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ABSTRACT

Introduction

Recent evidence from the United States and Canada suggests an unexplained increase in small-for-gestational-age (SGA) births (<10th percentile). This study aimed to identify reasons for the recent increase in SGA births in Canada.

Data and methods

Using Canada's Vital Statistics - Birth Database, the study population included all singleton live births, 2000 to 2016, inclusive. Temporal changes in birth weight (grams), birth weight for gestational age z-scores, and SGA births were examined. Multivariable logistic regression was used to determine if the increased risk of an SGA birth over time was eliminated or attenuated by adjusting for selected individual and sociodemographic factors that have previously been associated with SGA births.

Results

There were 5,941,820 singleton live births in Canada between 2000 and 2016. Mean birth weight for all births decreased from 3,442 grams in 2000, to 3,367 grams in 2016, while SGA birth increased from 7.2% in 2000 to 8.0% in 2016. The multivariable model showed higher odds of SGA birth among births to parents born outside of Canada, unmarried women, older women, nulliparous women and women residing in low income neighborhoods. After adjusting for sociodemographic factors, the crude 12% increase in odds of SGA birth in 2016 compared to 2000 (95% Confidence Interval (CI): [10 to 14%]) was attenuated, but not eliminated (adjusted odds ratio for calendar time 1.08 (95% CI: [1.06, 1.10])).

Interpretation

This study identified a decrease in fetal size in Canada between 2000 and 2016. The rise in SGA births in Canada was explained only partly as a result of concurrent changes in the demography of childbirth.

Keywords

Small-for-gestational-age births, birth weight, infant health, maternal and fetal medicine

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What is already known on this subject?

- A recent increase in the number and proportion of small-for-gestational-age (SGA) births—an important indicator of infant health—has been observed in Canada and the United States. The reasons for this rise are unclear. Changes in demographic factors, such as increasing immigration, fewer births per woman and advanced maternal age were hypothesized to be responsible.

What does this study add?

- This study investigated trends in birth weight and SGA births among all singleton live births in Canada from 2000 to 2016. Changes in the demography of childbirth explained some, but not all, of the increasing trend in SGA births between 2008 and 2016.

Small-for-gestational-age (SGA) birth, defined as a birth weight below the 10th percentile of a reference population by sex and gestational age,[1] is commonly monitored as a public health indicator because of its role as a proxy for fetal growth restriction. SGA infants are at an increased risk of neonatal complications including hypothermia, hypoglycemia, hyperglycaemia, hypocalcaemia, polycythemia, jaundice, feeding difficulties, feed intolerance, necrotizing enterocolitis, late onset sepsis and pulmonary haemorrhage as well as infant death.[2] The life-long health risks associated with small size at birth include increased risks of impaired neurodevelopment, psychological or emotional distress, and non-communicable diseases.[3-6]

Studies from a number of international jurisdictions have reported an increase in birth weight over time, and a decrease in the proportion of SGA births.[7-12] For example, a study from Canada on births from 1978 to 1996 found that babies born at, or beyond, term were getting bigger due to increases in maternal anthropometry (various measurements of size), reduced cigarette smoking and changes in sociodemographic factors.[13]

More recent evidence, however, suggests that this trend may have reversed. A recent study in the United States indicated a 29.9% increase in term SGA births between 2002 and 2011.[14] Similarly, a Canadian perinatal health report published in 2017 reported an increase in the proportion of SGA births from 8.2 per 100 singleton live births (95% CI: [8.1–8.3]) in 2008 to 9.1 (95% CI: [9.0–9.2]) per 100 in 2014.[15] Decreases in mean birth weight in the United States have been explained by a shift to younger gestational age at birth following an increased use of labour induction, but this does not explain the increase in SGA births, which is standardized for gestational age.[16] The reason(s) for these increases in SGA births remains unclear.

In Canada, the demography of childbirth has changed over time due to increased immigration,[17] delayed childbirth[18] and change in the income earning composition of couple families over time.[19] Changes in these factors could increase the risk of small infants through physiological pathways (advanced maternal age and variations in anthropometry by country of birth),[20] as well as psycho-social and material pathways (immigration, acculturation, neighborhood income and community size).[21,22]

The objective of this study was to identify reasons for the recent rise in SGA births in Canada; specifically, the role of demographic factors including maternal and paternal place of birth, marital relation, maternal age, number of liveborn children a mother has, community size and neighborhood income quintile of maternal residence. The changing demography of childbirth in Canada was hypothesized to be responsible for the recent increase in SGA births.

Methods

This research was exempt from Research Ethics Board review because it is based on data that are legally accessible to the public and appropriately protected by law through Statistics Canada (Article 2.2 and 2.4 for exemptions).

Study design

This study employed a cross-sectional panel study design.

Data sources

Statistics Canada's Vital Statistics - Birth Database was used, which contains data from all live births in Canada. In addition to individual-level characteristics, this dataset contains sociodemographic variables from Statistics Canada census files (such as neighborhood income quintile and community size) that are linked to each birth's postal code through the Postal Code Conversion File and Postal Code Conversion File Plus (PCCF+).[23]

Study population

The study population was drawn from all singleton live births in Canada born between 2000 and 2016, inclusive. The study excludes stillbirths, twins and higher-order multiples, births with gestational age less than 22 weeks or greater than 43 weeks, births with birth weights less than 300 grams or more than 5 999 grams, births to women who were not residents of Canada, and births with missing information on birth weight, pregnancy duration or sex.

SGA birth was defined using Health Canada's birth weight for gestational age reference charts developed by Kramer et al. in 2001.[24] These reference charts were based on all Canadian live births (excluding Ontario) between January 1, 1994, and December 31, 1996.[1] Gestational week-specific and sex-specific means and standard deviations of birth weight from the reference charts were used to generate a gestational-age and sex-specific z-score for each birth in this cohort using the formula:

$$Z-Score = \frac{[observed\ birth\ weight - mean\ birth\ weight\ (in\ reference\ chart)]}{SD\ (in\ reference\ chart)}$$

SGA births were defined as infants with a z-score of less than -1.28, which corresponds to the 10th percentile assuming a standard normal distribution.

