Research

Trends in rate of hypertensive disorders of pregnancy and associated morbidities in Canada: a population-based study (2012–2021)

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Abstract

Background: Hypertensive disorders of pregnancy (HDP) are a leading cause of severe maternal morbidity (SMM). We sought to explore trends in HDP and related morbidity outcomes in Canada.

Methods: In this retrospective population-based study, we used hospital discharge data from Canada, excluding Quebec, to identify females who had an HDP diagnosis during a birth admission between 2012 and 2021. We analyzed temporal and geographical trends in HDP, as well as temporal trends in adverse outcomes associated with HDP.

Results: Among 2 804 473 hospital admissions for birth between 2012 and 2021, the rate of any HDP increased from 6.1% to 8.5%, including pre-existing hypertension (0.6% to 0.9%), gestational hypertension (3.9% to 5.1%), and preeclampsia (1.6% to 2.6%). For 2017–2021 combined, relative to Ontario (6.9%), HDP were significantly more prevalent in nearly all other Canadian regions. For example, in Newfoundland and Labrador, the rate was 10.7% (unadjusted rate ratio 1.56, 95% confidence interval 1.49–1.63). Among females with any HDP, rates of cesarean delivery rose from 42.0% in 2012 to 44.3% in 2021, as did acute renal failure (0.4% to 0.6%), while rates of early preterm delivery, intrauterine fetal death, maternal hospital length of stay (≥ 7 d), admission to the maternal intensive care unit, severe hemorrhage, and SMM trended downward.

Interpretation: The rate of HDP has risen across Canada, with a concomitant decline in some HDP-associated morbidities. Ongoing surveillance of HDP is needed to assess the factors associated with temporal trends, including the effectiveness of evolving HDP prevention and management efforts.

Hypertensive disorders of pregnancy (HDP) include pre-existing (chronic) hypertension, gestational hypertension, and preeclampsia or eclampsia. Globally, hypertensive disorders affect 5%–10% of pregnancies and are responsible for more than 50 000 maternal deaths and 500 000 perinatal deaths annually.[1,2] In Canada, severe preeclampsia was the most common contributor to severe maternal morbidity (SMM) from 2012 to 2016.[3] Although preeclampsia and eclampsia pose the greatest risk, all forms of HDP heighten the risk of adverse pregnancy outcomes, including long-term risk of cardiovascular and metabolic disease.[4–6]

Risk factors for HDP are on the rise, including obesity, pre-pregnancy diabetes mellitus, and advanced maternal age.[7] Concomitantly, the prevention and management of HDP have seen advances, including use of low-dose acetylsalicylic acid (ASA) prophylaxis in females at increased risk of early-onset preeclampsia.[8–10] Evidence for the collective effect of these population and clinical changes on HDP in high-income countries is limited and varying. In Victoria, Australia, for example, rates of HDP remained stable between 2010 and 2017;[11] earlier studies reported decreased rates of gestational hypertension and preeclampsia in other regions of Australia and Northern Europe,[12] but increased rates in the United States.[13,14] We sought to examine trends in HDP and associated adverse outcomes in Canada.

Methods

Design and setting

We conducted a retrospective population-based cohort study of all hospital deliveries of livebirths and stillbirths at 20 weeks' gestation or later in Canada, except for Quebec. As all births were listed as being to females in administrative data, we use

female-centric terms herein. We included births from fiscal year 2012/13 (starting in April) to 2021/22 (ending in March), hereafter referred to as 2012 and 2021, respectively. The last 2 study years coincided with the SARS-CoV-2 pandemic, when in-person prenatal care was reduced to avoid viral transmission. The Reporting of Studies Conducted Using Observational Routinely Collected Health Data (RECORD) checklist is available in Appendix 1, at www.cmaj.ca/lookup/doi/10.1503/cmaj.231547/tab-related-content.

