Ghana; and those with a longer duration of residence in Ontario.

Our findings suggest that within low-income areas, newborns of immigrant females appear to have better neonatal outcomes than newborns of nonimmigrant females. This may be partly explained by the Healthy Immigrant Effect, which wanes with increasing duration of residency,[70,71] as described by the Convergence Hypothesis.[71] In addition, the Immigrant Paradox describes better health outcomes among immigrants than the native population within the host country, despite immigrants facing greater barriers to health care access.[43,71,72]

Table 1 (part 1 of 2): Characteristics of births among immigrant and nonimmigrant females residing in a low-income urban neighbourhood*

Characteristic	No. (%) of births†		Standardized difference‡
	Immigrants *n* = 148 050	Nonimmigrants *n* = 266 191	
Newborn			
Birth weight, g, mean ± SD	3254 ± 544	3351 ± 583	0.2
Gestational age at birth, wk, mean ± SD	38.8 ± 1.9	38.8 ± 2.0	0.03
Preterm birth (< 37 wk)	9453 (6.4)	20 019 (7.5)	0.05
Any structural congenital anomaly diagnosed at the index birth admission	6489 (4.4)	14 184 (5.3)	0.04
Maternal			
Age at the index birth, yr, mean ± SD	30.6 ± 5.2	27.9 ± 5.9	0.5
Age category at the index birth, yr			
15–19	1678 (1.1)	20 115 (7.6)	0.3
20–29	61 024 (41.2)	142 215 (53.4)	0.3
30–39	78 476 (53.0)	96 975 (36.4)	0.3
40–50	6872 (4.6)	6886 (2.6)	0.1
Parity			
0	59 397 (40.1)	121 483 (45.6)	0.1
1	55 488 (37.5)	85 388 (32.1)	0.1
2	21 879 (14.8)	36 383 (13.7)	0.03
≥ 3	11 286 (7.6)	22 937 (8.6)	0.04
Duration of residence in Ontario at the index birth, median (IQR), yr§	4.9 (2.3–9.9)	–	–
World region of origin§			
Caribbean	12 028 (8.1)	–	–
East Asia and Pacific	35 276 (23.8)	–	–
Western Nations and Europe	12 994 (8.8)	–	–
Latin America	9684 (6.5)	–	–
Middle East and North Africa	13 812 (9.3)	–	–
South Asia	52 428 (35.4)	–	–
Sub-Saharan Africa	11 790 (8.0)	–	–
Missing	38 (0.03)	–	–
Year of arrival§		–	–
1985–1990	6591 (4.5)	–	–
1991–2001	48 913 (33.0)	–	–
2002–2010	69 230 (46.8)	–	–
2011–2017	23 316 (15.7)	–	–
Age at arrival§, yr, mean ± SD	23.7 ± 7.4	–	–
Age category at arrival§, yr			
Infancy–9	7940 (5.4)	–	–
10–19	28 174 (19.0)	–	–
20–29	80 016 (54.0)	–	–
30–39	31 263 (21.1)	–	–
40–50	657 (0.4)	–	–

Table 1 (part 2 of 2): Characteristics of births among immigrant and nonimmigrant females residing in a low-income urban neighbourhood*

Characteristic	No. (%) of births†		Standardized difference‡
	Immigrants *n* = 148 050	Nonimmigrants *n* = 266 191	
English and/or French language ability§			
Yes	92 160 (62.2)	–	–
No	55 833 (37.7)	–	–
Missing	57 (0.04)	–	–
Highest level of education§			
Secondary school or less	78 841 (53.3)	–	–
Trade certificate or diploma, or some university	22 286 (15.1)	–	–
University degree	35 405 (23.9)	–	–
Graduate degree	11 013 (7.4)	–	–
Missing	505 (0.3)	–	–
Immigration class§			
Economic¶	52 184 (35.2)	–	–
Sponsored family**	95 866 (64.8)	–	–
Duration of residence in Ontario at index birth, yr§			
< 10	111 626 (75.4)	–	–
≥ 10	36 424 (24.6)	–	–

Note: IQR = interquartile range, SD = standard deviation.
*Data are limited to births to females who resided in an urban neighbourhood of the lowest income quintile and who had a singleton, in-hospital live birth at 20–42 weeks' gestation in Ontario, Canada, from 2002 to 2019. Immigrant female group excludes refugee immigrants.
†Unless indicated otherwise.
‡A standardized difference > 0.10 is considered to be clinically meaningful.[60]
§On arrival in Canada (immigrants only).
¶Immigrant female or her family member (if she was a child) selected for their skills and ability to contribute to Canada's economy.
**Immigrant female or her family member (if she was a child) sponsored by a Canadian citizen or a permanent resident living in Canada (aged ≥ 18 yr).

