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Socioeconomic Gradients of Adverse Birth Outcomes and Related Maternal Factors in Rural and Urban Alberta, Canada: A Concentration Index Approach.

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4 Rural and Urban Alberta, Canada: A Concentration Index Approach
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10 **Authors:** Maria B. Ospina, MSc, PhD;¹ Alvaro Osornio-Vargas, MD, PhD;² Charlene C.
11 Nielsen, PhD;² Susan Crawford, MSc;³ Manoj Kumar, MD, MSc;² Khalid Aziz, MD;² Jesus A.
12 Serrano-Lomelin, PhD¹
13
14
15
16
17
18

19 ¹Department of Obstetrics & Gynecology, Faculty of Medicine & Dentistry; University of
20 Alberta. Edmonton, Alberta (Canada)
21
22
23
24
25

26 ²Department of Pediatrics, Faculty of Medicine & Dentistry; University of Alberta. Edmonton,
27 Alberta (Canada)
28
29
30
31
32

33 ³Alberta Perinatal Health Program, Alberta Health Services. Calgary, Alberta (Canada).
34
35
36
37

38 **Corresponding Author**

39 Jesus Serrano-Lomelin, PhD

40 Department of Obstetrics & Gynecology, University of Alberta.

41 220A Heritage Medical Research Centre

42 11313 87 Ave NW, Edmonton, AB, Canada. T6G 2S2

43 Ph: (780) 735-8732; F: (780) 735-4981

44 [45 jaserran@ualberta.ca](mailto:jaserran@ualberta.ca)

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3 **Keywords:** health inequalities; concentration index; adverse birth outcomes; perinatal risk
4 factors; social medicine.
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10 **Contributors' Statement**

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12 Maria B. Ospina participated in investigation, conceptualization/design, methodology, drafted
13 the initial manuscript, and approved the final version of the manuscript.
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17 Alvaro Osornio-Vargas participated in funding acquisition, resources, conceptualization/design,
18 supervision, critically review/edit the manuscript, and approved the final version of the
19 manuscript.
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24 Charlene C. Nielsen, participated in conceptualization/design, methodology, geographic analysis,
25 and approved the final version of the manuscript.
26
27

28
29 Susan Crawford participated in conceptualization/design, resources (health data provider),
30 critically review/edit the manuscript, and approved the final version of the manuscript.
31
32

33
34 Manoj Kumar participated in funding acquisition, conceptualization/design, supervision,
35 critically review/edit the manuscript, and approved the final version of the manuscript.
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39 Khalid Aziz participated in funding acquisition, conceptualization/design, supervision, critically
40 review/edit the manuscript, and approved the final version of the manuscript.
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44 Jesus Serrano-Lomelin participated in funding acquisition, conceptualization/design, database
45 management, statistical analysis, critically review/edit the manuscript, and approved the final
46 version of the manuscript.
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ABSTRACT

Objective: Using a summary measure of health inequalities, this study evaluated the distribution of adverse birth outcomes (ABO) and related maternal risk factors across socioeconomic status (SES) gradients in urban and rural Alberta, Canada.

Design: Cross-sectional study using a validated perinatal clinical registry and an area-level SES.

Setting: The study was conducted in Alberta (Canada). Data about ABO and related maternal risk factors were obtained from the Alberta Perinatal Health Program (APHP). An area-level SES index derived from census data (2006) was linked to the postal code at delivery.

Participants: Women (n=330,957) having singleton live births with gestational age ≥ 22 weeks identified in the APHP between 2006 to 2012.

Primary and secondary outcome measures: We estimated concentration indexes to assess inequalities across SES gradients in both rural and urban areas (CIdx_R and CIdx_U, respectively) for spontaneous preterm birth (PTB), small for gestational age (SGA), large for gestational age (LGA), gestational hypertension, gestational diabetes, smoking and/or substance use during pregnancy, and pre-pregnancy weight > 91 kg.

Results: The highest health inequalities disfavoring low SES groups were identified for substance abuse and smoking in rural areas (CIdx_R -0.38 and -0.23, respectively). Medium inequalities were identified for LGA (CIdx_R -0.08), weight >91 kg (CIdx_R -0.07), substance use (CIdx_U -0.15), smoking (CIdx_U -0.14), gestational diabetes (CIdx_U -0.10), and SGA (CIdx_U -0.07). Low inequalities were identified for PTB (CIdx_R -0.05; CIdx_U -0.05) and gestational diabetes (CIdx_R -0.04). Inequalities disfavoring high SES groups were identified for gestational hypertension (CIdx_R +0.04), SGA (CIdx_R +0.03), and LGA (CIdx_U +0.03).

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3 **Conclusions:** Adverse birth outcomes and related maternal risk factors were unequally
4 distributed across the socioeconomic gradient in urban-rural settings, with the greatest
5 concentrations in lower SES groups of rural areas. Future research is needed on underlying
6 mechanisms driving SES gradients in perinatal health across the rural/urban spectrum.
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14 **Strengths and limitations of this study**

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18 • This population-based study used a high-quality clinical perinatal registry to quantify
19 health inequalities for adverse birth outcomes and related risk factors across
20 socioeconomic groups in rural and urban Alberta (Canada); a province with universal and
21 free access to medically necessary hospital and physician services for its inhabitants.
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- 27 • We used a well-known and robust method, the concentration index, to compare
28 socioeconomic inequalities in perinatal health in urban and rural areas.
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- 32 • The area-level socioeconomic status (SES) index used for this study is based on the 2006
33 census data. Potential misclassification of the SES may occur as we are assuming no
34 changes in area-level SES index between 2006 and 2012.
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- 38 • Substance abuse and smoking prevalence are expected to be underestimated since they
39 are self-reported.
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INTRODUCTION

Adverse birth outcomes such as preterm birth (PTB), small for gestational age (SGA), and large for gestational age (LGA) are major drivers of morbidity and mortality in neonates and infants and important contributors to long-term physical and psychological health.[1-3] Many of the determinants of adverse birth outcomes start in pregnancy and even before conception. Maternal factors implicated with the occurrence of adverse outcomes at birth include pre-pregnancy overweight, maternal health problems during pregnancy (e.g., gestational hypertension and diabetes), and certain behaviours such as smoking and substance use.[1, 4] All these perinatal exposures and outcomes constitutes the “canary in the coal mine” as fundamental early-life indicators of the impact of social and structural determinants of health operating in a very sensitive period of human life.[5] Health inequalities at birth would then represent a magnifying glass of preconception disadvantages, and a forecast for adult inequalities.[6]