Data source

We obtained data from the Canadian Institute for Health Information's Discharge Abstract Database, which includes records for all hospital births in Canada, excluding Quebec. Around 98% of births in Canada occur in hospitals.[15] Data included information on maternal characteristics, with diagnoses coded using the Canadian version of the *International Classification of Diseases and Related Health Problems, 10th Revision* (ICD-10-CA). Information from maternal records in the Discharge Abstract Database have been validated against medical records.[16]

Outcomes

The primary study outcome was the rate of any HDP, as recorded during the hospital admission for birth. We categorized HDP as pre-existing (chronic) hypertension, gestational hypertension, preeclampsia (including hemolysis, elevated liver enzymes and low platelets [HELLP] syndrome) or eclampsia, and any HDP, defined as any of the previous conditions or unspecified maternal hypertension. Appendix 2, Table S1, available at www.cmaj.ca/lookup/doi/10.1503/cmaj.231547/tab-related-content, provides corresponding ICD-10-CA codes. These categories were not mutually exclusive (e.g., someone with pre-existing hypertension could also have preeclampsia or eclampsia). We combined all preeclampsia and eclampsia codes into 1 category, as previous studies suggested a lack of discrimination in preeclampsia severity using ICD codes.[17,18] We added preeclampsia with preterm birth as a measure of disease severity, as early delivery is generally indicated in severe preeclampsia.

Secondary outcomes were indicators of morbidity known to be associated with HDP.[1,4,5] These were rates of cesarean delivery; preterm delivery, divided into early (20–31 wk gestation), moderate (32–33 wk gestation) and late (34–36 wk gestation) preterm birth as a marker of the degree of morbidity; intrauterine fetal death; delivery hospital length of stay of 7 days or longer; maternal admission to an intensive care unit; acute renal failure or receipt of dialysis;[19] severe peripartum hemorrhage;[19] and a validated composite measure of SMM,[19] with omission of HDP from the SMM composite to avoid conflating the HDP exposure with the outcome.

Statistical analysis

We conducted time-trend analyses for HDP for all of Canada (excluding Quebec) and by province or territory, between 2012 and 2021, using autoregressive integrated moving average (ARIMA) models. We modelled monthly rates, accounting for autocorrelated and heteroscedastic residuals and seasonality. We also assessed temporal trends of HDP by known risk factors for HDP, chosen a priori and based on their availability in the data set, including maternal age; plurality (singleton or multiple pregnancy); livebirth parity, which was solely based on the number of previous livebirths; pre-existing diabetes; and rural or urban residence.[20,21]

We calculated rates of HDP by each province or territory of residence for 2017–2021 combined. Comparing the most recent 5 study years provided more stable estimates in jurisdictions with smaller populations than a single-year estimate. We used rate ratios and 95% confidence intervals (CIs) to compare rates of HDP for each province or territory with the rate for Ontario. We chose Ontario as the referent because it is the jurisdiction with the greatest number of births in Canada.

We analyzed temporal trends of adverse outcomes using ARIMA models of monthly rates. In addition, we used a difference-in-differences approach to compare 2012 and 2021 rates of each adverse outcome among females with HDP with rates among females with none of the HDPs. We defined the latter as the absence of any aforementioned ICD-10-CA codes for HDP.

We determined associations between maternal characteristics (age, plurality, livebirth parity, pre-existing diabetes, residence, and year of delivery) and HDP using logistic regression analysis, expressed as odds ratios (ORs) and 95% CIs. We adjusted ORs for each of these characteristics. We included year of delivery to assess any temporal trend distinct from how other maternal variables varied with time. For each characteristic, the group with the lowest risk of HDP served as the referent. Each birth was treated as an independent observation. We created a missing category for livebirth parity (6.9% missing) and rural or urban residence (0.4% missing).

We analyzed data using SAS Enterprise Guide version 7.1 (SAS Institute).

Sensitivity analysis

As Ontario accounted for 49% of our sample, we conducted sensitivity analyses to assess the impact of excluding Ontario on temporal trends.

Ethics approval

Ethics approval was not required because the study used anonymized data and was conducted under the surveillance mandate of the Public Health Agency of Canada.