Individual and contextual factors and measurements

The mother/father's geographic birth place were two separate categorical variables created by regrouping the mother/father's country of birth into Canadian-born and continent specific geographical sub-regions (Canada, North America excluding Canada, Central America, Caribbean and Bermuda, South America, Western Europe, Eastern Europe, Northern Europe, Southern Europe, Western Africa, Eastern Africa, Northern Africa, Central Africa, Southern Africa, West Central Asia and the Middle East, Eastern Asia, Southeast Asia, Southern Asia, Oceania/Antarctica and adjacent islands, and missing/unknown) using the Statistical Classification of Countries and Areas of Interest for Social Statistics (SCCAI, 2017). This standard was developed by Statistics Canada for social statistics and based on the International Standard for country codes (ISO 3166-1: 2013).[25] The missing/unknown category contained any parental place of birth that did not match one of the subregions above or had a missing value for mother/father's country of birth. Maternal age at delivery was categorized as younger than 20, 20 to 24, 25 to 29, 30 to 34, 35 to 39, 40 years or older, and unknown. The number of liveborn children indicates the number of children ever liveborn to the mother, previous to, and including, this birth event. This excludes fetal deaths or stillbirths. Marital relation was categorized as single, married and other. Due to inconsistencies in reporting categories across provinces, the "other" category contained a mix of partnered and non-partnered women (widowed, divorced, separated, common-law, not-married and unknown) and therefore limited interpretability.

Community size was categorized as n=1,250,000 +; 500,000 to 1,249,999; 100,000 to 499,999; 10,000 to 99,999; < 10,000; and missing, based on the size of the mother's community of residence. The neighborhood income per single person equivalent describes the household size-adjusted measure of household income based on census summary data at the smallest reporting area (n = ~400 to 700 individuals) and using person-equivalents implied by the low-income cut-offs established by Statistics Canada.[23] Those two variables were based on census year 2006 for births between 2000 and 2008 (PCCF+ versions 5E), 2009 ((PCCF+ versions 5J3) and 2010 (PCCF+ versions 5K0); on census year 2011 (PCCF+ versions 6D) for births between 2011 and 2015; and on census year 2016 (PCCF+ versions 7A) for births in 2016.

Data analysis

Temporal trends in mean birth weight and rate of SGA birth were summarized descriptively using means with standard deviations or frequencies and proportions, and plotted over time by year of birth. Temporal trends in mean birth weight z-scores were also examined to identify underlying trends in birth weights while accounting for changes over time in the timing of delivery.

Logistic regression was used to quantify the increased odds of SGA birth over time, compared with the year 2000 as a reference. A multivariable regression model that included selected individual and sociodemographic factors previously associated with SGA birth[2,26] was used to determine if the increased risk of SGA birth over time was eliminated or attenuated by inclusion of these variables. Aside from the main independent variable, these selected factors were included as confounders, due to their association with birth year (changes in socio-demographic factors over time), and their known association with an increased risk of an SGA birth.[2,26] Missing and/or unknown values were entered as a separate category for each variable in the model. A sensitivity analysis including adjustment for maternal province/territory of residence was further explored in Appendix Table A. Analyses were conducted using Stata version 13.1 (StataCorp, 2013).

Results

There were 5,941,820 singleton live births in Canada between 2000 and 2016. Of these, 449,015 (7.6%) were small for being of gestational age. As shown in Figure 1, the proportion of SGA births increased throughout the study period, from 7.2% in 2000 to 8.0% in 2016. This corresponded with a 12% increase (95% CI: [1.10, 1.14]) in the odds of SGA birth in 2016 compared with 2000 (Table 1). In absolute measures, there were 6,595 more SGA newborns in 2016 compared to 2000. The distribution of all singleton births and SGA births by birth year, as well as specific maternal characteristics can be found in Appendix Table B.

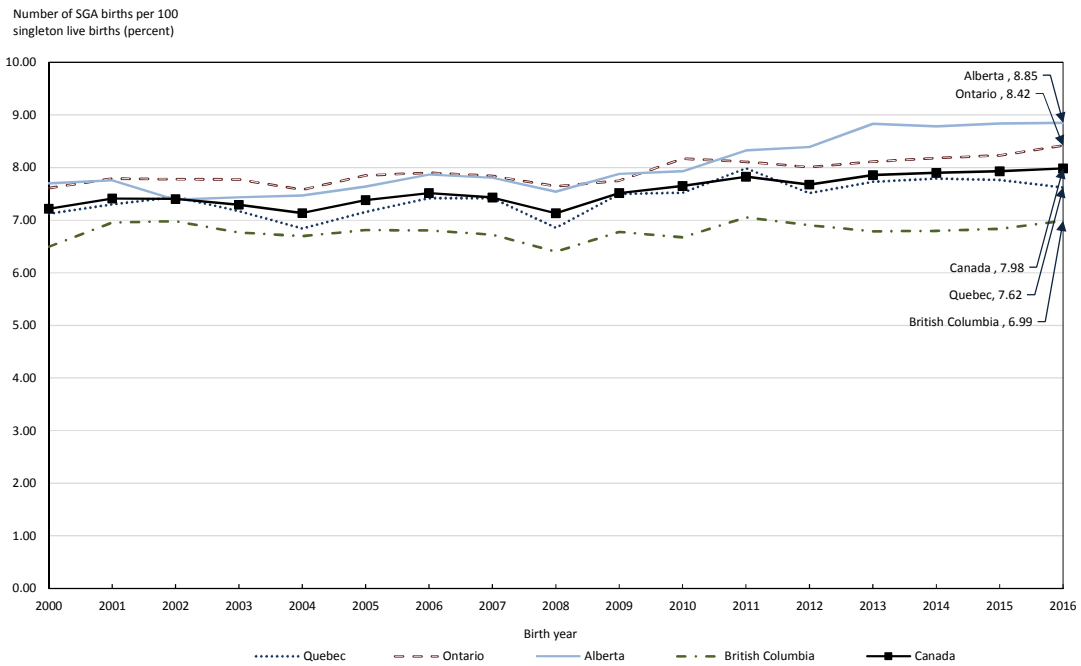
Table 1
Multiple logistic regression model results for a small-for-gestational-age birth using all singleton live births in Canada (2000 to 2016)