Socioeconomic inequalities in health are quantitative differences in the occurrence of health outcomes across socioeconomic groups,[7] and a topic of great interest in social epidemiology to better understand the structural causes of health and disease.[8, 9] Recent systematic reviews have examined the influences of socioeconomic characteristics on the risk of adverse birth outcomes, suggesting a strong link between area-level socioeconomic status (SES) gradients and a variety of adverse birth outcomes.[12-15] Despite the growing interest in recent years about the role of spatial[16] and socioeconomic-driven inequalities[9] in the distribution of adverse birth outcomes and associated maternal factors, studies in this area have mainly evaluated urban populations. Few studies[17, 18] have examined the relationship between adverse birth outcomes and neighborhood deprivation in rural versus urban communities, a relevant health policy issue

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3 in countries where the access to health services is universal. The study of socioeconomic health
4 inequalities have been traditionally based on population-at-risk approaches, which have
5 underpinned the socioeconomic gradient as a risk factor for poor health.[10, 11] The majority of
6 these studies have used analytical approaches based on measures of association (i.e., regression
7 and Pearson coefficients), and measures of potential impact (i.e., proportion attributable
8 proportions[28]) while other methods based on summary measures of health inequality have
9 been seldom explored.[28]
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21 Using the health concentration index approach, this study quantified health inequalities in the
22 distribution of PTB, SGA, LGA, and related known maternal factors (i.e., pre-pregnancy weight
23 >91 kg, gestational hypertension, gestational diabetes, self-reported smoking and/or substance
24 use during pregnancy) in urban and rural Alberta (Canada) across a socioeconomic gradient.
25 Like all other Canadian provinces, Alberta has a universal, publicly funded health care system
26 that guarantees Albertans receive free access to medically necessary hospital and physician
27 services. The concentration index quantifies the magnitude of perinatal health inequalities across
28 different populations while taking into account both the distribution of the study population
29 across the different socioeconomic groups.
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44 **METHODS**

45 This study is part of a broader environmental health research that explored associations between
46 environmental and social factors with adverse birth outcomes.[19] The study received ethics
47 approval from the University of Alberta Research Ethics Board in Edmonton, Alberta (Canada).
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Study design and population

We conducted a cross-sectional population-based study using provincial health data from Alberta (Canada) for the period of January 1, 2006, to December 31, 2012. Alberta is a culturally diverse province located in Western Canada with a population of 4,067,175 inhabitants in 2016 with approximately 83% living in urban centers.[20]

The study population consisted of all women having singleton live births with gestational age \geq 22 completed weeks during the study period. The APHP is a validated clinical perinatal registry that collects data directly from the provincial delivery record for all births occurring in a hospital or attended by a registered midwife at home in Alberta. Delivery characteristics and newborn health status recorded in the APHP include birth weight, gestational age at delivery in completed weeks, maternal postal code of residence at delivery, lifestyle behaviours before and during pregnancy, maternal health status, obstetric interventions and neonatal outcomes.

Adverse birth outcomes

Preterm birth (PTB) was defined as newborn with less than 37 completed weeks of gestational age. Newborns were identified as SGA (birth weight below the 10th percentile) and LGA (birth weight above the 90th percentile) according to Canadian sex-age specific, population-based standards.[21]

Maternal factors related with PTB, SGA and LGA

Information on the following maternal factors was extracted from the APHP: age at delivery, pre-pregnancy weight >91 kg, gestational hypertension, gestational diabetes (documented

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3 hyperglycemia with diagnosis during current pregnancy only), self-reported smoking (anytime
4 during pregnancy) and/or substance use during pregnancy (three drinks or more on any occasion
5 during pregnancy or one or more alcohol drinks per day while pregnant, and/or drug dependency,
6 inappropriate or excessive use of any substance).
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14 **Definitions of urban and rural maternal place of residence at delivery**

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16 The six-character postal codes of the maternal place of residence at delivery were classified as
17 rural or urban according to population concentration and density. First, postal codes were
18 assigned to their corresponding dissemination area (DA: a census geographic area larger than
19 postal codes with a population of 400 to 700 persons according to the 2006 census geography
20 definition).[22] A vector overlay of postal code locations within the Statistics Canada DA
21 boundary file was performed to capture postal codes not included in the 2006 geographic
22 framework.[23, 24] The DA geolocation of postal codes was then used to classify maternal place
23 of residence at delivery into urban or rural. A DA was considered urban if it had a minimum
24 population concentration of 1,000 persons and a population density of at least 400 persons per
25 square kilometer based on the 2006 Census population count; otherwise, the DA was classified
26 as rural.[22] The Statistics Canada GeoSuite was the standard to identify geographical
27 characteristics of georeferenced data.[25]
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46 **Socioeconomic status gradients**

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48 The 2006 socioeconomic status (SES) index developed by Chan et al.[26] was chosen to
49 represent area-based socioeconomic gradients in the study population. This index is based on
50 area-level information about education attainment, employment status, income, marital status,
51 home ownership, transport mode, and year of home-construction, among other variables taken
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3 from the 2006 national Census. Additionally, the SES index incorporated a measure of
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5 Indigenous status or the human developmental index of the individuals' country of origin as a
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7 proxy for ethnicity; which is a variable that has been linked to perinatal outcomes.[13, 27] The
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9 SES index was ranked in quintiles (Q1 to Q5) at the DA level, where Q1 and Q5 correspond to
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11 the lowest and highest SES, respectively.
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16 17 **Statistical analyses**

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19 We calculated the period prevalence of PTB, SGA, LGA, and related maternal factors in both
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21 urban and rural settings across SES quintiles. We calculated the absolute concentration index[28]
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23 with 95% confidence intervals (95%CI) to measure inequalities in the period prevalence of
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25 adverse birth outcomes and related maternal factors by SES groups in both rural (CIdx_U) and
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27 urban (CIdx_U) settings. Briefly, the concentration index measures inequality in the distribution of
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29 a health variable (i.e., adverse birth outcomes or related maternal factors) over the population
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31 grouped across the SES quintiles.[28, 29] Values of the concentration index range from -1 to +1
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33 where the larger the absolute value of the concentration index, the higher the level of health
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35 inequalities.[11] A value of zero indicates the absence of a socioeconomic gradient in the
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37 distribution of adverse birth outcomes and related factors in the study population. Positive values
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39 indicate a concentration of the health outcome among advantaged groups, while negative values
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41 indicate a concentration of the health outcome among the more disadvantaged ones.[30] Degrees
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43 of inequalities were interpreted based on the absolute value of the concentration index as low (\leq
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45 |0.05|), medium (|0.06 to 0.19|), and high (\geq |0.20|).[31]
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53 We used forest plots to display CIdx_U and CIdx_U values with 95% CI for both adverse birth
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55 outcomes and related maternal factors. If the estimate of the concentration index and its 95%CI
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3 cross zero (no inequality), all SES groups have the same distribution of the health outcome and
4 no socioeconomic gradient exists. If concentration index and 95% CI values are to the left of the
5 no inequality line, a socioeconomic gradient exist with lower SES groups having a higher
6 concentration of the outcomes. If values are to the right of the no inequality line, the outcome is
7 concentrated in higher SES groups. All statistical analyses were performed using STATA
8 version 15.1 (STATA Corp., College Station, TX, USA).
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19 RESULTS