Results

We included 2 804 473 hospital deliveries recorded between 2012 and 2021. Across that era, the rate of any HDP rose significantly from 6.1% to 8.5%, a relative increase of 40% (95% CI 37%–43%) (Table 1). Rates of different types of HDP increased as well, with pre-existing hypertension increasing from 0.6% to 0.9% (relative increase 44%, 95% CI 36%–53%), gestational hypertension increasing from 3.9% to 5.1% (relative increase 31%, 95% CI 28%–34%), preeclampsia increasing from 1.6% to 2.6% (relative increase 69%, 95% CI 63%–75%), and preeclampsia with preterm birth increasing from 0.6% to 0.9% (relative increase 50%, 95% CI 41%–59%). We observed increases across all strata of studied

Table 1: Temporal changes in the rates of hypertensive disorders of pregnancy (HDP) by maternal characteristics between 2012 and 2021, Canada (excluding Quebec)*

Maternal characteristic	No. (%) of births		Proportion of births with pre-existing hypertension, %		Proportion of births with gestational hypertension, %		Proportion of births with preeclampsia or eclampsia, %		Proportion of births with preeclampsia or eclampsia with concomitant preterm birth, %		Proportion of births with any HDP†, %	
	2012 *n* = 283 601	2021 *n* = 275 775	2012	2021	2012	2021	2012	2021	2012	2021	2012	2021
Age group, yr												
< 20	10 966 (3.9)	4291 (1.6)	0.1	0.3	3.5	4.7	2.2	4.1	0.6	1.0	5.9	9.2
20–24	40 119 (14.1)	24 081 (8.7)	0.2	0.5	3.6	5.0	1.5	2.8	0.5	0.9	5.4	8.1
25–29	82 828 (29.2)	69 678 (25.3)	0.4	0.5	3.7	5.1	1.5	2.5	0.6	0.9	5.6	8.1
30–34	93 357 (32.9)	106 324 (38.6)	0.7	0.7	3.9	4.8	1.4	2.3	0.6	0.8	6.0	7.8
35–39	46 109 (16.3)	58 995 (21.4)	1.1	1.4	4.4	5.5	1.7	2.7	0.8	1.1	7.1	9.4
≥ 40	10 222 (3.6)	12 406 (4.5)	2.2	3.4	5.8	7.0	2.5	4.0	1.3	1.8	10.2	13.6
Plurality												
Singleton	278 741 (98.3)	271 550 (98.5)	0.6	0.9	3.9	5.1	1.5	2.5	0.5	0.8	5.9	8.4
Multiple	4860 (1.7)	4225 (1.5)	1.0	1.7	6.8‡	7.2‡	6.7	8.4	5.1	6.8	14.2	16.8
Livebirth parity												
0	97 038 (34.2)	118 762 (43.1)	0.6	0.9	5.4	6.4	2.3	3.8	0.9	1.3	8.2	10.8
1	77 285 (27.3)	95 437 (34.6)	0.5	0.9	2.8	4.1	0.9	1.7	0.3	0.6	4.2	6.6
2	30 882 (10.9)	37 299 (13.5)	0.7	1.0	2.9	4.3	1.0	1.6	0.5	0.7	4.5	6.8
≥ 3	18 427 (6.5)	24 202 (8.8)	0.9	1.3	3.3	4.3	1.0	2.1	0.4	0.8	5.1	7.4
Missing	59 969 (21.1)	75 (0.0)	0.8	1.3	3.7	2.7	1.7‡	2.7‡	0.7‡	0.0‡	6.2‡	6.7‡
Pre-pregnancy diabetes												
Absent	281 072 (99.1)	272 237 (98.7)	0.6	0.8	3.8	5.1	1.5	2.5	0.6	0.9	5.9	8.2
Present	2529 (0.9)	3538 (1.3)	7.2	9.9	12.1‡	12.2‡	7.6	10.1	4.7	6.2	25.3	30.0
Urban or rural residence												
Urban	236 592 (83.4)	230 349 (83.5)	0.6	0.9	3.8	5.0	1.5	2.6	0.6	0.9	6.0	8.4
Rural	46 481 (16.4)	45 006 (16.3)	0.7	0.9	4.3	5.9	1.6	2.7	0.6	0.9	6.6	9.3
Missing	528 (0.2)	420 (0.2)	0.6‡	0.2‡	3.8‡	5.5‡	2.5‡	2.6‡	1.7‡	1.7‡	7.2‡	8.6‡
All births	283 601 (100.0)	275 775 (100.0)	0.6	0.9	3.9	5.1	1.6	2.6	0.6	0.9	6.1	8.5