	Small-for-gestational-age births							
	N = 5,941,820		N = 5,941,815			N = 5,941,815		
	N	Relative (percent)	Crude odds ratio	Lower bound (95% confidence interval)	Upper bound (95% confidence interval)	Adjusted odds ratio	Lower bound (95% confidence interval)	Upper bound (95% confidence interval)
Year (reference: 2000)	318,510	5.36	...	...	...	...	...	...
2001	322,260	5.42	1.03	1.01	1.05	1.03	1.01	1.05
2002	317,480	5.34	1.03	1.01	1.05	1.03	1.01	1.05
2003	323,305	5.44	1.01	0.99	1.03	1.00	0.98	1.02
2004	324,685	5.46	0.99	0.97	1.01	0.98	0.96	0.99
2005	331,060	5.57	1.02	1.01	1.04	1.01	0.99	1.03
2006	342,725	5.77	1.04	1.03	1.06	1.03	1.01	1.05
2007	355,885	5.99	1.03	1.01	1.05	1.02	1.00	1.04
2008	365,660	6.15	0.99	0.97	1.01	0.97	0.96	0.99
2009	367,595	6.19	1.05	1.03	1.06	1.03	1.01	1.05
2010	364,175	6.13	1.06	1.05	1.08	1.02	1.00	1.04
2011	361,590	6.09	1.09	1.07	1.11	1.08	1.06	1.10
2012	368,960	6.21	1.07	1.05	1.09	1.05	1.03	1.07
2013	367,140	6.18	1.10	1.08	1.12	1.07	1.05	1.09
2014	370,955	6.24	1.10	1.08	1.12	1.08	1.06	1.10
2015	369,290	6.22	1.11	1.09	1.13	1.08	1.06	1.10
2016	370,545	6.24	1.12	1.10	1.14	1.08	1.06	1.10
Maternal birth place (reference: Canada)	4,293,520	72.26	...	...	...	...	...	...
North America, excluding Canada	61,460	1.03	0.94	0.91	0.97	1.03	1.00	1.07
Central America	63,630	1.07	1.08	1.05	1.11	1.10	1.06	1.14
Caribbean and Bermuda	81,170	1.37	1.71	1.67	1.75	1.40	1.36	1.44
South America	69,880	1.18	1.45	1.41	1.49	1.29	1.25	1.33
Western Europe	46,010	0.77	1.02	0.98	1.06	1.04	1.00	1.08
Eastern Europe	94,130	1.58	0.94	0.91	0.96	0.97	0.93	1.00
Northern Europe	54,280	0.91	1.05	1.02	1.09	1.13	1.09	1.16
Southern Europe	45,960	0.77	1.04	1.01	1.08	1.04	1.00	1.09
Western Africa	34,320	0.58	1.63	1.57	1.68	1.49	1.42	1.57
Eastern Africa	55,100	0.93	1.53	1.49	1.58	1.34	1.29	1.40
Northern Africa	78,330	1.32	1.10	1.07	1.13	1.10	1.05	1.16
Central Africa	15,880	0.27	1.10	1.04	1.17	1.08	1.00	1.17
Southern Africa	9,690	0.16	1.31	1.22	1.41	1.36	1.26	1.47
West Central Asia and the Middle East	137,920	2.32	1.32	1.29	1.34	1.27	1.23	1.31
Eastern Asia	205,470	3.46	1.37	1.35	1.40	1.13	1.09	1.16
Southeast Asia	189,810	3.19	1.87	1.85	1.90	1.30	1.27	1.33
Southern Asia	299,780	5.05	2.31	2.29	2.34	1.76	1.71	1.81
Oceania/Antarctica and adjacent islands	13,990	0.24	1.54	1.46	1.63	1.47	1.39	1.56
Missing/unknown	91,490	1.54	1.31	1.28	1.34	1.15	1.12	1.17
Paternal birth place (reference: Canada)	3,955,970	66.58	...	...	...	...	...	...
North America, excluding Canada	62,240	1.05	1.00	0.96	1.03	1.03	1.00	1.06
Central America	62,990	1.06	1.11	1.07	1.14	1.13	1.09	1.17
Caribbean and Bermuda	98,090	1.65	1.64	1.60	1.67	1.33	1.30	1.37
South America	64,710	1.09	1.49	1.45	1.53	1.31	1.27	1.36
Western Europe	53,090	0.89	1.00	0.97	1.04	0.98	0.95	1.02
Eastern Europe	77,440	1.30	0.95	0.93	0.98	1.01	0.97	1.05
Northern Europe	68,790	1.16	0.94	0.91	0.97	0.95	0.92	0.98
Southern Europe	56,330	0.95	1.09	1.06	1.13	1.12	1.08	1.16
Western Africa	38,700	0.65	1.52	1.47	1.57	1.16	1.11	1.22
Eastern Africa	53,530	0.90	1.53	1.48	1.57	1.27	1.21	1.32
Northern Africa	85,450	1.44	1.13	1.10	1.16	1.12	1.07	1.17
Central Africa	16,880	0.28	1.10	1.04	1.17	1.04	0.96	1.12
Southern Africa	10,080	0.17	1.19	1.11	1.28	1.14	1.05	1.24
West Central Asia and the Middle East	146,770	2.47	1.33	1.30	1.35	1.20	1.17	1.24
Eastern Asia	168,820	2.84	1.44	1.42	1.47	1.34	1.30	1.38
Southeast Asia	150,310	2.53	2.11	2.08	2.15	1.75	1.71	1.80
Southern Asia	297,370	5.00	2.36	2.33	2.38	1.54	1.50	1.58
Oceania/Antarctica and adjacent islands	16,690	0.28	1.47	1.39	1.54	1.33	1.26	1.41
Missing/unknown	457,590	7.70	1.50	1.48	1.51	1.29	1.27	1.30
Marital status (reference: married)	3,643,615	61.32	...	...	...	...	...	...
Single	1,711,600	28.81	1.17	1.16	1.17	1.27	1.26	1.28
Other	586,600	9.87	1.15	1.14	1.16	1.23	1.22	1.25
Maternal age (reference: 25 to 29 years)	1,799,935	30.29	...	...	...	...	...	...
Less than 20	231,355	3.89	1.24	1.22	1.26	0.96	0.94	0.98
20 to 24	903,870	15.21	1.17	1.16	1.18	1.06	1.05	1.07
30 to 34	1,916,675	32.26	0.93	0.92	0.93	1.02	1.01	1.02
35 to 39	906,910	15.26	0.96	0.95	0.97	1.09	1.08	1.10
More than or equal to 40	182,695	3.07	1.09	1.07	1.11	1.21	1.18	1.23
Missing/unknown	375	0.01	1.40	1.00	1.96	1.23	0.88	1.73
Number of live-born children (reference: 1)	2,645,905	44.53	...	...	...	...	...	...
2	2,091,475	35.20	0.57	0.56	0.57	0.57	0.56	0.57
3	786,105	13.23	0.55	0.54	0.55	0.54	0.53	0.54
4	254,640	4.29	0.57	0.56	0.58	0.55	0.54	0.56
5 or more	161,080	2.71	0.60	0.59	0.61	0.57	0.56	0.59
Missing/unknown	2,610	0.04	1.06	0.94	1.21	0.97	0.85	1.10
Community size (reference: 1,250,000 or more)	2,087,340	35.13	...	...	...	...	...	...
500,000 to 1,249,999	1,083,340	18.23	0.90	0.89	0.91	1.02	1.01	1.03
100,000 to 499,999	971,725	16.35	0.79	0.79	0.80	0.96	0.95	0.97
10,000 to 99,999	689,165	11.60	0.78	0.78	0.79	0.98	0.97	0.99
Less than 10,000 (rural)	1,061,010	17.86	0.75	0.74	0.75	0.97	0.96	0.98
Missing/unknown	49,235	0.83	0.77	0.75	0.80	1.04	0.99	1.08
Neighborhood income quintile (reference: 1 (lowest))	972,640	16.37	...	...	...	...	...	...
2	1,333,820	22.45	0.90	0.89	0.91	0.95	0.94	0.96
3	1,174,880	19.77	0.82	0.81	0.82	0.91	0.90	0.92
4	1,163,790	19.59	0.75	0.75	0.76	0.88	0.87	0.89
5 (highest)	1,160,445	19.53	0.70	0.70	0.71	0.85	0.85	0.86
Missing/unknown	136,245	2.29	0.83	0.81	0.85	0.90	0.88	0.93