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21 A total of 349,762 births occurred in Alberta between 2006 and 2012, of which 334,894 were
22 singleton live births with gestational age >22 of completed weeks. A total of 330,957 deliveries
23 were included in the analyses after geographic classification (**Figure 1**), of which 292,357 were
24 births from women living in urban settings, and 38,600 from those living in rural areas at time of
25 delivery.
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35 Prevalence of adverse birth outcomes and related maternal factors in urban and rural 36 settings 37

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39 **Table 1** shows the prevalence of adverse birth outcomes and maternal factors by SES groups in
40 rural and urban areas. The PTB prevalence was similar in both rural and urban settings (6.8%);
41 with small differences across SES quintiles and reductions as the SES increased. The prevalence
42 of SGA was consistently higher in urban areas (9.2%; 95% CI 9.1, 9.3 versus 6.8%; 95% CI 6.5,
43 7.0). Urban prevalence of SGA decreased with higher SES while rural SGA prevalence increased
44 with higher SES. LGA prevalence was higher in rural areas (12.7%; 95% CI 12.3, 13.0) and
45 decreased as the SES increased (Q1: 16.1%; 95% CI 15.3, 16.9; Q5: 10.5%; 95% CI 9.9, 11.2);
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3 while in urban settings, LGA prevalence increased from 8.6% (95% CI 8.3, 8.8) to 10.1% (95%
4 CI 9.8, 10.3) across the SES gradient.
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10 Gestational hypertension was more prevalent in urban (5.3%; 95% CI 5.2, 5.4) versus rural
11 settings (4.7%; 95% CI 4.5, 4.9) with similar distributions across the SES groups in both urban
12 and rural areas of residence. The proportion of women with pre-pregnancy weight >91 kg was
13 higher in rural (11.2%; 95% CI 10.8, 11.5) versus urban areas (9.0%; 95% CI 8.9, 9.1) and both
14 settings had a clear gradient across the SES groups with highest values in the most deprived
15 group. The prevalence of gestational diabetes was higher in urban (5.2%; 95% CI 5.1, 5.3) than
16 in rural settings (3.6%; 95% CI 3.4, 3.8), with larger differences between the lowest and highest
17 SES groups (Q1 7.2%; 95% CI 5.1, 5.3. Q5: 4.1%; 95% CI 4.0, 4.3). In rural settings, gestational
18 diabetes prevalence was particularly high in the most disadvantaged group compared to the other
19 SES groups.
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35 Smoking during pregnancy was higher in rural (24.1%; 95% CI 23.6, 24.5) versus urban (15.2%;
36 95% CI 15.0, 15.3) areas, particularly in the most deprived rural SES group (Q1 45.7%; 95%
37 44.7, 46.8). For both urban and rural areas, there was a SES gradient in the prevalence of
38 smoking in pregnancy with lower SES groups having the higher burden of disease. Substance
39 use during pregnancy was more prevalent in rural areas (5.5%; 95% CI 5.2, 5.7) and showed
40 slight variations in the distribution across SES groups. Urban prevalence of substance use during
41 pregnancy (3.0%; 95% CI 2.9, 3.0) showed a gradient across SES groups, with decreasing
42 numbers as SES increased.
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Table 1. Prevalence of ABO and Maternal Risk Factors by Socio-Economic Quintiles in Urban and Rural Alberta (2006-2012).

Maternal Area of Residence at Delivery		Adverse Birth Outcomes			Maternal Risk Factors				
		PTB	SGA	LGA	Weight > 91kg	Gestational hypertension	Gestational diabetes	Smoking	Substance use
Urban	N	19,924	26,893	27,874	25,987	15,452	15,147	44,004	8,634
	Overall (% [95%CI])	6.8 [6.7, 6.9]	9.2 [9.1, 9.3]	9.5 [9.4, 9.6]	9.0 [8.9, 9.1]	5.3 [5.2, 5.4]	5.2 [5.1, 5.3]	15.2 [15.0, 15.3]	3.0 [2.9, 3.0]
	Q1 (low SES)	7.9 [7.7, 8.2]	11.4 [11.1, 11.7]	8.6 [8.3, 8.8]	9.0 [8.7, 9.3]	5.2 [5.0, 5.4]	7.2 [7.0, 7.5]	20.1 [19.8, 20.5]	4.3 [4.1, 4.4]
	Q2	7.2 [7.0, 7.4]	10 [9.7, 10.2]	9.4 [9.1, 9.6]	9.9 [9.6, 10.1]	5.3 [5.1, 5.5]	5.8 [5.6, 6.0]	19.1 [18.8, 19.5]	3.5 [3.3, 3.6]
	Q3	6.9 [6.7, 7.1]	9.1 [8.9, 9.3]	9.6 [9.3, 9.8]	9.5 [9.3, 9.8]	5.4 [5.2, 5.5]	4.9 [4.7, 5.1]	16.6 [16.3, 16.9]	3.2 [3.1, 3.4]
	Q4	6.5 [6.3, 6.7]	8.8 [8.5, 9.0]	9.7 [9.5, 9.9]	8.8 [8.5, 9.0]	5.5 [5.3, 5.7]	5.0 [4.8, 5.1]	13.4 [13.1, 13.7]	2.5 [2.4, 2.7]
	Q5 (high SES)	6.1 [5.9, 6.3]	7.9 [7.7, 8.1]	10.1 [9.8, 10.3]	8.1 [7.9, 8.2]	5.2 [5.1, 5.4]	4.1 [4.0, 4.3]	10.0 [9.8, 10.2]	2.0 [1.9, 2.1]
Rural	N	2,636	2,616	4,895	4,248	1,790	1,360	9,170	2,112
	Overall (% [95%CI])	6.8 [6.6, 7.1]	6.8 [6.5, 7.0]	12.7 [12.3, 13.0]	11.2 [10.8, 11.5]	4.7 [4.5, 4.9]	3.6 [3.4, 3.8]	24.1 [23.6, 24.5]	5.5 [5.2, 5.7]
	Q1 (low SES)	8.4 [7.8, 8.9]	6.4 [5.9, 7.0]	16.1 [15.3, 16.9]	13.5 [12.8, 14.2]	4.2 [3.8, 4.7]	4.5 [4.1, 5.0]	45.7 [44.7, 46.8]	14.3 [13.6, 15.0]
	Q2	6.1 [5.6, 6.6]	6.1 [5.6, 6.6]	13.0 [12.2, 13.7]	11.4 [10.6, 12.1]	4.7 [4.2, 5.2]	3.1 [2.7, 3.5]	19.1 [18.2, 19.9]	2.9 [2.5, 3.3]
	Q3	6.8 [6.1, 7.4]	7.2 [6.6, 7.9]	11.7 [10.8, 12.5]	10.7 [9.9, 11.5]	4.7 [4.2, 5.3]	3.2 [2.7, 3.7]	20.6 [19.6, 21.7]	3.8 [3.3, 4.3]
	Q4	6.5 [6.0, 7.0]	7.2 [6.6, 7.7]	11.7 [11.1, 12.4]	10.6 [10.0, 11.3]	4.5 [4.1, 4.9]	3.3 [2.9, 3.7]	20.1 [19.2, 20.9]	3.2 [2.8, 3.6]
	Q5 (high SES)	6.3 [5.8, 6.8]	7.0 [6.4, 7.6]	10.5 [9.9, 11.2]	9.4 [8.8, 10.1]	5.4 [4.9, 5.9]	3.5 [3.1, 3.9]	12.7 [12.0, 13.4]	2.2 [1.9, 2.5]