*For all 10 years of data, we conducted autoregressive integrated moving average (ARIMA) modelling for each type of HDP by each stratum of a given maternal characteristic. We modelled monthly HDP rates, although yearly rates are presented. All temporal trend tests were statistically significant ($p < 0.05$), unless otherwise indicated. Relative increases between 2012 and 2021 were calculated with unrounded rates.
†Any HDP was defined as pre-existing hypertension, gestational hypertension, preeclampsia or eclampsia, or unspecified maternal hypertension.
‡Temporal trend test not significant ($p \geq 0.05$).

maternal characteristics, except among females with missing information on livebirth parity or urban or rural residence. We did not observe a difference in trends during the SARS-CoV-2 pandemic years (Appendix 3, Figure S1, available at www.cmaj.ca/lookup/doi/10.1503/cmaj.231547/tab-related-content). Among deliveries with an HDP, 4.6% had more than 1 HDP recorded.

In both 2012 and 2021, we observed a J-shaped relation between maternal age and HDP, with higher rates of HDP among females younger than 20 years and those older than 34 years than those aged 20–29 years (Table 1 and Appendix 4, Figure S2, available at www.cmaj.ca/lookup/doi/10.1503/cmaj.231547/tab-related-content). Females younger than 20 years had the largest

relative increase of HDP at 56%. Furthermore, HDP were more common among females with a first birth, those with a multiple-gestation pregnancy, those with pre-pregnancy diabetes, and those living in rural communities. The proportion of females with a first birth, females with pre-existing diabetes, and females aged 30–34, 35–39, or 40 years or older increased from 2012 to 2021 (Table 1).

Rates of HDP varied across provinces and territories (Table 2). For 2017–2021, relative to Ontario (6.9%), the highest rate was in Newfoundland and Labrador (10.7%; rate ratio 1.56, 95% CI 1.49–1.63), and the lowest was in the Northwest Territories (6.5%), although this rate was not significantly different from that in Ontario. Geographic patterns for HDP subtypes were somewhat similar (Table 2). Between 2012 and 2021, rates of HDP and HDP subtypes generally increased significantly over time in each province or territory (Appendix 3, Figure S1). Ontario had the lowest relative increases in HDP.

Among females with any HDP, rates of cesarean delivery rose between 2012 and 2021, as did acute renal failure, while rates of early preterm delivery, intrauterine fetal death, maternal hospital length of stay (≥ 7 d), admission to the maternal intensive care unit, severe hemorrhage, and SMM trended downward (Table 3). Adverse outcomes were more common among females with than without HDP. However, adverse outcomes changed relatively less among females with HDP. For example, the increase in the rate of cesarean delivery between 2012 and 2021 was less pronounced among females with HDP (from 42.0% to 44.3%) than among those without HDP (from 27.4% to 31.9%) — a difference in differences of −2.2% (95% CI −3.2% to −1.3%) (Table 3). We observed similar relative effects for other adverse outcomes, with the exception of acute renal failure, whereby the rate increased from 0.4% to 0.6% among females with HDP, and from 0.02% to 0.03% among those without HDP — a positive difference in differences of 0.3% (95% CI 0.2%–0.3%) (Table 3).