... not applicable

Note: Due to vetting procedures at Statistics Canada's Research Data Centres, univariate descriptives were rounded to the nearest 5 or 10 where needed. As a result, some rows may not sum to the total.
Sources: Statistics Canada's Vital Statistics - Birth Database (VSBD).

Figure 1
Small-for-gestational-age births as a proportion of all singleton live births within Alberta, British Columbia, Ontario, Quebec and all Canada from 2000 to 2016



Note: SGA = Small-for-gestational-age.
Source: Statistics Canada's Vital Statistics - Birth Database (VSBD).

Mean birth weight decreased from 3 442 grams (95% CI: [3440,3444]) in 2000, to 3 367 grams (95% CI: [3365, 3369]) in 2016. When stratifying by sex, a female birth in 2016 (mean birth weight: 3 383 grams (95% CI: [3380, 3386]) weighed on average 73 grams less than that in 2000 (mean birth weight: 3 310 grams (95% CI: [3307, 3312]), while a male birth in 2016 (3 421 grams (95% CI: [3419, 3424])) weighed on average 78 grams less than in 2000 (3 499 grams (95% CI: [3496, 3502])).

Temporal trends in mean birth weight z-scores are plotted in Figure 2. Between 2000 and 2016, the mean birth weight z-score for male, female and all births combined appeared to follow a similar declining trend. Overall, mean birth weight z-scores for female births were consistently higher than those of male births over the entire study period. Over time the mean z-score for all births decreased from 0.12 (95% CI: [0.11, 0.12]) in 2000 to 0.01 (95% CI: [0.01, 0.01]) in 2016.

Results from the multivariable model showed that, as expected, odds of an SGA birth were higher among births to parents born outside of Canada, unmarried women, older women, nulliparous women and women with a lower neighborhood income residence (Table 1 and Figure 3A,3B). In contrast, although the association between community size and an SGA birth was statistically significant, it was small in magnitude. Adjusting for these sociodemographic factors attenuated the temporal increase in SGA birth, but a statistically significant increase in the odds of an SGA birth (at a 95% confidence level) remained for the period from 2009 to 2016. For instance, after adjustment for sociodemographic factors, an 8% increase in the odds of SGA birth in 2016 remained (95% CI: [1.06, 1.10]), attenuated from a crude odds ratio of 1.12 (95% CI: [1.10, 1.14]).