Table 2: Risk of severe neonatal morbidity and neonatal mortality (SNMM) arising in the index birth admission and up to 27 days thereafter, comparing newborns born to immigrant and nonimmigrant females*

Exposure group	No. with SNMM (rate per 1000 live births)	Unadjusted RR (95% CI)†	Adjusted RR (95% CI)†‡	Adjusted absolute risk difference per 1000 live births (95% CI)†‡
Nonimmigrants (*n* = 266 191)	17 457 (65.6)	1.00 (Ref.)	1.00 (Ref.)	0.0 (Ref.)
Immigrants (*n* = 148 050)	7352 (49.7)	0.76 (0.74 to 0.78)	0.76 (0.74 to 0.79)	–15.2 (–16.6 to –13.8)

Note: CI = confidence interval, Ref. = reference category, RR = relative risk.
*Data are limited to births to females who resided in an urban neighbourhood of the lowest income quintile and who had a singleton, in-hospital live birth at 20–42 weeks' gestation in Ontario, Canada, from 2002 to 2019. Immigrant group excludes refugee immigrants.
†Using modified Poisson regression with a robust error variance. Generalized estimating equations with an exchangeable correlation structure accounted for correlated errors of potentially more than 1 birth clustered within the same mother.
‡Adjusted for maternal age (15–19 yr, 20–29 yr, 30–39 yr, 40–50 yr), parity (0, 1, 2, ≥ 3) and any structural congenital anomaly (yes or no).

Our findings also suggest that the Healthy Immigrant Effect may transfer from a recent immigrant female to her newborn, as evidenced by a lower risk of SNMM, with some variation by maternal country of origin. Immigrant females who are healthier and more resilient may be most capable of migration; the immigration policy of a host country may preferentially select healthy immigrants.[71] Another explanation may be that some immigrants have greater net income, educational achievement and health literacy than the average for a low-income neighbourhood. In contrast, some nonimmigrants may experience multigenerational poverty. The observed relation between shorter maternal duration of residence and lower SNMM may be owing to the

Table 3: Odds ratio of having a higher number of severe neonatal morbidity and neonatal mortality (SNMM) indicators versus having 0 SNMM indicators in the index birth admission and up to 27 days thereafter, comparing newborns born to immigrant and nonimmigrant females*†‡

	Newborns with 1 SNMM indicator †‡		Newborns with 2 SNMM indicators †‡		Newborns with ≥ 3 SNMM indicators †‡	
Exposure group	No. (rate per 1000 live births)	Adjusted OR (95% CI)§¶	No. (rate per 1000 live births)	Adjusted OR (95% CI)§¶	No. (rate per 1000 live births)	Adjusted OR (95% CI)§¶
Nonimmigrants (*n* = 266 191)	9078 (34.1)	1.00 (Ref.)	3368 (12.7)	1.00 (Ref.)	5011 (18.8)	1.00 (Ref.)
Immigrants (*n* = 148 050)	3803 (25.7)	0.74 (0.71 to 0.76)	1310 (8.8)	0.68 (0.64 to 0.73)	2239 (15.1)	0.82 (0.78 to 0.86)

Note: CI = confidence interval, OR = odds ratio, Ref. = reference category.
*Data are limited to births to females who resided in an urban neighbourhood of the lowest income quintile and who had a singleton hospital livebirth at 20–42 weeks' gestation in Ontario, Canada, from 2002 to 2019. Immigrant female group excludes refugee immigrants.
†248 734 (93.4%) newborns born to nonimmigrant females had 0 SNMM indicators.
‡140 698 (95.0%) newborns born to immigrant females had 0 SNMM indicators.
§Using multinomial logistic regression. Generalized estimating equations with an independent correlation structure accounted for correlated errors of potentially more than 1 birth clustered within the same mother.
¶Adjusted for maternal age (15–19 yr, 20–29 yr, 30–39 yr, 40–50 yr), parity (0, 1, 2, ≥ 3) and any structural congenital anomaly (yes or no).

Table 4: Risk of severe neonatal morbidity and neonatal mortality (SNMM) arising in the index birth admission and up to 27 days thereafter, comparing newborns of immigrants from each world region of origin and those of nonimmigrant females*

Maternal world region of origin†	No. with SNMM (rate per 1000 live births)	Unadjusted RR (95% CI)‡	Adjusted RR (95% CI)‡§	Adjusted absolute risk difference (per 1000 live births, 95% CI)‡§
Nonimmigrant (*n* = 266 191)	17 457 (65.6)	1.00 (Ref.)	1.00 (Ref.)	0.0 (Ref.)
South Asia (*n* = 52 428)	2368 (45.2)	0.69 (0.66 to 0.72)	0.72 (0.69 to 0.75)	−18.5 (−20.4 to −16.6)
Middle East and North Africa (*n* = 13 812)	625 (45.3)	0.69 (0.64 to 0.75)	0.70 (0.65 to 0.76)	−19.0 (−22.5 to −15.5)
East Asia and Pacific (*n* = 35 276)	1625 (46.1)	0.70 (0.67 to 0.74)	0.67 (0.64 to 0.71)	−21.2 (−23.5 to −18.9)
Latin America (*n* = 9684)	492 (50.8)	0.77 (0.71 to 0.85)	0.79 (0.73 to 0.87)	−13.4 (−17.7 to −9.1)
Western Nations and Europe (*n* = 12 994)	665 (51.2)	0.78 (0.72 to 0.84)	0.77 (0.71 to 0.83)	−12.9 (−16.8 to −9.1)
Sub-Saharan Africa (*n* = 11 790)	712 (60.4)	0.93 (0.86 to 1.00)	0.94 (0.87 to 1.01)	−4.6 (−9.0 to −0.3)
Caribbean (*n* = 12 028)	863 (71.7)	1.10 (1.02 to 1.17)	1.12 (1.04 to 1.19)	5.1 (0.6 to 9.6)

Note: CI = confidence interval, Ref. = reference category, RR = relative risk.
*Data are limited to births to females who resided in an urban neighbourhood of the lowest income quintile and who had a singleton, in-hospital live birth at 20–42 weeks' gestation in Ontario, Canada, from 2002 to 2019, excluding refugee immigrants.
†Excludes 38 births to females missing world region of birth.
‡Using modified Poisson regression with a robust error variance. Generalized estimating equations with an exchangeable correlation structure accounted for correlated errors of potentially more than 1 birth clustered within the same mother.
§Adjusted for maternal age (15–19 yr, 20–29 yr, 30–39 yr, 40–50 yr), parity (0, 1, 2, ≥ 3) and any structural congenital anomaly (yes or no).

movement of immigrant females whose newborns are at lowest risk of SNMM, out of low-income areas soon after their arrival to Ontario, while those who are similar to nonimmigrants remain in low-income neighbourhoods.