Each 1-year increase in maternal age was associated with an adjusted OR of 1.14 (95% CI 1.13–1.14) for pre-existing hypertension, with less pronounced associated effects for the other HDP (Table 4). A multiple pregnancy had a higher adjusted OR for preeclampsia (3.93, 95% CI 3.79–4.07), as did nulliparity (2.43, 95% CI 2.38–2.48) and pre-pregnancy diabetes (5.15, 95% CI 4.95–5.36). Pre-pregnancy diabetes had the strongest association with pre-existing hypertension (adjusted OR 10.90, 95% CI 10.43–11.40). Rural residence was associated with an adjusted OR of 1.27 (95% CI 1.25–1.29) for HDP. Each progressive year in the study period was associated with an adjusted OR of 1.04 (95% CI 1.04–1.04) of HDP (Table 4).

Sensitivity analysis

We found similar temporal increases in rates of HDP when we excluded Ontario. For example, the rate of any HDP increased from 6.4% in 2012 to 9.6% in 2021 (a relative increase of 50%, 95% CI 46%–54%). Excluding Ontario also did not change the general downward trend observed for adverse outcomes associated with HDP.

Table 2: Rates of hypertensive disorders of pregnancy (HDP) by province or territory of residence in Canada (excluding Quebec), 2017–2021 combined

	Pre-existing hypertension		Gestational hypertension		Preeclampsia or eclampsia		Any HDP	
Province or territory (total no. of births)	Rate, %	Rate ratio* (95% CI)	Rate, %	Rate ratio* (95% CI)	Rate, %	Rate ratio* (95% CI)	Rate, %	Rate ratio* (95% CI)
Ontario (*n* = 671 432)	0.7	1.00 (Ref.)	4.1	1.00 (Ref.)	2.2	1.00 (Ref.)	6.9	1.00 (Ref.)
Northwest Territories (*n* = 2913)	1.3	1.75 (1.27–2.40)	2.6	0.64 (0.51–0.80)	2.6	1.21 (0.97–1.52)	6.5	0.94 (0.82–1.09)
British Columbia (*n* = 205 855)	0.9	1.21 (1.14–1.27)	3.8	0.93 (0.91–0.96)	3.1	1.40 (1.36–1.44)	7.8	1.13 (1.11–1.15)
Alberta (*n* = 244 462)	0.8	1.08 (1.03–1.14)	5.6	1.36 (1.34–1.39)	2.3	1.08 (0.05–1.11)	8.6	1.25 (1.23–1.27)
Yukon (*n* = 2126)	0.6	0.82 (0.48–1.41)	3.7	0.90 (0.72–1.13)	4.5	2.07 (1.70–2.53)	8.7	1.26 (1.09–1.45)
Saskatchewan (*n* = 71 497)	0.9	1.21 (1.12–1.32)	5.5	1.33 (1.29–1.38)	3.1	1.42 (1.36–1.49)	9.1	1.33 (1.29–1.36)
Prince Edward Island (*n* = 6588)	0.5	0.67 (0.48–0.94)	6.5	1.58 (1.43–1.74)	1.9	0.86 (0.72–1.03)	9.2	1.33 (1.23–1.45)
Nova Scotia (*n* = 39 138)	1.2	1.66 (1.51–1.82)	4.8	1.15 (1.10–1.21)	3.4	1.54 (1.46–1.63)	9.3	1.34 (1.30–1.39)
Manitoba (*n* = 80 498)	1.1	1.45 (1.35–1.56)	6.3	1.52 (1.48–1.57)	2.1	0.95 (0.90–1.00)	9.3	1.35 (1.31–1.38)
Nunavut (*n* = 4151)	0.7	0.87 (0.60–1.27)	4.8	1.18 (1.02–1.35)	4.2	1.95 (1.68–2.26)	9.5	1.38 (1.25–1.52)
New Brunswick (*n* = 31 131)	1.7	2.22 (2.03–2.44)	5.3	1.30 (1.24–1.36)	3.3	1.53 (1.44–1.63)	9.5	1.38 (1.33–1.43)
Newfoundland and Labrador (*n* = 19 074)	1.6	2.10 (1.87–2.36)	7.3	1.77 (1.67–1.86)	2.1	0.99 (0.89–1.09)	10.7	1.56 (1.49–1.63)
Canada (*n* = 1 378 865)†	0.9	–	4.6	–	2.4	–	7.8	–

Note: CI = confidence interval, Ref. = reference category.
*Unadjusted for other variables.
†Excluding Quebec.