CI = confidence interval; n = number of cases; Q = quintiles; SES = socioeconomic status

Concentration indices by SES groups in urban and rural settings

Figure 2 shows rural ($CIdx_U$) and urban ($CIdx_U$) concentration indexes for adverse birth outcomes and related maternal factors. The majority of adverse birth outcomes and related maternal factors were unequally distributed, and concentrated in the lower SES groups except for SGA (which was concentrated in higher SES groups of rural areas; $CIdx_R$ 0.03; 95% CI 0.01, 0.05), LGA (concentrated in urban higher SES groups; $CIdx_U$ 0.03; 95% CI 0.02, 0.03) and gestational hypertension (concentrated in higher SES groups of rural areas; $CIdx_R$ 0.04; 95% CI 0.01, 0.06). There were no inequalities in the distribution of gestational hypertension by SES groups in urban areas.

The highest degrees of health inequalities across SES groups were found for substance abuse and smoking in rural areas ($CIdx_R$ |0.38| and |0.23|, respectively). Medium inequalities across SES groups were identified for LGA and weight >91kg in rural areas ($CIdx_R$ |0.08| and |0.07|, respectively) and for substance use ($CIdx_U$ |0.15|), smoking ($CIdx_U$ |0.14|), gestational diabetes ($CIdx_U$ |0.10|), and SGA ($CIdx_U$ |0.07|) in urban settings. A low degree of inequalities was identified in the distribution of PTB ($CIdx_R$ |0.05|), SGA ($CIdx_R$ |0.03|), gestational hypertension ($CIdx_R$ |0.04|), and gestational diabetes ($CIdx_R$ |0.04|) across SES in rural settings. LGA ($CIdx_U$ |0.03|), gestational hypertension ($CIdx_U$ |0.01|), and weight >91 kg ($CIdx_U$ |0.03|) also had a low degree of inequalities across SES groups in urban settings.

DISCUSSION

In this cross-sectional population-based study, we used concentration indexes to examine SES gradients for adverse birth outcomes and related maternal behavioural factors in urban and rural

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3 areas of Alberta. The results revealed that adverse birth outcomes and related maternal factors
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5 are unequally distributed across the socioeconomic gradient in the urban-rural divide, with the
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7 majority of them concentrating in lower SES groups. Specifically, the concentration indexes of
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9 PTB and related maternal factors (pre-pregnancy weight > 91 kg, gestational diabetes, smoking
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11 and substance abuse) demonstrated the existence of a gradient of perinatal inequalities in both
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13 urban and rural areas that affected the lowest SES groups. The largest socioeconomic gradient
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15 was observed for smoking and substance use during pregnancy as lower SES groups from rural
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17 areas were affected the most.
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24 Area-level deprivation seems to affect differentially fetal growth and pregnancy length. One of
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26 the potential explanations for these results is that women residing in rural areas are more
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28 vulnerable to neighbourhood deprivation.[32] For example, there is evidence that pregnant
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30 women in the younger groups living in rural areas have the highest odds for adverse pregnancy
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32 outcomes compared to their counterparts living in urban settings.[33] Additionally, lower SES,
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34 more unhealthy maternal behaviours, and more limited access to health care resources and
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36 adequate prenatal care have been described among rural residents compared to those in urban
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38 areas.[17, 34-36] The existence of synergistic deleterious influences of area-level determinants
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40 and individual factors may account for these differences.
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47 To our knowledge, few studies (reported in [40]) have evaluated SES gradients in adverse birth
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49 outcomes and related maternal factors in Canada. One study[40] evaluated socioeconomic
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51 inequality in health across the provinces in Canada over time (1998-2011) suggesting that those
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53 inequalities have widened over time, especially among women. However, in this study Alberta
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3 was merged with Saskatchewan and Manitoba to form the Prairies. A few studies have evaluated
4 the influence of area-level SES on adverse birth outcomes in rural and urban areas using other
5 epidemiological approaches and yielding conflicting results.[32, 37].
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12 We used a well-known and robust method, the concentration index, to compare socioeconomic
13 inequalities in perinatal health in urban and rural areas.[11, 29, 30] Compared to other
14 approaches to the study of health inequalities, the concentration index has some advantages. For
15 example, results are not biased by the sample size of the SES strata in the study population. The
16 graphical display of the concentration index allows a visual representation of the dominance
17 relationships in the distribution of the outcomes across SES strata and between urban and rural
18 groups.
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31 This study described the prevalence of maternal factors related to adverse birth outcomes in
32 Alberta for a singleton birth cohort; thus, generalization of the analysis of concentration indexes
33 to other places or populations is limited. There are other limitations in this study inherent to the
34 cross-sectional nature of the study and the lack of detailed clinical information available in the
35 APHP regarding maternal factors. For example, the variable pre-pregnancy maternal weight > 91
36 kg was used as a proxy for overweight/obesity since information on the exact weight and height
37 is not available in the APHP to calculate body mass index. Another limitation of the study is the
38 reliance on self-reporting of smoking and substance use during pregnancy. Self-reporting is a
39 common problem in population studies[38] as these factors may introduce non-differential bias
40 in the evaluation of the exposures.
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3 Another potential limitation in the study is that the SES measure incorporates area-level census
4 information about income in the calculation. In rural areas, where farming and informal
5 economic sectors are highly prevalent, income may not be precisely estimated and this may
6 introduce some misclassification of the SES in the calculations. Furthermore, no changes in the
7 area-level SES were assumed. Despite this, area-level SES indicators have been used in health
8 research as a good proxy for a missing individual-level measures [41,42], and our analyses were
9 disaggregated by SES quantiles in urban and rural areas separately. This approach allowed the
10 identification of subgroups where special attention is needed in both urban and rural areas.
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24 Studies about socioeconomic gradients in health provide a way to identify gaps that characterize
25 the health (or ill health) of socioeconomic groups,[7] helping health authorities to evaluate the
26 performance of health care systems, policies, and interventions.[39] Our evaluation of
27 inequalities in perinatal health and influential factors across urban and rural areas have important
28 implications. First, improving accessibility and adequate and high-quality prenatal care,
29 especially for the lower SES groups may reduce socioeconomic-related inequalities in maternal
30 and perinatal health in both rural and urban areas. Particularly, the most disadvantaged groups
31 are concentrated in rural areas in terms of their perinatal outcomes. Interventions targeting these
32 rural populations in terms of increasing perinatal health and income can be a cost-effective tool
33 to tackle these health inequalities.
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49 In summary, using a concentration index approach, we identified SES-related inequalities in the
50 distribution of adverse birth outcomes and related maternal factors, with a major impact in rural
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3 areas. Future research is needed on the underlying mechanisms driving the observed different
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5 patterns of socioeconomic inequalities in health distribution across the rural–urban spectrum.
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14 **COMPETING INTERESTS**

15
16
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FIGURE LEGENDS

Figure 1. Study population flow diagram.