Discussion

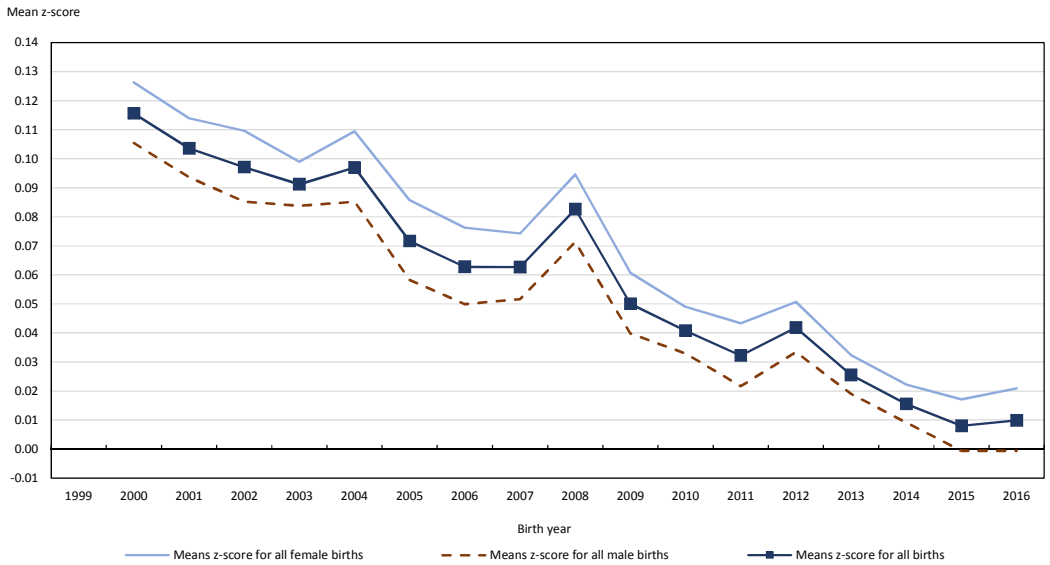
Main findings

In this study, the extent to which demographic factors such as increased immigration, decreasing numbers of births per woman and increasing maternal age at birth may be responsible for the previously-reported[15] increase in the proportion of SGA births in Canada was investigated. This has also been reported in the United States.[14] The rise was only partially explained by changes in contextual factors such as births to parents born outside Canada, older women, unmarried women, nulliparous women and lower neighborhood income residence.

Results from univariate and multivariable regression analyses showed a more pronounced increase in the odds of an SGA birth in Canada after 2008. Adjusting for the changing demography of birth attenuated these odds only in the latter part of the study period. Parental birth place and number of liveborn children were most strongly associated with SGA birth, with up to 136% higher odds for certain regions of parental birth place.

These findings are consistent with recent changes in Canada (immigration and delayed childbirth)[17,18] as well as the known evidence regarding their association with SGA births. Using

Figure 2
Trends in mean birth weight z-scores for male, female, and all singleton live births Canada from 2000 to 2016.



Source: Statistics Canada's Vital Statistics - Birth Database (VSBD).
Birth weight z-score = [observed birth weight – mean birth weight (in reference chart)] / SD (in reference chart)

place of birth as an indicator for ethnicity and immigration can account for the physiological factors related to ethnicity (anthropometry) as well as the social and cultural factors that contribute to these disparities. It can also be explained through pathological differences between ethnicities (such as higher rates of gestational diabetes mellitus (GDM) among South Asian and South-East Asian mothers)[27] and other social and cultural factors related to immigration (such as lifestyle, culture and acculturation).[28]

Findings of this study also show a modest reduction in the mean birth weight of Canadian singleton births between 2000 and 2016, suggesting a potential decrease in fetal size over time. These results were consistent even after using birth weight z-scores to isolate changes over time in birth weight from changes in the timing of delivery (i.e., younger gestational ages at delivery due to the increased use of obstetric interventions such as induction of labour).[29]

Birth weight trends in this study are consistent with recent findings in the United States,[14,30] Japan[31] and Germany,[32] but differ from trends in England, Wales[33] and China.[34] In Germany, these trends could not be explained by simultaneous changes in the rates of primiparity, smoking and gestational diabetes.[32] Similarly, in the United States, a decrease in fetal growth among U.S., term, singleton births was also not explained by changes in maternal and infant characteristics, obstetric practices or gestational length.[30] Alternatively, in England and Wales, a recent study using births from 1986 to 2012 showed that babies have become heavier over the past three decades.[33] In addition, the incidence of SGA births in Guangzhou, China, decreased significantly between 2001 and 2015.[34]

Although this study was unable to examine the contribution of factors such as maternal smoking and maternal anthropometry, these factors are unlikely to explain the temporal rise in SGA births. Recent evidence from the province of Ontario showed a decrease in the prevalence of maternal smoking between 1995 and 2010.[35] Additionally, the prevalence of obesity in Canada between 1985 and 2011, has increased from 6.1% to 18.3%. Evidence from these studies would suggest a reduction in SGA births, not the opposite.

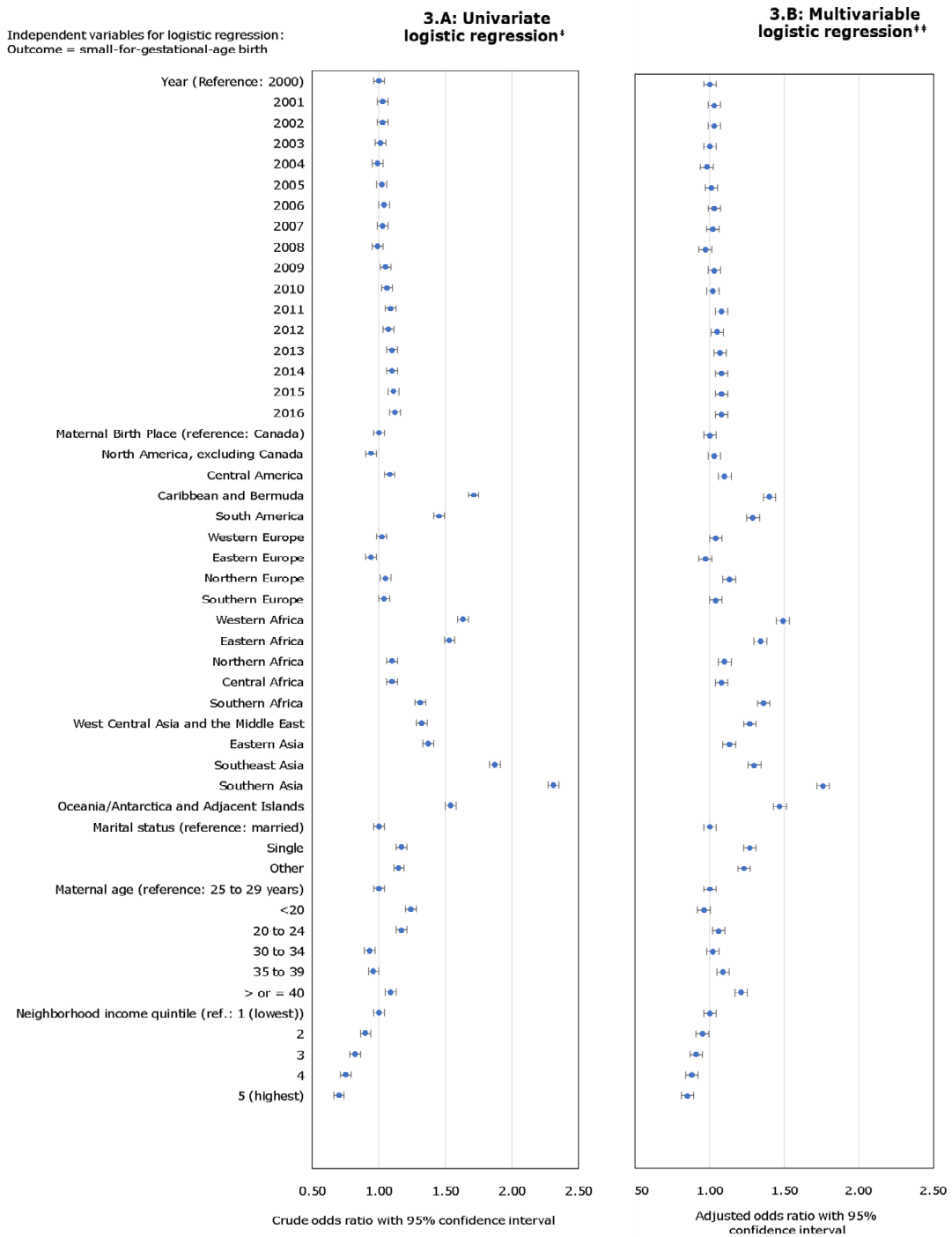
The use of assisted reproductive technology (ART) increased in Canada during our study period, and births occurring through ART are known to have, on average, higher risks of adverse birth outcomes, including SGA births.[39] Although the increased use of ART may have contributed to the trends observed in our study, its impact was likely modest as the ART births only make up a small fraction of all births (1.36% of all births or 5,031 singleton births) in 2012.[36]