Interpretation

We observed a 40% relative increase in the rate of HDP between 2012 and 2021 in Canada (excluding Quebec), with the largest increase in the rate of preeclampsia. These increases occurred across almost all strata of studied maternal characteristics and among all provinces and territories, with certain jurisdictions experiencing higher overall rates than others. These interprovincial and territorial trends could inform regional priorities for clinical and public health initiatives. Except for cesarean delivery and acute renal failure, we observed downward trends for rates of adverse outcomes associated with HDP.

The increasing rate of HDP in Canada is similar to that observed in the US, but differs from stable or downward trends observed in other countries. In the US, from 2007 to 2019, the incidence of new-onset hypertension rose from 3.7% to 7.7% in rural areas and from 4.9% to 8.4% in urban regions.[22] In Victoria, Australia, rates of any HDP were stable over time at 5.7% in 2010 and 5.9% in 2017.[11] In the Nordic countries, the rate of preeclampsia declined between 1997 and 2007,[12] but more recent estimates are not available. Although different definitions and methods for identifying HDP subtypes may explain some differences in international rates,[23] further study is needed to determine whether the temporal increases in North America are because of a rise in risk factors for HDP not seen in other countries. Furthermore, the threshold to diagnose preeclampsia may have changed over time, including the removal of the traditional requisite feature of proteinuria.[5] If the ensuing effect was a rise in preeclampsia diagnoses, this should have concomitantly led to a decline in diagnoses of gestational hypertension, which we did not observe.

Many risk factors for HDP have been identified.[20,21] Of those we explored, the proportion of females in rural areas remained unchanged and the proportion of multiple pregnancies decreased, while the proportions of females with advanced maternal age, nulliparity, and pre-existing diabetes increased. However, adjusting for these factors did not significantly attenuate the higher odds of HDP over time, suggesting that the rise in HDP may be explained by factors that we did not account for, including body mass index (BMI).[21,24] High BMI is a known risk factor for hypertension, including during pregnancy.[21,24] In Canada, between 2015 and 2021, overweight or obese BMI status increased from 41% to 48% among females aged 18–34 years, and from 56% to 64% among those aged 35–49 years.[25] Provinces with higher rates of obesity, such as New Brunswick and Newfoundland and Labrador,[26] also had higher rates of HDP in our study. Although this suggests that increasing maternal weight could be a contributor to the trend of increasing rates of hypertension, further study is

Table 3: Temporal changes in the rate of adverse pregnancy outcomes among females with and without hypertensive disorders of pregnancy (HDP) between 2012 and 2012, Canada (excluding Quebec)*

	Pre-existing hypertension, %		Gestational hypertension, %		Preeclampsia or eclampsia, %		Any HDP, %		No HDP, %		Difference in rate change between 2012 and 2021, comparing females with or without any HDP‡ (95% CI)
Adverse outcome	2012	2021	2012	2021	2012	2021	2012	2021	2012	2021	
Cesarean birth	50.7	55.7	36.7	38.5	54.8§	54.3§	42.0	44.3	27.4	31.9	−2.2 (−3.2 to −1.3)
Preterm birth, wk											
20–31	6.2	5.3	0.9§	0.9§	8.8	6.3	3.1	2.7	1.2§	1.2§	−0.5 (−0.7 to −0.2)
32–33	3.8	3.2	1.3	1.0	6.7	5.5	2.7	2.3	0.7§	0.8§	−0.4 (−0.6 to −0.2)
34–36	13.6§	15.6§	8.9§	8.4§	24.4	23.5	12.8§	13.1§	5.0	5.1	0.1 (−0.4 to 0.6)
Intrauterine fetal death	1.4	1.3	0.4§	0.4§	1.2§	0.9§	0.7	0.6	0.5§	0.5§	−0.1 (−0.3 to 0.01)
Hospital length of stay ≥ 7 d	12.4	7.9	4.7	2.6	20.0	12.2	8.7	5.4	1.1	1.0	−3.0 (−3.3 to −2.8)
Intensive care unit admission	2.9	1.5	1.6	0.5	4.8	3.1	2.4	1.2	0.3	0.2	−1.1 (−1.2 to −1.0)
Acute renal failure or dialysis	0.3	1.2	0.1	0.2	1.2	1.7	0.4	0.6	0.02	0.03	0.3 (0.2 to 0.3)
Severe peripartum hemorrhage	1.2§	1.2§	1.0	0.7	2.3	1.4	1.3	0.9	0.6	0.5	−0.3 (−0.5 to −0.2)
Severe maternal morbidity†	5.9	4.3	3.0	1.8	9.0	6.5	4.6	3.2	1.2	1.1	−1.3 (−1.5 to −1.0)