Previous studies have evaluated immigrant status[6,16,17,46] or area-level income[12,15] as independent risk factors for SNM, including some that used race and ethnicity as predictors of SNM.[11,12] One Australian study found no association between immigrant status and SNM, but used an SNM composite with 3 indicators and no procedures.[6] Previous Canadian research has yielded similar findings to our current study; however, the study cohorts in those and our current study overlap somewhat. One study used a composite outcome measure like ours, and observed a similar relation between immigrant status and SNM in Ontario.[16] Other studies observed that the risk of adverse perinatal outcomes varied by maternal birthplace, including a higher risk among immigrant females from the Caribbean region, and countries such as Jamaica and Ghana, compared with Canadian-born females.[44,45]

The current study complements our previous research on neighbourhood income level and risk of concomitant preterm birth and small-for-gestational-age birth weight, by identifying attributes of mother–infant pairs who are at higher risk of adverse neonatal outcomes within lowest-income neighbourhoods.[35] Collectively, the findings from this current study and

Table 5: Risk of severe neonatal morbidity and neonatal mortality (SNMM) arising in the index birth admission and up to 27 days thereafter, among newborns of immigrant mothers from the 20 countries contributing the greatest number of births in Ontario, relative to newborns of nonimmigrant females*

Maternal country of birth exposure group†	No. with SNMM (rate per 1000 live births)	Unadjusted RR (95% CI)‡	Adjusted RR (95% CI)‡§
Nonimmigrant (*n* = 266 191)	17 457 (65.6)	1.00 (Ref.)	1.00 (Ref.)
China (*n* = 13 077)	389 (29.7)	0.45 (0.41 to 0.50)	0.44 (0.40 to 0.48)
Lebanon (*n* = 1863)	62 (33.3)	0.51 (0.40 to 0.65)	0.52 (0.41 to 0.67)
Vietnam (*n* = 3738)	130 (34.8)	0.53 (0.45 to 0.63)	0.54 (0.46 to 0.64)
Poland (*n* = 1616)	58 (35.9)	0.55 (0.43 to 0.71)	0.55 (0.42 to 0.70)
Sri Lanka (*n* = 7797)	329 (42.2)	0.64 (0.58 to 0.72)	0.66 (0.60 to 0.74)
Pakistan (*n* = 15 158)	641 (42.3)	0.64 (0.60 to 0.70)	0.68 (0.63 to 0.73)
India (*n* = 21 123)	966 (45.7)	0.70 (0.66 to 0.74)	0.73 (0.68 to 0.77)
Iraq (*n* = 2175)	102 (46.9)	0.71 (0.58 to 0.87)	0.74 (0.61 to 0.90)
Afghanistan (*n* = 2619)	132 (50.4)	0.77 (0.65 to 0.91)	0.82 (0.69 to 0.98)
Nigeria (*n* = 1579)	83 (52.6)	0.80 (0.65 to 0.99)	0.78 (0.63 to 0.97)
Romania (*n* = 1281)	68 (53.1)	0.81 (0.64 to 1.02)	0.76 (0.60 to 0.95)
Bangladesh (*n* = 5156)	275 (53.3)	0.81 (0.72 to 0.91)	0.84 (0.75 to 0.94)
Philippines (*n* = 15 084)	968 (64.2)	0.98 (0.92 to 1.04)	0.93 (0.87 to 0.99)
Somalia (*n* = 2131)	113 (53.0)	0.82 (0.68 to 0.98)	0.84 (0.70 to 1.01)
Iran (*n* = 1644)	99 (60.2)	0.92 (0.76 to 1.11)	0.84 (0.69 to 1.01)
Ethiopia (*n* = 2075)	125 (60.2)	0.92 (0.77 to 1.10)	0.92 (0.77 to 1.10)
Guyana (*n* = 3538)	215 (60.8)	0.93 (0.81 to 1.06)	0.95 (0.83 to 1.08)
Trinidad and Tobago (*n* = 1555)	100 (64.3)	0.98 (0.81 to 1.19)	0.98 (0.81 to 1.20)
Jamaica (*n* = 7971)	580 (72.8)	1.11 (1.03 to 1.21)	1.14 (1.05 to 1.23)
Ghana (*n* = 2731)	207 (75.8)	1.16 (1.01 to 1.34)	1.20 (1.05 to 1.38)

Note: CI = confidence interval, Ref. = reference category, RR = relative risk.
*Data are limited to births to females who resided in an urban neighbourhood of the lowest income quintile and who had a singleton, in-hospital live birth at 20–42 weeks' gestation in Ontario, Canada, from 2002 to 2019, excluding refugee immigrants.
†Excludes 38 births to females missing world region of birth, and 34 101 births to females not originating from 1 of the top 20 countries.
‡Using modified Poisson regression with a robust error variance. Generalized estimating equations with an exchangeable correlation structure accounted for correlated errors of potentially more than 1 birth clustered within the same mother.
§Adjusted for maternal age (15–19 yr, 20–29 yr, 30–39 yr, 40–50 yr), parity (0, 1, 2, ≥ 3) and any structural congenital anomaly (yes or no).

recent data about SMMM among females residing in low-income neighbourhoods[47] suggest that immigrant females and their newborns each have an overall lower risk of adverse birth outcomes than their Canadian-born counterparts.