Finally, when looking at the rate at which SGA births increased over time, a more pronounced upward trend between 2008 and 2016 was notable. This trend may be influenced by larger underlying economic factors.[37]

Following the global financial crisis in 2008, Canada suffered from an economic recession.[38] The negative effects of an economic recession on maternal health has been well documented in literature. These effects can influence the financial and psychological wellbeing of an entire household as well as an individual. A study looking at the impact of economic recessions on maternal and infant mortality found substantial and statistically significant increases in maternal mortality in Canada with decreases in gross domestic product between 1950

to 1966.[39] The World Health Organization's conceptual framework of social determinants of infant mortality[40] outlines many pathways that connect larger macroeconomic factors—such as an economic recession—to adverse birth outcomes. The important factors connected to adverse birth outcomes in a period of economic recession are unemployment, income, stress and psychosocial wellbeing.[41]

Figure 3
Logistic regression model results for a small-for-gestational-age birth using all singleton livebirths in Canada (2000 to 2016)



‡ Univariate models were performed on each independent variable separately.
‡‡ Multivariable model further adjusted for paternal place of birth, number of liveborn children ever born and community size.
Source: Statistics Canada's Vital Statistics - Birth Database (VSBD).

Strengths and limitations

This study focused on understanding the role of changes in the demography of childbearing women in Canada, rather than individual medical factors, as large population-based shifts were hypothesized to have the most likely impact on the risk of SGA birth. Although there have been increases in some medical risk factors associated with SGA birth during the study period, such as preeclampsia,[42] GDM, pre-gestational diabetes[22] and ART, these conditions are not common enough to have likely caused the population-level rises in SGA birth—because of their relatively low prevalence. However, a cumulative effect of multiple medical conditions associated with an increased risk of SGA cannot be ruled out.

Despite the widespread use of the Canadian reference charts for evaluating adverse birth outcomes in Canada, using different reference charts such as the INTERGROWTH-21st Project standard may have resulted in smaller differences over time. A recent Canadian study evaluated SGA and large-for-gestational-age (LGA) births between 2002 and 2012, using both the INTERGROWTH-21st Project standard and the Canadian reference.[43] The authors concluded that the centile distribution of the INTERGROWTH-21st newborn standard is left-shifted compared with the Canadian reference, leading to lower proportions of SGA births and higher proportions of LGA births in comparison with the Canadian reference. Therefore, based on these results, and assuming the centile cut-offs for identifying these high risk subpopulations remained unchanged, the use of the INTERGROWTH-21st Project standard in this study may have resulted in narrower absolute temporal changes over time.

Due to data limitations, factors such as pre-pregnancy body mass index (BMI), pregnancy weight gain and maternal smoking could not be controlled for. However, as the temporal changes in pre-pregnancy BMI, pregnancy weight gain and smoking would be expected to have decreased—not increased—the SGA rate, these are unlikely to have caused the increase in SGA birth observed in this study.

Additionally, mean birth-weight measurements tend to be driven by term births, and examining gestational-age subgroups was beyond the scope of these analyses. However, reporting on birth weight in addition to SGA birth facilitates international comparisons. Another limitation pertains to the secondary use of administrative data for health care research. Since the data are collected for administrative (birth registration) rather than research purposes, the selection and quality of data collection is not under the researcher's control and hence can be difficult to validate.[44] Nevertheless, there is no reason to suspect changes in the accuracy of birth weight measurement over time.

Despite these limitations, this study uses all Canadian singleton births without exclusions to provinces or territories, thereby representing complete geographic diversity. In addition to using complete national datasets, this is the first descriptive study on SGA temporal trends in Canada to report on a study period spanning 17 years of data—from 2000 to 2016. Most of the literature to date have used a two year study period,[26] or at the most 10 years.[15] The study population of these studies is often limited to one province or excludes Quebec.[15]

Conclusions

This study found that infants in Canada have gotten smaller between 2000 and 2016, a trend which was explained only partly as a result of concurrent changes in important risk factors such as an increase in maternal and paternal immigration (parental place of birth outside Canada), delayed childbirth (advanced maternal age), an increase in first-time mothers (number of liveborn children), an increase in non-married women, or variations in community size and neighborhood income quintile of maternal residence.