Note: CI = confidence interval.
*For all 10 years of data, we conducted autoregressive integrated moving average (ARIMA) modelling for each adverse outcome by type of HDP. We modelled monthly adverse outcome rates, although yearly rates are presented. All temporal trend tests were statistically significant ($p < 0.05$), unless otherwise indicated.
†Excludes HDP.
‡Calculated using a difference-in-differences approach with unrounded rates of adverse events.
§Temporal trend test not significant ($p \geq 0.05$).

Table 4: Association between maternal characteristics and hypertensive disorders of pregnancy (HDP), Canada (excluding Quebec), 2012 to 2021

	Pre-existing hypertension		Gestational hypertension		Preeclampsia or eclampsia		Any HDP	
Maternal characteristic	**Unadjusted OR (95% CI)**	**Adjusted OR* (95% CI)**	**Unadjusted OR (95% CI)**	**Adjusted OR* (95% CI)**	**Unadjusted OR (95% CI)**	**Adjusted OR* (95% CI)**	**Unadjusted OR (95% CI)**	**Adjusted OR* (95% CI)**
Age (per yr)	1.14 (1.14–1.14)	1.14 (1.13–1.14)	1.02 (1.02–1.02)	1.03 (1.03–1.03)	1.01 (1.01–1.02)	1.03 (1.03–1.03)	1.03 (1.03–1.03)	1.04 (1.04–1.04)
Plurality								
Singleton	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)
Multiple	1.77 (1.63–1.92)	1.45 (1.33–1.57)	1.67 (1.61–1.74)	1.58 (1.53–1.64)	4.08 (3.94–4.23)	3.93 (3.79–4.07)	2.48 (2.42–2.55)	2.35 (2.29–2.42)
Livebirth parity								
0	1.04 (1.01–1.07)	1.31 (1.27–1.35)	1.74 (1.72–1.77)	1.87 (1.84–1.90)	2.29 (2.25–2.34)	2.43 (2.38–2.48)	1.84 (1.82–1.86)	2.01 (1.99–2.04)
1	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)
2	1.22 (1.17–1.28)	1.08 (1.03–1.13)	1.01 (0.99–1.03)	0.97 (0.95–0.99)	1.01 (0.98–1.04)	0.97 (0.94–1.01)	1.04 (1.02–1.05)	0.99 (0.97–1.00)
≥ 3	1.49 (1.42–1.56)	1.04 (0.99–1.10)	1.11 (1.08–1.14)	0.99 (0.97–1.02)	1.15 (1.11–1.19)	1.01 (0.98–1.05)	1.17 (1.15–1.19)	1.01 (0.99–1.03)
Missing	1.14 (1.08–1.21)	1.44 (1.36–1.53)	1.10 (1.07–1.13)	1.28 (1.24–1.32)	1.40 (1.35–1.45)	1.77 (1.71–1.84)	1.23 (1.20–1.25)	1.49 (1.45–1.52)
Pre-pregnancy diabetes								
Absent	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)
Present	13.38 (12.81–13.98)	10.90 (10.43–11.40)	2.79 (2.69–2.90)	2.71 (2.61–2.92)	5.12 (4.93–5.33)	5.15 (4.95–5.36)	5.07 (4.94–5.20)	4.98 (4.85–5.12)
Urban or rural residence								
Urban	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)
Rural	0.96 (0.93–1.00)	1.23 (1.18–1.28)	1.13 (1.11–1.15)	1.27 (1.25–1.29)	1.07 (1.04–1.09)	1.20 (1.18–1.23)	1.11 (1.10–1.12)	1.27 (1.25–1.29)
Missing	0.74 (0.57–0.96)	0.73 (0.56–0.94)	0.63 (0.56–0.71)	0.60 (0.54–0.68)	0.90 (0.78–1.04)	0.85 (0.74–0.98)	0.71 (0.65–0.78)	0.68 (0.62–0.74)
Delivery year (per yr)	1.05 (1.04–1.05)	1.03 (1.03–1.04)	1.04 (1.04–1.04)	1.03 (1.03–1.03)	1.06 (1.05–1.06)	1.06 (1.05–1.06)	1.04 (1.04–1.05)	1.04 (1.04–1.04)