This study highlights the importance of evaluating health outcomes like SNMM within area-level, constrained income groups, particularly when there is a known gradient effect across income levels. This approach can identify pregnant parents and newborns at highest risk, who stand to benefit the most from targeted screening, surveillance and services. Our findings also suggest that not all immigrants appear to experience the Healthy Immigrant Effect, which further emphasizes the importance of within-neighbourhood research to inform policy and practice regarding the needs of immigrants and their infants in low-income areas. The needs of nonimmigrants and their infants within low-income areas may not be uniform, and future studies should evaluate the multigenerational attributes of nonimmigrant populations. Furthermore, our findings underscore a need to move beyond using a dichotomous approach to immigrant status (i.e., immigrant v. nonimmigrant) in policy, practice and research. Such aggregation bias, where distinct but smaller subgroups are categorized together, masks important nuances among immigrant subgroups.[73]

Limitations

We excluded multifetal pregnancies from the cohort, and findings may not be applicable to those newborns.[74] A few stillbirths and neonatal deaths may have been missed within the data sets.[75] Although the secondary outcome of the number of SNMM indicators has not been validated, it was akin to our approach in a previous study, where we observed that maternal mortality was exponentially associated with the number of severe maternal morbidity indicators.[59]

A small proportion of immigrant females may not have been linked to the Immigration, Refugees and Citizenship Canada Permanent Residents database and would have therefore been classified as nonimmigrants (i.e., Canadian-born). This may have occurred if their immigration record was missing or if they entered Ontario before 1985 or via another province. Such misclassification

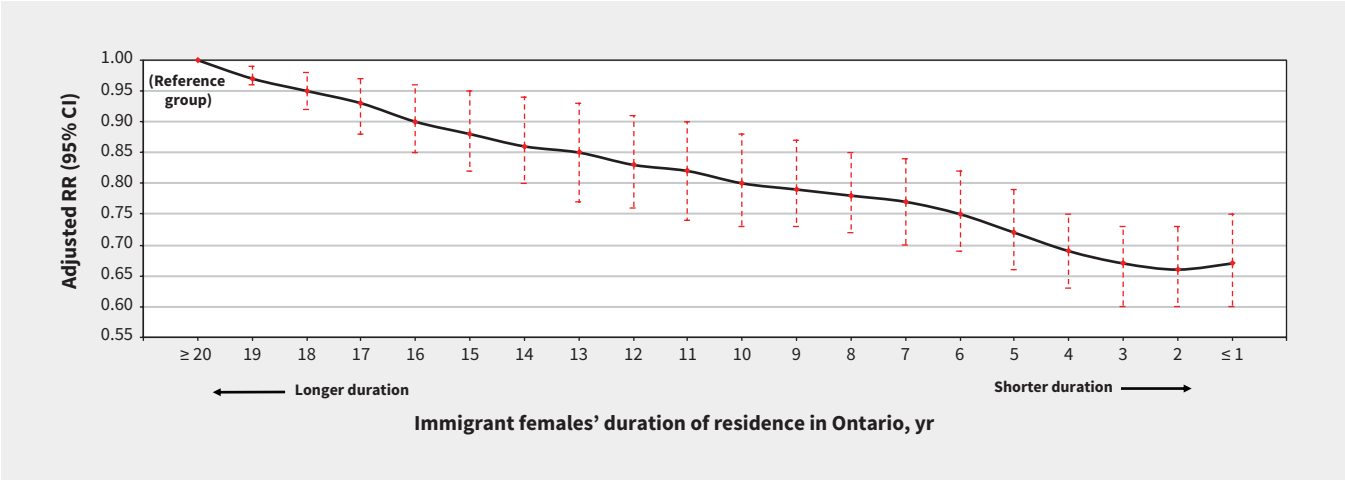

Figure 2: Adjusted relative risk (RR) of severe neonatal morbidity and neonatal mortality (SNMM) arising in the index birth admission and up to 27 days thereafter by declining duration of residence in Ontario. Those residing in Ontario for at least 20 years are the reference group. Data are restricted to immigrant females residing in urban neighbourhoods of the lowest income quintile, and who had a singleton, in-hospital live birth at 20–42 weeks' gestation in Ontario, Canada, from 2002 to 2019. Analysis adjusted for maternal age (15–19 yr, 20–29 yr, 30–39 yr, 40–50 yr), parity (0, 1, 2, ≥ 3), any structural congenital anomaly (yes or no), world region of birth (Caribbean, East Asia and Pacific, Latin America, Middle East and North Africa, South Asia, Sub-Saharan Africa, Western Nations and Europe), and the following variables at arrival to Canada: highest level of education (secondary school or less; trade certificate or diploma, or some university; university degree; graduate degree), English and/or French language ability (yes or no) and immigration class (economic, sponsored family). Analysis excludes 266 191 nonimmigrant females, 505 immigrant females missing highest level of education at arrival to Canada, 38 females missing world region of birth and 18 immigrant females missing English and/or French language ability at arrival to Canada. Note: CI = confidence interval.