Figure 2. Concentration index (CIdx) of adverse birth outcomes and related maternal factors among urban and rural populations in Alberta (2006 – 2012). Horizontal lines indicate 95% confidence interval around the Concentration Index (CIdx). Degrees of inequalities were interpreted based on the absolute value of the concentration index as low ($\leq |0.05|$), medium ($|0.06$ to $0.19|$), and high ($\geq |0.20|$).

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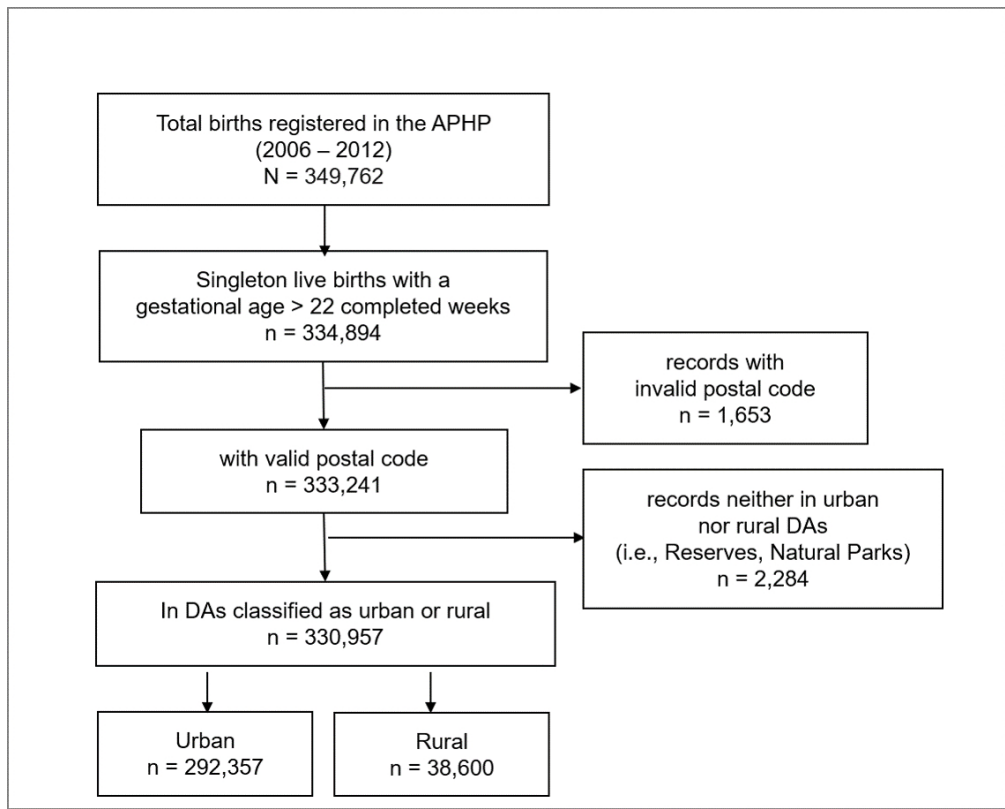


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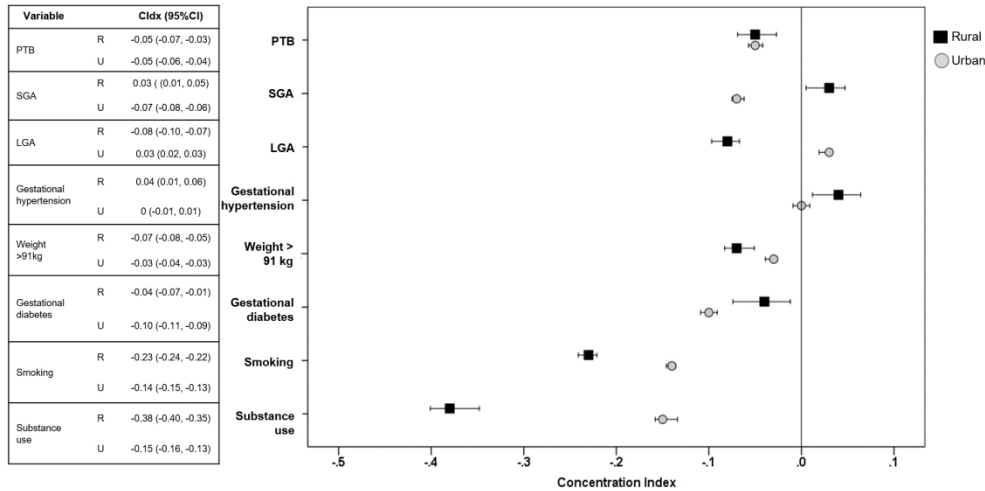


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STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-9
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	Population data
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	9-10
		(b) Describe any methods used to examine subgroups and interactions	
		(c) Explain how missing data were addressed	
		(d) If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	Figure 1
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-11
		(b) Indicate number of participants with missing data for each variable of interest	Table 1

Outcome data	15*	Report numbers of outcome events or summary measures	Table 1
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 1
		(b) Report category boundaries when continuous variables were categorized	
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	13 and Figure 2
Discussion			
Key results	18	Summarise key results with reference to study objectives	13-14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15-16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

BMJ Open

Socioeconomic Gradients of Adverse Birth Outcomes and Related Maternal Factors in Rural and Urban Alberta, Canada: A Concentration Index Approach.