These results could be of potential concern since SGA births have long been used as an indicator of infant health, and have a strong association with short-term and long-term health and economic consequences. The findings of this study strengthen findings from similar studies in the United States, Germany and Japan, where a decrease in fetal growth remained unexplained even after controlling for known maternal and contextual risk factors.

Identifying whether the increase in SGA births was due to an increase in "constitutionally small" or growth-restricted newborns can help allocate appropriate and necessary health resources. This calls for further research and clinical investigation through up-to-date linked clinical and social data because distinguishing physiological from pathological growth restriction is known to be specifically challenging in large population studies.[45] There is a need for an improved understanding of these trends by exploring other medical, environmental and economic factors.

Appendix

Table A
Sensitivity analysis: Multiple logistic regression model results for a small-for-gestational-age birth using all singleton live births in Canada (2000 to 2016) including adjustment for maternal province/territory of residence

	SGA birth (N = 5,941,815)		
	Adjusted odds ratio	Lower bound (95% confidence interval)	Upper bound (95% confidence interval)
Year (reference 2000)			
2001	1.03	1.01	1.05
2002	1.03	1.01	1.05
2003	1.00	0.98	1.02
2004	0.97	0.96	0.99
2005	1.01	0.99	1.03
2006	1.03	1.01	1.05
2007	1.01	1.00	1.03
2008	0.97	0.95	0.99
2009	1.03	1.01	1.05
2010	1.02	1.00	1.04
2011	1.07	1.05	1.09
2012	1.04	1.02	1.06
2013	1.07	1.05	1.09
2014	1.07	1.05	1.09
2015	1.07	1.05	1.09
2016	1.08	1.06	1.10
Maternal birth place (reference: Canada)			
North America, excluding Canada	1.04	1.00	1.07
Central America	1.09	1.05	1.13
Caribbean and Bermuda	1.38	1.34	1.42
South America	1.27	1.23	1.31
Western Europe	1.04	1.01	1.09
Eastern Europe	0.96	0.93	0.99
Northern Europe	1.13	1.10	1.17
Southern Europe	1.04	1.00	1.08
Western Africa	1.47	1.39	1.55
Eastern Africa	1.33	1.27	1.38
Northern Africa	1.10	1.05	1.15
Central Africa	1.08	0.99	1.17
Southern Africa	1.37	1.26	1.47
West Central Asia and the Middle East	1.26	1.23	1.30
Eastern Asia	1.14	1.11	1.17
Southeast Asia	1.29	1.26	1.32
Southern Asia	1.76	1.71	1.81
Oceania/Antarctica and adjacent islands	1.52	1.43	1.61
Missing/unknown	1.15	1.13	1.18
Paternal birth place (reference: Canada)			
North America, excluding Canada	1.04	1.01	1.07
Central America	1.12	1.08	1.16
Caribbean and Bermuda	1.31	1.28	1.35
South America	1.30	1.26	1.34
Western Europe	0.99	0.95	1.02
Eastern Europe	1.00	0.97	1.04
Northern Europe	0.96	0.93	0.99
Southern Europe	1.11	1.07	1.16
Western Africa	1.15	1.10	1.21
Eastern Africa	1.26	1.20	1.31
Northern Africa	1.11	1.06	1.17
Central Africa	1.04	0.96	1.12
Southern Africa	1.15	1.06	1.24
West Central Asia and the Middle East	1.20	1.17	1.24
Eastern Asia	1.34	1.30	1.39
Southeast Asia	1.76	1.71	1.80
Southern Asia	1.54	1.50	1.58
Oceania/Antarctica and adjacent islands	1.37	1.30	1.45
Missing/unknown	1.28	1.26	1.30
Marital status (reference: married)			
Single	1.29	1.28	1.31
Other	1.23	1.22	1.24
Maternal age (reference: 25 to 29 years)			
Less than 20	0.95	0.93	0.97
20 to 24	1.05	1.04	1.06
25 to 29	...	...	...
30 to 34	1.02	1.01	1.03
35 to 39	1.10	1.09	1.11
More than or equal to 40	1.22	1.19	1.24
Missing/unknown	1.23	0.87	1.72
Number of live-born children (reference: 1)			
2	0.57	0.56	0.57
3	0.53	0.53	0.54
4	0.55	0.54	0.56
5 or more	0.57	0.56	0.58
Missing/unknown	0.97	0.86	1.10

... not applicable

Note: SGA = Small-for-gestational-age.

Source: Statistics Canada's Vital Statistics - Birth Database (VSBD).

Table A
Sensitivity analysis: Multiple logistic regression model results for a small-for-gestational-age birth using all singleton live births in Canada (2000 to 2016) including adjustment for maternal province/territory of residence (continued)

	SGA birth (N = 5,941,815)		
	Adjusted odds ratio	Lower bound (95% confidence interval)	Upper bound (95% confidence interval)
Community size (reference: 1,250,000 or more)			
500,000 to 1,249,999	0.92	0.91	0.93
100,000 to 499,999	0.94	0.93	0.95
10,000 to 99,999	0.95	0.94	0.96
<Less than 10,000 (rural)	0.93	0.92	0.94
Missing/unknown	0.99	0.95	1.04
Neighborhood income quintile (reference: 1 (lowest))			
2	0.95	0.94	0.96
3	0.91	0.90	0.92
4	0.88	0.87	0.89
5 (highest)	0.86	0.85	0.86
Missing/unknown	0.90	0.87	0.92
Maternal province/territory of residence (reference: Ontario)			
Newfoundland and Labrador	0.91	0.88	0.94
Prince Edward Island	0.89	0.85	0.95
Nova Scotia	1.12	1.10	1.14
New Brunswick	1.02	0.99	1.04
Quebec	0.98	0.97	0.99
Manitoba	1.03	1.01	1.05
Saskatchewan	1.02	1.00	1.04
Alberta	1.16	1.15	1.18
British Columbia	0.84	0.83	0.85
Yukon	0.78	0.70	0.87
Northwest Territories	0.72	0.66	0.79
Nunavut	0.74	0.68	0.80

... not applicable
Note: SGA = Small-for-gestational-age.
Source: Statistics Canada's Vital Statistics - Birth Database (VSBD).