would tend to bias the results toward the null. We did not include refugees or other special-status immigrants in the study because they may have lacked an OHIP number for data linkage. Furthermore, as refugees tend to have different migration experiences (e.g., nonvoluntary migration and secondary migration) than nonrefugee immigrants, our findings may not be generalizable to their newborns. Even so, newborns in both refugee and nonrefugee immigrant groups may experience similar degrees of SNMM.[16]

This study focused on newborns among females living in urban areas, so findings may not be generalizable to those living in low-income rural areas,[76] given differences in health care access and health indicators between urban and rural residents.[77] Neighbourhood income quintile reflects area-level income status;[78] however, details of individual-level income were unavailable. A female lacking an up-to-date residential address may have been incorrectly assigned to the wrong neighbourhood income quintile, but the likelihood of this is low, given her active use of OHIP for antenatal and delivery care. Nonindependence may also have been present owing to clustering by geography (e.g., females in the same neighbourhood may be more similar than those in different neighbourhoods).

Data were not available on certain sociodemographic factors among nonimmigrants. Among immigrants, early life exposures and obstetrical events pre-migration were also unknown. In addition, we had no information on psychosocial, employment and behavioural factors (e.g., smoking, substance use), as well as measures of obesity and quality of care, potentially leading to residual confounding in all analytical models. Differences in SNMM between newborns of immigrant and nonimmigrant females, and by immigrant country of origin, may be explained by these factors. Future research is needed to clarify if the disparities we observed are owing to unmeasured confounders or true differences.

Conclusion

Among females residing in low-income urban areas in Ontario, newborns of immigrants had a considerably lower risk of SNMM than nonimmigrants. However, that risk varied by maternal birthplace and duration of residence in Ontario. Efforts should be aimed at improving the overall health and well-being of all females residing in low-income areas, and at determining if the risk of adverse birth outcomes can be equitably reduced among immigrant and nonimmigrant groups. Research should also focus on females originating from specific countries and their newborns, who may require additional monitoring and interventions in the perinatal period.

References

1. Santos JP, Pileggi-Castro C, Camelo JS Jr, et al. Neonatal near miss: a systematic review. *BMC Pregnancy Childbirth* 2015;15:320.
2. Lain SJ, Algert CS, Nassar N, et al. Incidence of severe adverse neonatal outcomes: use of a composite indicator in a population cohort. *Matern Child Health J* 2012;16:600-8.
3. Surve SV, Chauhan S, Kulkarni R. Neonatal near miss review: tracking its conceptual evolution and wayforward. *Curr Pediatr Res* 2017;21:264-71.
4. Goldenberg RL, McClure EM. Maternal, fetal and neonatal mortality: lessons learned from historical changes in high income countries and their potential application to low-income countries. *Matern Health Neonatol Perinatol* 2015;1:3.
5. Edstedt Bonamy AK, Zeitlin J, Piedvache A, et al.; Epice Research Group. Wide variation in severe neonatal morbidity among very preterm infants in European regions. *Arch Dis Child Fetal Neonatal Ed* 2019;104:F36-45.
6. Hassen TA, Chojenta C, Egan N, et al. Determinants of neonatal near miss in Australia: a multilevel analysis. *Early Hum Dev* 2021;156:105343.
7. Perinatal Health Indicators for Canada 2017. Ottawa: Public Health Agency of Canada; 2017. Available: https://publications.gc.ca/collections/collection_2020/aspc-phac/HP7-1-2017-1-eng.pdf (accessed 2022 June 15).
8. Knight HE, Oddie SJ, Harron KL, et al. Establishing a composite neonatal adverse outcome indicator using English hospital administrative data. *Arch Dis Child Fetal Neonatal Ed* 2019;104:F502-9.