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2
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4 Rural and Urban Alberta, Canada: A Concentration Index Approach
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10 **Authors:** Maria B. Ospina, MSc, PhD;¹ Alvaro Osornio-Vargas, MD, PhD;² Charlene C.
11 Nielsen, PhD;² Susan Crawford, MSc;³ Manoj Kumar, MD, MSc;² Khalid Aziz, MD;² Jesus A.
12 Serrano-Lomelin, PhD¹
13
14
15
16
17
18

19 ¹Department of Obstetrics & Gynecology, Faculty of Medicine & Dentistry; University of
20 Alberta. Edmonton, Alberta (Canada)
21
22
23
24
25

26 ²Department of Pediatrics, Faculty of Medicine & Dentistry; University of Alberta. Edmonton,
27 Alberta (Canada)
28
29
30
31
32

33 ³Alberta Perinatal Health Program, Alberta Health Services. Calgary, Alberta (Canada).
34
35
36
37

38 **Corresponding Author**

39 Jesus Serrano-Lomelin, PhD

40 Department of Obstetrics & Gynecology, University of Alberta.

41 220A Heritage Medical Research Centre

42 11313 87 Ave NW, Edmonton, AB, Canada. T6G 2S2

43 Ph: (780) 735-8732; F: (780) 735-4981

44 [45 jaserran@ualberta.ca](mailto:jaserran@ualberta.ca)

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3 **Keywords:** health inequalities; concentration index; adverse birth outcomes; perinatal risk
4 factors; social medicine.
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10 **Contributors' Statement**

11
12 Maria B. Ospina participated in investigation, conceptualization/design, methodology, drafted
13 the initial manuscript, and approved the final version of the manuscript.
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15

16
17 Alvaro Osornio-Vargas participated in funding acquisition, resources, conceptualization/design,
18 supervision, critically review/edit the manuscript, and approved the final version of the
19 manuscript.
20
21

22
23
24 Charlene C. Nielsen, participated in conceptualization/design, methodology, geographic analysis,
25 and approved the final version of the manuscript.
26
27

28
29 Susan Crawford participated in conceptualization/design, resources (health data provider),
30 critically review/edit the manuscript, and approved the final version of the manuscript.
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34
35 Manoj Kumar participated in funding acquisition, conceptualization/design, supervision,
36 critically review/edit the manuscript, and approved the final version of the manuscript.
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38

39
40 Khalid Aziz participated in funding acquisition, conceptualization/design, supervision, critically
41 review/edit the manuscript, and approved the final version of the manuscript.
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45 Jesus Serrano-Lomelin participated in funding acquisition, conceptualization/design, database
46 management, statistical analysis, critically review/edit the manuscript, and approved the final
47 version of the manuscript.
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ABSTRACT

Objective: Using a summary measure of health inequalities, this study evaluated the distribution of adverse birth outcomes (ABO) and related maternal risk factors across area-level socioeconomic status (SES) gradients in urban and rural Alberta, Canada.

Design: Cross-sectional study using a validated perinatal clinical registry and an area-level SES.

Setting: The study was conducted in Alberta (Canada). Data about ABO and related maternal risk factors were obtained from the Alberta Perinatal Health Program (APHP) between 2006 to 2012. An area-level SES index derived from census data (2006) was linked to the postal code at delivery.

Participants: Women (n=330,957) having singleton live births with gestational age ≥ 22 weeks.

Primary and secondary outcome measures: We estimated concentration indexes to assess inequalities across SES gradients in both rural and urban areas (CIdx_R and CIdx_U, respectively) for spontaneous preterm birth (PTB), small for gestational age (SGA), large for gestational age (LGA), gestational hypertension, gestational diabetes, smoking and/or substance use during pregnancy, and pre-pregnancy weight > 91 kg.

Results: The highest health inequalities disfavoring low SES groups were identified for substance abuse and smoking in rural areas (CIdx_R -0.38 and -0.23, respectively). Medium inequalities were identified for LGA (CIdx_R -0.08), weight >91 kg (CIdx_R -0.07), substance use (CIdx_U -0.15), smoking (CIdx_U -0.14), gestational diabetes (CIdx_U -0.10), and SGA (CIdx_U -0.07). Low inequalities were identified for PTB (CIdx_R -0.05; CIdx_U -0.05) and gestational diabetes (CIdx_R -0.04). Inequalities disfavoring high SES groups were identified for gestational hypertension (CIdx_R +0.04), SGA (CIdx_R +0.03), and LGA (CIdx_U +0.03).

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3 **Conclusions:** Adverse birth outcomes and related maternal risk factors were unequally
4 distributed across the socioeconomic gradient in urban-rural settings, with the greatest
5 concentrations in lower SES groups of rural areas. Future research is needed on underlying
6 mechanisms driving SES gradients in perinatal health across the rural/urban spectrum.
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14 **Strengths and limitations of this study**

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18 • This population-based study used a high-quality clinical perinatal registry to quantify
19 health inequalities for adverse birth outcomes and related risk factors across
20 socioeconomic groups in rural and urban Alberta (Canada); a province with universal and
21 free access to medically necessary hospital and physician services for its inhabitants.
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- 27 • We used a well-known and robust method, the concentration index, to compare
28 socioeconomic inequalities in perinatal health in urban and rural areas.
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- 32 • The area-level socioeconomic status (SES) index used for this study is based on the 2006
33 census data. Potential misclassification of the SES may occur as we are assuming no
34 changes in area-level SES index between 2006 and 2012.
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- 38 • Substance abuse and smoking prevalence are expected to be underestimated since they
39 are self-reported.
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INTRODUCTION

Adverse birth outcomes such as preterm birth (PTB), small for gestational age (SGA), and large for gestational age (LGA) are major drivers of morbidity and mortality in neonates and infants and important contributors to long-term physical and psychological health.[1-3] Many of the determinants of adverse birth outcomes start in pregnancy and even before conception. Maternal factors implicated with the occurrence of adverse outcomes at birth include pre-pregnancy overweight, maternal health problems during pregnancy (e.g., gestational hypertension and diabetes), and certain behaviours such as smoking and substance use.[1, 4] All these perinatal exposures and outcomes constitutes the “canary in the coal mine” as fundamental early-life indicators of the impact of social and structural determinants of health operating in a very sensitive period of human life.[5] Health inequalities at birth would then represent a magnifying glass of preconception disadvantages, and a forecast for adult inequalities.[6]

Socioeconomic inequalities in health are quantitative differences in the occurrence of health outcomes across socioeconomic groups,[7] and a topic of great interest in social epidemiology to better understand the structural causes of health and disease.[8, 9] Recent systematic reviews have examined the influences of socioeconomic characteristics on the risk of adverse birth outcomes, suggesting a strong link between area-level socioeconomic status (SES) gradients and a variety of adverse birth outcomes.[10-13] Knowledge gaps remain to fully understand the interconnections between socioeconomic characteristics, area of residence, and maternal and perinatal health. Exploring this association is particularly important as both urban and rural living have been also associated with adverse health outcomes.[14] However, it is unknown whether health advantages and disadvantages of living in urban and rural areas are equally