Note: CI = confidence interval, OR = odds ratio, Ref. = reference category.
*Adjusted for all other characteristics.

needed to assess this relationship in Canada, as a US study found that secular trends in obesity could not explain the rising rates of chronic hypertension in pregnancy between 1970 and 2010.[13]

Despite the increasing rates of HDP, we observed a relative decline in adverse pregnancy outcomes among those with HDP. This finding is consistent with those of a study from Quebec, conducted between 1989 and 2012, which reported an increase in rates of preeclampsia from 2.6% to 5.1%, with a decline in mortality and morbidity (except acute renal failure) among females with preeclampsia — something also seen in our study. A factor contributing to the increased rate of acute renal failure may be changes in the management of preeclampsia, such as better blood pressure control and delayed delivery, the latter of which may permit ongoing reduced renal blood flow and worsen glomerular filtration.[28] However, downward trends in other adverse outcomes suggest that the clinical management of HDP may have improved over time. This underscores the importance of standard measurement of blood pressure at each prenatal visit and the institution of evidence-based antihypertensive therapy.[5,10] In a randomized clinical trial of pregnant females with mild chronic hypertension, starting antihypertensive therapy at a relatively lower blood pressure threshold was associated with a reduced risk of severe preeclampsia, provider-initiated preterm delivery, placental abruption, and perinatal death.[29] Moreover, among females at risk of early-onset preeclampsia, low-dose ASA can reduce the risk of preterm preeclampsia and other adverse outcomes.[8–10] Although these potential gains are noteworthy, females with HDP remain at higher risk of adverse outcomes than those without HDP.

Limitations

We may have misclassified HDP by ICD-10-CA diagnostic codes, which were last validated in 2009.[16,17] We mitigated this problem by combining all preeclampsia and eclampsia codes and by examining preeclampsia with concomitant preterm birth as a proxy for early-onset (and, presumably, more severe) preeclampsia. In addition to BMI, history of HDP was unknown, as was use of ASA prophylaxis or other medications. Moreover, smoking, dietary and activity lifestyle factors, and several relevant sociodemographic measures, such as race and ethnicity, could not be accounted for in this study.[20,30] Although data from Quebec were unavailable, a study from that province saw trends that mirrored those in the rest of the country.[27] As we focused on short-term maternal and fetal outcomes, longer-term outcomes, as well as newborn and child outcomes, should be evaluated in a future study.

Conclusion

The rate of HDP has risen across Canada, with notable geographic variation and a concomitant decline in some HDP-associated morbidity. The decline in HDP-associated morbidity may reflect improvements in the management of blood pressure and timing of birth among females at risk of, or already affected by, HDP. Ongoing surveillance of HDP — including newborn outcomes — should assess the factors associated with temporal trends, including the effectiveness of evolving HDP prevention and management efforts.

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