9. Geller SE, Koch AR, Garland CE, et al. A global view of severe maternal morbidity: moving beyond maternal mortality. *Reprod Health* 2018;15(Suppl 1):98.
10. de Barros Medeiros P, Bailey C, Andrews C, et al. Neonatal near miss: a review of current definitions and the need for standardisation. *Aust N Z J Obstet Gynaecol* 2022;62:358-63.
11. Kale PL, Prado de Mello-Jorge MH, Silveira da Silva K, et al. Neonatal near miss and mortality: factors associated with life-threatening conditions in newborns at six public maternity hospitals in Southeast Brazil. *Cad Saude Publica* 2017;33:e00179115.
12. Dawson P, Auvray B, Jaye C, et al. Social determinants and inequitable maternal and perinatal outcomes in Aotearoa New Zealand. *Womens Health (Lond)* 2022;18: 17455065221075913 10.1177/17455065221075913.
13. Battarbee AN, Venkatesh KK, Aliaga S, et al. The association of pregestational and gestational diabetes with severe neonatal morbidity and mortality. *J Perinatol* 2020;40:232-9.
14. Lebreton E, Menguy C, Fresson J, et al. Measuring severe neonatal morbidity using hospital discharge data in France. *Paediatr Perinat Epidemiol* 2022;36:190-201.
15. Adane AA, Bailey HD, Marriott R, et al. Disparities in severe neonatal morbidity and mortality between Aboriginal and non-Aboriginal births in Western Australia: a decomposition analysis. *J Epidemiol Community Health* 2021;75:1187-94.
16. Wanigaratne S, Cole DC, Bassil K, et al. Severe neonatal morbidity among births to refugee women. *Matern Child Health J* 2016;20:2189-98.
17. Margioula-Siarkou C, Petousis S, Kalogiannidis I, et al. Immigrants present improved obstetric and neonatal outcomes compared to native women. A Northern Greek population analysis. *J Immigr Minor Health* 2013;15:249-54.
18. Abebe H, Wasie A, Yeshaneh A, et al. Determinant factors of neonatal near miss among neonates in Gurage Zone hospitals, Ethiopia: a case-control study. *Pediatric Health Med Ther* 2021;12:129-39.
19. de Souza Campos Assis T, Guidolini Martinelli K, Granado Nogueira da Gama S, et al. Associated factors of neonatal near miss among newborns of adolescent mothers in Brazil. *Rev Esc Enferm USP* 2022;56:e20210359.
20. Costa Carvalho OM, Brazil Viana A Jr, Costa Carvalho Augusto M, et al. Delays in obstetric care increase the risk of neonatal near-miss morbidity events and death: a case-control study. *BMC Pregnancy Childbirth* 2020;20:437.
21. Barbosa de Lima TH, Katz L, Kassar SB, et al. Neonatal near miss determinants at a maternity hospital for high-risk pregnancy in Northeastern Brazil: a prospective study. *BMC Pregnancy Childbirth* 2018;18:401.
22. Habte A, Lukas K, Melis T, et al. Determinants of neonatal near miss among neonates admitted to public hospitals in Southern Ethiopia, 2021: a case-control study. *PLoS One* 2022;17:e0268041.
23. Wondimu M, Balcha F, Bacha G, et al. The magnitude of neonatal near miss and associated factors among live births in public hospitals of Jimma Zone, Southwest Ethiopia, 2020: a facility-based cross-sectional study. *PLoS One* 2021;16:e0251609.
24. Gomes Pereira T, Marano da Rocha D, Fonseca VM, et al. Factors associated with neonatal near miss in Brazil. *Rev Saude Publica* 2020;54:123.
25. Sushma R, Norhayati MN, Nik Hazlina NH. Prevalence of neonatal near miss and associated factors in Nepal: a cross-sectional study. *BMC Pregnancy Childbirth* 2021;21:422.
26. Tassew HA, Kassie FY, Mihret MS. Neonatal near miss and its predictors among neonates delivered at Debretabor General Hospital, Northern Ethiopia; a retrospective analysis. *Int J Pediatr* 2020;2020:1092479.
27. Tekelab T, Chojenta C, Smith R, et al. Incidence and determinants of neonatal near miss in south Ethiopia: a prospective cohort study. *BMC Pregnancy Childbirth* 2020;20:354.
28. *A conceptual framework for action on the social determinants of health.* Geneva: World Health Organization; 2010.
29. Dagher RK, Linares DE. A critical review on the complex interplay between social determinants of health and maternal and infant mortality. *Children (Basel)* 2022;9:394.
30. Blumenshine P, Egerter S, Barclay CJ, et al. Socioeconomic disparities in adverse birth outcomes: a systematic review. *Am J Prev Med* 2010;39:263-72.
31. Metcalfe A, Lail P, Ghali WA, et al. The association between neighbourhoods and adverse birth outcomes: a systematic review and meta-analysis of multilevel studies. *Paediatr Perinat Epidemiol* 2011;25:236-45.
32. Daoud N, O'Campo P, Minh A, et al. Patterns of social inequalities across pregnancy and birth outcomes: a comparison of individual and neighborhood socioeconomic measures. *BMC Pregnancy Childbirth* 2015;14:393.
33. Vos AA, Posthumus AG, Bonsel GJ, et al. Deprived neighborhoods and adverse perinatal outcome: a systematic review and meta-analysis. *Acta Obstet Gynecol Scand* 2014;93:727-40.
34. Gilbert NL, Auger N, Wilkins R, et al. Neighbourhood income and neonatal, postneonatal and sudden infant death syndrome (SIDS) mortality in Canada, 1991–2005. *Can J Public Health* 2013;104:e187-92.
35. Jairam JA, Vigod SN, O'Campo P, et al. Neighbourhood income and risk of having an infant with concomitant preterm birth and severe small for gestational age birth weight. *J Obstet Gynaecol Can* 2020;42:156-62.e1.
36. Bartsch E, Park AL, Jairam J, et al. Concomitant preterm birth and severe small-for-gestational age birth weight among infants of immigrant mothers in Ontario originating from the Philippines and East Asia: a population-based study. *BMJ Open* 2017;7:e015386.
37. Behboudi-Gandevani S, Bidhendi-Yarandi R, Panahi MH, et al. A systematic review and meta-analysis of the risk of stillbirth, perinatal and neonatal mortality in immigrant women. *Int J Public Health* 2022;67:1604479.
38. Vang ZM, Sigouin J, Flenon A, et al. Are immigrants healthier than native-born Canadians? A systematic review of the healthy immigrant effect in Canada. *Ethn Health* 2017;22:209-41.
39. Gagnon AJ, Zimbeck M, Zeitlin J; ROAM Collaboration, et al. Migration to western industrialised countries and perinatal health: a systematic review. *Soc Sci Med* 2009;69:934-46.
40. Park AL, Urquia ML, Ray JG. Risk of preterm birth according to maternal and paternal country of birth: a population-based study. *J Obstet Gynaecol Can* 2015;37:1053-62.
41. Urquia ML, Qiao Y, Ray JG, et al. Birth outcomes of foreign-born, native-born, and mixed couples in Sweden. *Paediatr Perinat Epidemiol* 2015;29:123-30.
42. Urquia ML, Frank JW, Glazier RH, et al. Neighborhood context and infant birthweight among recent immigrant mothers: a multilevel analysis. *Am J Public Health* 2009;99:285-93.
43. Khanlou N, Haque N, Skinner A, et al. Scoping review on maternal health among immigrant and refugee women in Canada: prenatal, intrapartum, and postnatal care. *J Pregnancy* 2017;2017:8783294.
44. Medcalf KE, Park AL, Vermeulen MJ, et al. Maternal origin and risk of neonatal and maternal ICU admission. *Crit Care Med* 2016;44:1314-26.
45. Ray JG, Wanigaratne S, Park AL, et al. Preterm preeclampsia in relation to country of birth. *J Perinatol* 2016;36:718-22.
46. Wanigaratne S, Shakya Y, Gagnon AJ, et al. Refugee maternal and perinatal health in Ontario, Canada: a retrospective population-based study. *BMJ Open* 2018;8:e018979.
47. Jairam JA, Vigod SN, Siddiqi A, et al. Severe maternal morbidity and mortality among immigrant and Canadian-born women residing within low-income neighbourhoods. *JAMA Netw Open* 2023;6:e2256203.
48. Hudon T. Women in Canada: a gender-based statistical report — immigrant women. Cat. no. 89-503-X. Ottawa: Statistics Canada; 2015. Available: https://www150.statcan.gc.ca/n1/en/pub/89-503-x/2015001/article/14217-eng.pdf?st=depRv5eo (accessed 2022 Mar. 15).
49. Benchimol EI, Smeeth L, Guttmann A, et al.; RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) statement. *PLoS Med* 2015;12:e1001885.
50. Wen SW, Liu S, Marcoux S, et al. Uses and limitations of routine hospital admission/separation records for perinatal surveillance. *Chronic Dis Can* 1997;18:113-9.
51. Joseph KS, Fahey J; Canadian Perinatal Surveillance System. Validation of perinatal data in the Discharge Abstract Database of the Canadian Institute for Health Information. *Chronic Dis Can* 2009;29:96-100.
52. Juurlink D, Preyra C, Croxford R, et al. *Canadian Institute for Health Information Discharge Abstract Database: a validation study*. Toronto: ICES; 2006.
53. Cernat G, Wall C, Iron K, et aal. *Initial validation of Landed Immigrant Data System (LIDS) with the Registered Person's Database (RPDB) at ICES.* Internal ICES Report to Health Canada. Toronto: ICES; 2002.
54. Chiu M, Lebenbaum M, Lam K, et al. Describing the linkages of the immigration, refugees and citizenship Canada permanent resident data and vital statistics death registry to Ontario's administrative health database. *BMC Med Inform Decis Mak* 2016;16:135.
55. Postal Code^{OM} Conversion File Plus (PCCF+) Version 7B, reference guide: November 2018 postal codes^{OM}. Ottawa: Statistics Canada; 2019. Available: https://mdl.library.utoronto.ca/sites/default/public/mdldata/open/canada/national/statcan/postalcodes/pccfplus/2016/2018nov/Userguide-EN-11042019.pdf (accessed 2022 Mar. 28).
56. Urquia ML, Ying I, Glazier RH, et al. Serious preeclampsia among different immigrant groups. *J Obstet Gynaecol Can* 2012;34:348-52.
57. *A neglected tragedy: the global burden of stillbirths — report of the UN Interagency Group for Child Mortality Estimation, 2020*. New York: United Nations Children's Fund; 2020.
58. Methodology: standard country or area codes for statistical use (M49). New York: Statistics Division, United Nations; 2019; Available: https://unstats.un.org/unsd/methodology/m49/overview/ (accessed 2018 Dec. 15).