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3 distributed in all socioeconomic groups or if gradients in health exist affecting the more
4 disadvantaged groups. On the one hand, diverse theories about urban residence posit that cities
5 create harmful environments for human health.[15-17] Alternatively, rural areas encompassing
6 vast extensions of land have been also associated with poor outcomes.[18] Despite the growing
7 interest in recent years about the role of spatial[19] and socioeconomic-driven inequalities[9] in
8 the distribution of adverse birth outcomes and associated maternal factors, studies in this area
9 have mainly evaluated urban populations. Few studies[14, 20] have examined the relationship
10 between adverse birth outcomes and neighborhood deprivation in rural versus urban
11 communities, a relevant health policy issue in countries where the access to health services is
12 universal. The study of socioeconomic health inequalities have been traditionally based on
13 population-at-risk approaches, which have underpinned the socioeconomic gradient as a risk
14 factor for poor health.[21, 22] The majority of these studies have used analytical approaches
15 based on measures of association (i.e., regression and Pearson coefficients), and measures of
16 potential impact (i.e., proportion attributable proportions[23]) while other methods based on
17 summary measures of health inequality have been seldom explored.[23]

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40 Using the health concentration index approach, this study quantified health inequalities in the
41 distribution of PTB, SGA, LGA, and related known maternal factors (i.e., pre-pregnancy weight
42 >91 kg, gestational hypertension, gestational diabetes, self-reported smoking and/or substance
43 use during pregnancy) in urban and rural Alberta (Canada) across a socioeconomic gradient.
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49 Like all other Canadian provinces, Alberta has a universal, publicly funded health care system
50 that guarantees Albertans receive free access to medically necessary hospital and physician
51 services. The concentration index quantifies the magnitude of perinatal health inequalities across
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3 different populations while taking into account both the distribution of the study population
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5 across the different socioeconomic groups. We hypothesize that adverse birth outcomes in urban
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7 and rural areas are distributed differently and potentially related to socioeconomic gradients
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9 within the two areas of residence.
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14 **METHODS**

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17 This study is part of a broader environmental health research that explored associations between
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19 environmental and social factors with adverse birth outcomes.[24] The study received ethics
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21 approval from the University of Alberta Research Ethics Board in Edmonton, Alberta (Canada).
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26 **Study design and population**

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28 We conducted a cross-sectional population-based study using provincial health data from Alberta
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30 (Canada) for the period of January 1, 2006, to December 31, 2012. Alberta is a culturally diverse
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32 province located in Western Canada with a population of 4,067,175 inhabitants in 2016 with
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34 approximately 83% living in urban centers.[25]
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40 The study population consisted of all women having singleton live births with gestational age \geq
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42 22 completed weeks during the study period. We used data from the Alberta Perinatal Health
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44 Program (APHP), which is a validated clinical perinatal registry that collects data directly from
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46 the provincial delivery record for all births occurring in a hospital or attended by a registered
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48 midwife at home in Alberta. Delivery characteristics and newborn health status recorded in the
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50 APHP include birth weight, gestational age at delivery in completed weeks, maternal postal code
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52 of residence at delivery, lifestyle behaviours before and during pregnancy, maternal health status,
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54 obstetric interventions and neonatal outcomes.
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Adverse birth outcomes

Preterm birth (PTB) was defined as newborn with less than 37 completed weeks of gestational age. Newborns were identified as SGA (birth weight below the 10th percentile) and LGA (birth weight above the 90th percentile) according to Canadian sex-age specific, population-based standards.[26]

Maternal factors related with PTB, SGA and LGA

Information on the following maternal factors was extracted from the APHP: age at delivery, pre-pregnancy weight >91 kg, gestational hypertension, gestational diabetes (documented hyperglycemia with diagnosis during current pregnancy only), self-reported smoking (anytime during pregnancy) and/or substance use during pregnancy (three drinks or more on any occasion during pregnancy or one or more alcohol drinks per day while pregnant, and/or drug dependency, inappropriate or excessive use of any substance).

Definitions of urban and rural maternal place of residence at delivery

We used the 2006 geographic standards provided by Statistics Canada to classify areas of residence (urban, rural) and georeferenced data for postal code locations.[27] The six-character postal codes of the maternal place of residence at delivery were classified as rural or urban according to population concentration and density, based on the 2006 geographic framework. First, postal codes were assigned to their corresponding dissemination area (DA: a census geographic area larger than postal codes with a population of 400 to 700 persons according to the 2006 census geography definition).[28] A vector overlay of postal code locations within the Statistics Canada DA boundary file was performed to capture postal codes not included in the

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3 2006 geographic framework.[29] The DA geolocation of postal codes was then used to classify
4 maternal place of residence at delivery into urban or rural. A DA was considered urban if it had a
5 minimum population concentration of 1,000 persons and a population density of at least 400
6 persons per square kilometer based on the 2006 Census population count; otherwise, the DA was
7 classified as rural.[28]
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14 15 16 17 **Socioeconomic status gradients**

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19 The 2006 socioeconomic status (SES) index developed by Chan et al[30] was chosen to
20 represent area-based socioeconomic gradients in the study population. This index is based on
21 area-level information about education attainment, employment status, income, marital status,
22 home ownership, transport mode, and year of home-construction, among other variables taken
23 from the 2006 national Census. Additionally, the SES index incorporated a measure of
24 Indigenous status or the human developmental index of the individuals' country of origin as a
25 proxy for ethnicity; which is a variable that has been linked to perinatal outcomes.[11, 31] The
26 SES index was ranked in quintiles (Q1 to Q5) at the DA level, where Q1 and Q5 correspond to
27 the lowest and highest SES, respectively.
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42 **Statistical analyses**

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44 We calculated the period prevalence of PTB, SGA, LGA, and related maternal factors in both
45 urban and rural settings across SES quintiles. We calculated the absolute concentration index[23]
46 with 95% confidence intervals (95%CI) to measure inequalities in the period prevalence of
47 adverse birth outcomes and related maternal factors by SES groups in both rural (CId_{x_R}) and
48 urban (CId_{x_U}) settings. Briefly, the concentration index measures inequality in the distribution of
49 a health variable (i.e., adverse birth outcomes or related maternal factors) over the population
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3 grouped across the SES quintiles.[23, 32] Values of the concentration index range from -1 to +1
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5 where the larger the absolute value of the concentration index, the higher the level of health
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7 inequalities.[22] A value of zero indicates the absence of a socioeconomic gradient in the
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9 distribution of adverse birth outcomes and related factors in the study population. Positive values
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11 indicate a concentration of the health outcome among advantaged groups, while negative values
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13 indicate a concentration of the health outcome among the more disadvantaged ones.[33] Degrees
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15 of inequalities were interpreted based on the absolute value of the concentration index as low (\leq
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17 $|0.05|$), medium ($|0.06$ to $0.19|$), and high ($\geq |0.20|$).[34]
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24 We used forest plots to display $CIdx_R$ and $CIdx_U$ values with 95% CI for both adverse birth
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26 outcomes and related maternal factors. If the estimate of the concentration index and its 95%CI
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28 cross zero (no inequality), all SES groups have the same distribution of the health outcome and
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30 no socioeconomic gradient exists. If concentration index and 95% CI values are to the left of the
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32 no inequality line, a socioeconomic gradient exist with lower SES groups having a higher
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34 concentration of the outcomes. If values are to the right of the no inequality line, the outcome is
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36 concentrated in higher SES groups. All statistical analyses were performed using Stata version
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38 15.1 (StataCorp., College Station, TX, USA).
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44 **Patient or public involvement**