Appendix Table B

Distribution of all births and small-for-gestational-age (SGA) births by maternal characteristics in 2000 and 2016

	Birth year							
	All births in 2000 (N=318,510)		All births in 2016 (N=370,545)		SGA births in 2000 (N=22,985)		SGA births in 2016 (N=29,580)	
Characteristics	Number of singleton live births in 2000	Proportion of all singleton live births in 2000	Number of singleton Live births in 2016	Proportion of all singleton live births in 2016	Number of SGA births in 2000	Proportion of all SGA births in 2000	Number of SGA births in 2016	Proportion of all SGA births in 2016
	number	percent	number	percent	number	percent	number	percent
Maternal age								
Less than 20	17,190	5.40	8,380	2.30	1,585	6.90	820	2.80
20 to 24	58,265	18.30	44,145	11.90	4,915	21.40	3,880	13.10
25 to 29	98,500	30.90	106,465	28.70	6,835	29.70	8,605	29.10
30 to 34	93,265	29.30	131,985	35.60	6,015	26.20	9,965	33.70
35 to 39	43,640	13.70	66,020	17.80	3,010	13.10	5,200	17.60
More or equal to 40	7,610	2.40	13,550	3.70	625	2.70	1,110	3.80
Missing/unknown	45	0.00	0	0.00	5	0.00	0	0.00
Number of liveborn children								
1	142,825	44.80	159,785	43.10	12,980	56.50	17,060	57.70
2	111,365	35.00	131,310	35.40	6,335	27.60	8,015	27.10
3	42,550	13.40	50,755	13.70	2,410	10.50	2,835	9.60
4	13,575	4.30	17,035	4.60	790	3.40	950	3.20
5 or more	8,150	2.60	11,400	3.10	470	2.00	695	2.40
Missing/unknown	45	0.00	255	0.10	5	0.00	30	0.10
Mother's birth place								
Canada	240,035	75.36	253,435	68.40	15,640	68.03	17,690	59.80
North America, excluding Canada	3,820	1.20	3,565	0.96	220	0.96	240	0.81
Central America	2,790	0.88	3,940	1.06	190	0.83	260	0.88
Caribbean and Bermuda	5,330	1.67	4,385	1.18	560	2.44	470	1.59
South America	3,325	1.04	4,435	1.20	320	1.39	410	1.39
Western Europe	2,545	0.80	3,335	0.90	150	0.65	200	0.68
Eastern Europe	3,790	1.19	6,070	1.64	240	1.04	380	1.28
Northern Europe	4,295	1.35	2,375	0.64	280	1.22	170	0.57
Southern Europe	3,715	1.17	2,340	0.63	240	1.04	180	0.61
Western Africa	925	0.29	3,645	0.98	80	0.35	410	1.39
Eastern Africa	2,640	0.83	4,360	1.18	270	1.17	450	1.52
Northern Africa	1,645	0.52	6,700	1.81	120	0.52	480	1.62
Central Africa	410	0.13	1,650	0.45	40	0.17	130	0.44
Southern Africa	460	0.14	575	0.16	30	0.13	50	0.17
West Central Asia and the Middle East	5,290	1.66	11,615	3.13	440	1.91	1,060	3.58
Eastern Asia	9,360	2.94	16,015	4.32	830	3.61	1,540	5.21
Southeast Asia	9,790	3.07	13,920	3.76	1,110	4.83	1,710	5.78
Southern Asia	12,645	3.97	21,150	5.71	1,730	7.53	3,140	10.62
Oceania/Antarctica and adjacent islands	920	0.29	705	0.19	100	0.43	50	0.17
Missing/unknown	4,775	1.50	6,330	1.71	400	1.74	570	1.93
Father's birth place								
Canada	223,315	70.11	238,240	64.29	13,980	60.81	16,290	55.07
North America, excluding Canada	3,660	1.15	3,770	1.02	200	0.87	280	0.95
Central America	2,715	0.85	4,080	1.10	180	0.78	280	0.95
Caribbean and Bermuda	5,940	1.86	5,915	1.60	640	2.78	570	1.93
South America	3,145	0.99	4,170	1.13	310	1.35	370	1.25
Western Europe	2,855	0.90	3,920	1.06	160	0.70	280	0.95
Eastern Europe	3,390	1.06	5,060	1.37	200	0.87	320	1.08
Northern Europe	4,815	1.51	3,530	0.95	280	1.22	230	0.78
Southern Europe	4,920	1.54	2,805	0.76	320	1.39	200	0.68
Western Africa	1,125	0.35	4,075	1.10	90	0.39	430	1.45
Eastern Africa	2,680	0.84	4,185	1.13	260	1.13	410	1.39
Northern Africa	1,955	0.61	7,165	1.93	130	0.57	520	1.76
Central Africa	470	0.15	1,755	0.47	40	0.17	140	0.47
Southern Africa	460	0.14	650	0.18	30	0.13	50	0.17
West Central Asia and the Middle East	6,065	1.90	12,285	3.32	490	2.13	1,080	3.65
Eastern Asia	8,365	2.63	13,265	3.58	740	3.22	1,300	4.39
Southeast Asia	7,955	2.50	11,020	2.97	980	4.26	1,470	4.97
Southern Asia	12,860	4.04	21,480	5.80	1,730	7.53	3,160	10.68
Oceania/Antarctica and adjacent islands	965	0.30	1,015	0.27	110	0.48	70	0.24
Missing/unknown	20,860	6.55	22,160	5.98	2,110	9.18	2,150	7.27
Marital relation								
Single	85,845	27.00	111,435	30.10	7,175	31.20	9,305	31.50
Married	196,025	61.50	224,895	60.70	12,925	56.20	17,625	59.60
Other (widowed, divorced, common-law, unknown)	36,640	11.50	34,215	9.20	2,885	12.60	2,655	9.00

Notes: SGA = small-for-gestational-age. Due to vetting procedures at Statistics Canada's Research Data Centres, univariate descriptives were roudned to the nearest 5 or 10 where needed. As a result, some rows may not sum to the total.

Source: Statistics Canada's Vital Statistics - Birth Database (VSBD).

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