59. Ray JG, Park AL, Dzakpasu S, et al. Prevalence of Severe Maternal Morbidity and Factors Associated With Maternal Mortality in Ontario, Canada. *JAMA Netw Open* 2018;1:e184571.
60. Austin PC. Using the standardized difference to compare the prevalence of a binary variable between two groups in observational research. *Commun Stat Simul Comput* 2009;38:1228-34.
61. Zou G. A modified poisson regression approach to prospective studies with binary data. *Am J Epidemiol* 2004;159:702-6.
62. Hilbe JM. *Modeling count data*. New York: Cambridge University Press; 2014.
63. Yelland LN, Salter AB, Ryan P. Performance of the modified Poisson regression approach for estimating relative risks from clustered prospective data. *Am J Epidemiol* 2011;174:984-92.
64. Hubbard AE, Ahern J, Fleischer NL, et al. To GEE or not to GEE: comparing population average and mixed models for estimating the associations between neighborhood risk factors and health. *Epidemiology* 2010;21:467-74.
65. Kayode GA, Ansah E, Agyepong IA, et al. Individual and community determinants of neonatal mortality in Ghana: a multilevel analysis. *BMC Pregnancy Childbirth* 2014;14:165.
66. Royston R, Sauerbrei W. *Multivariable model: building — a pragmatic approach to regression anaylsis based on fractional polynomials for modelling continuous variables.* Chicheser (UK): John Wiley & Sons; 2008.
67. Fang J, Austin P, Tu JV. Test for linearity between continuous confounder and binary outcome first, run a multivariate regression analysis second. *Proceedings of the Global Forum*; 2009 Mar. 22–25; Washington (DC). Cary (NC): SAS Institute; 2009.
68. Urquia ML, Frank JW, Moineddin R, et al. Immigrants' duration of residence and adverse birth outcomes: a population-based study. *BJOG* 2010;117:591-601.
69. Manuck TA, Rice MM, Bailit JL, et al.; Eunice Kennedy Shriver National Institute of Child Health and Human Development Maternal-Fetal Medicine Units Network. Preterm neonatal morbidity and mortality by gestational age: a contemporary cohort. *Am J Obstet Gynecol* 2016;215:103.e1-14.
70. Ramraj C, Pulver A, Siddiqi A. Intergenerational transmission of the healthy immigrant effect (HIE) through birth weight: a systematic review and meta-analysis. *Soc Sci Med* 2015;146:29-40.
71. Urquia ML, Gagnon AJ. Glossary: migration and health. *J Epidemiol Community Health* 2011;65:467-72.
72. Urquia ML, O'Campo PJ, Heaman MI. Revisiting the immigrant paradox in reproductive health: the roles of duration of residence and ethnicity. *Soc Sci Med* 2012;74:1610-21.
73. Urquia ML, Wanigaratne S, Ray JG, et al. Severe maternal morbidity associated with maternal birthplace: a population-based register study. *J Obstet Gynaecol Can* 2017;39:978-87.
74. Ray JG, Urquia ML, Berger H, et al. Maternal and neonatal separation and mortality associated with concurrent admissions to intensive care units. *CMAJ* 2012;184:E956-62.
75. Fell DB, Park AL, Sprague AE, et al. A new record linkage for assessing infant mortality rates in Ontario, Canada. *Can J Public Health* 2020;111:278-85.
76. Sibley LM, Weiner JP. An evaluation of access to health care services along the rural-urban continuum in Canada. *BMC Health Serv Res* 2011;11:20.
77. Pong RW, DesMeules M, Heng D, et al. Patterns of health services utilization in rural Canada. *Chronic Dis Inj Can* 2011;31(Suppl 1):1-36.
78. Galobardes B, Shaw M, Lawlor DA, et al. Indicators of socioeconomic position (part 2). *J Epidemiol Community Health* 2006;60:95-101.

Competing interests: Simone Vigod receives royalties from UpToDate for authorship of materials related to depression and pregnancy. She is the president of the Canadian Association of Psychiatric Epidemiology, and the president-elect of the Marce Society of North America (perinatal mental health). Patricia O'Campo reports funding from the Canadian Institutes for Health Research and the Public Health Agency of Canada, outside of the submitted work. No other competing interests were declared.

This article has been peer reviewed.

Affiliations: Division of Epidemiology (Jairam, Siddiqi, O'Campo), Dalla Lana School of Public Health, University of Toronto; MAP Centre for Urban Health Solutions (Jairam, O'Campo), St. Michael's Hospital; Women's College Hospital (Vigod); ICES Central (Vigod, Guan, Boblitz, Wang, Ray), Toronto, Ont.; Gillings School of Global Public Health (Siddiqi), University of North Carolina-Chapel Hill, Chapel Hill, NC; Department of Obstetrics and Gynaecology (Ray), St. Michael's Hospital, Toronto, Ont.

Contributors: Jennifer Jairam, Patricia O'Campo and Joel Ray contributed to study concept and design. All of the authors acquired, analyzed or interpreted the data. Jennifer Jairam performed the statistical analysis. Jennifer Jairam, Patricia O'Campo and Joel Ray drafted the manuscript. All of the authors revised it critically for important intellectual content, gave final approval of the version to be published and agreed to be accountable for all aspects of the work.

Funding: Jennifer Jairam received PhD funding from University of Toronto Open Fellowship; University of Toronto, Dalla Lana School of Public Health, Doctoral Completion Award; University of Toronto School of Graduate Studies, Mary Gertrude I'Anson Scholarship; St. Michael's Unity Health Toronto Research Training Centre Top-Up Award; Ontario Graduate Scholarship; and Queen Elizabeth II/C.P. Shah Graduate Scholarship in Science & Technology. The funding organizations had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Data sharing: The data set from this study is held securely in coded form at ICES. While data sharing agreements prohibit ICES from making the data set publicly available, access may be granted to those who meet pre-specified criteria for confidential access, available at https://www.ices.on.ca/DAS. The full data set 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.

Disclaimer: This study was supported by ICES, which is funded by an annual grant from the Ontario Ministry of Health (MOH) and the Ministry of Long-Term Care (MLTC). 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. Parts of this material are based on data and/or information compiled and provided by the MOH, Canadian Institute for Health Information (CIHI), and Immigration, Refugees and Citizenship Canada Permanent Resident Database (IRCC-PRD) current to 2017. However, the analyses, conclusions, opinions and statements expressed in the material are those of the authors, and not necessarily those of MOH, CIHI or IRCC-PRD. Parts of this report are based on Ontario Registrar General (ORG) information on deaths, the original source of which is Service Ontario. The views expressed therein are those of the authors and do not necessarily reflect those of ORG or the Ministry of Public and Business Service Delivery. This document used data adapted from the Statistics Canada Postal Code Conversion File, which is based on data licensed from Canada Post Corporation, and/or data adapted from the Ontario Ministry of Health Postal Code Conversion File, which contains data copied under license from Canada Post Corporation and Statistics Canada.

Accepted: Apr. 17, 2023

Correspondence to: Joel Ray, rayj@smh.ca