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46 No patient involved.
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51 **RESULTS**

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53 A total of 349,762 births occurred in Alberta between 2006 and 2012, of which 334,894 were
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55 singleton live births with gestational age >22 of completed weeks. A total of 330,957 deliveries
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3 were included in the analyses after geographic classification (**Figure 1**), of which 292,357 were
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5 births from women living in urban settings, and 38,600 from those living in rural areas at time of
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7 delivery. Small numbers of missing values were present for maternal weight, gestational
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9 hypertension, gestational diabetes, and smoking during pregnancy in the urban (0.81%; n =
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11 2,667) and rural areas (1.3%; n = 497). There were no missing values for PTB, SGA, and LGA
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13 categories in both urban and rural areas.
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19 **Prevalence of adverse birth outcomes and related maternal factors in urban and rural** 20 **settings**

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22 **Table 1** and **Figures 2** and **3** show the prevalence of adverse birth outcomes and maternal factors
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24 by SES groups in rural and urban areas. The overall PTB prevalence was similar in both rural
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26 and urban settings (6.8%); with small differences across SES quintiles and reductions as the SES
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28 and urban settings (6.8%); with small differences across SES quintiles and reductions as the SES
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30 increased in urban areas. The prevalence of SGA was consistently higher in urban areas (9.2%
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32 [95% CI 9.1, 9.3] versus 6.8% [95% CI 6.5, 7.0]). Urban prevalence of SGA decreased with
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34 higher SES while rural SGA prevalence increased with higher SES. LGA prevalence was higher
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36 in rural areas (12.7% [95% CI 12.3, 13.0]) and decreased as the SES increased (Q1: 16.1% [95%
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38 CI 15.3, 16.9]; Q5: 10.5% [95% CI 9.9, 11.2]); while in urban settings, LGA prevalence
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40 increased from 8.6% (95% CI 8.3, 8.8) to 10.1% (95% CI 9.8, 10.3) across the SES gradient.
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47 Gestational hypertension was more prevalent in urban (5.3% [95% CI 5.2, 5.4]) versus rural
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49 settings (4.7% [95% CI 4.5, 4.9]) with similar distributions across the SES groups in both urban
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51 and rural areas of residence. The proportion of women with pre-pregnancy weight >91 kg was
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53 higher in rural (11.2% [95% CI 10.8, 11.5]) versus urban areas (9.0% [95% CI 8.9, 9.1]) and
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3 both settings had a clear gradient across the SES groups with highest values in the most deprived
4 group. The prevalence of gestational diabetes was higher in urban (5.2% [95% CI 5.1, 5.3]) than
5 in rural settings (3.6% [95% CI 3.4, 3.8]), with larger differences between the lowest and highest
6 SES groups (Q1 7.2% [95% CI 5.1, 5.3]; Q5: 4.1% [95% CI 4.0, 4.3]). In rural settings,
7 gestational diabetes prevalence was particularly high in the most disadvantaged group compared
8 to the other SES groups.
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19 Smoking during pregnancy was higher in rural (24.1% [95% CI 23.6, 24.5]) versus urban (15.2%
20 [95% CI 15.0, 15.3]) areas, particularly in the most deprived rural SES group (Q1 45.7% [95%
21 44.7, 46.8]). For both urban and rural areas, there was a SES gradient in the prevalence of
22 smoking in pregnancy with lower SES groups having the higher burden of disease. Substance
23 use during pregnancy was more prevalent in rural areas (5.5% [95% CI 5.2, 5.7]) and showed
24 slight variations in the distribution across SES groups. Urban prevalence of substance use during
25 pregnancy (3.0% [95% CI 2.9, 3.0]) showed a gradient across SES groups, with decreasing
26 numbers as SES increased.
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Table 1. Prevalence of ABO and Maternal Risk Factors by Socio-Economic Quintiles in Urban and Rural Alberta (2006-2012).

Maternal Area of Residence at Delivery		Adverse Birth Outcomes			Maternal Risk Factors				
		PTB	SGA	LGA	Weight > 91kg	Gestational hypertension	Gestational diabetes	Smoking	Substance use
Urban	N	19,924	26,893	27,874	25,987	15,452	15,147	44,004	8,634
	Overall (% [95%CI])	6.8 [6.7, 6.9]	9.2 [9.1, 9.3]	9.5 [9.4, 9.6]	9.0 [8.9, 9.1]	5.3 [5.2, 5.4]	5.2 [5.1, 5.3]	15.2 [15.0, 15.3]	3.0 [2.9, 3.0]
	Q1 (low SES)	7.9 [7.7, 8.2]	11.4 [11.1, 11.7]	8.6 [8.3, 8.8]	9.0 [8.7, 9.3]	5.2 [5.0, 5.4]	7.2 [7.0, 7.5]	20.1 [19.8, 20.5]	4.3 [4.1, 4.4]
	Q2	7.2 [7.0, 7.4]	10 [9.7, 10.2]	9.4 [9.1, 9.6]	9.9 [9.6, 10.1]	5.3 [5.1, 5.5]	5.8 [5.6, 6.0]	19.1 [18.8, 19.5]	3.5 [3.3, 3.6]
	Q3	6.9 [6.7, 7.1]	9.1 [8.9, 9.3]	9.6 [9.3, 9.8]	9.5 [9.3, 9.8]	5.4 [5.2, 5.5]	4.9 [4.7, 5.1]	16.6 [16.3, 16.9]	3.2 [3.1, 3.4]
	Q4	6.5 [6.3, 6.7]	8.8 [8.5, 9.0]	9.7 [9.5, 9.9]	8.8 [8.5, 9.0]	5.5 [5.3, 5.7]	5.0 [4.8, 5.1]	13.4 [13.1, 13.7]	2.5 [2.4, 2.7]
	Q5 (high SES)	6.1 [5.9, 6.3]	7.9 [7.7, 8.1]	10.1 [9.8, 10.3]	8.1 [7.9, 8.2]	5.2 [5.1, 5.4]	4.1 [4.0, 4.3]	10.0 [9.8, 10.2]	2.0 [1.9, 2.1]
Rural	N	2,636	2,616	4,895	4,248	1,790	1,360	9,170	2,112
	Overall (% [95%CI])	6.8 [6.6, 7.1]	6.8 [6.5, 7.0]	12.7 [12.3, 13.0]	11.2 [10.8, 11.5]	4.7 [4.5, 4.9]	3.6 [3.4, 3.8]	24.1 [23.6, 24.5]	5.5 [5.2, 5.7]
	Q1 (low SES)	8.4 [7.8, 8.9]	6.4 [5.9, 7.0]	16.1 [15.3, 16.9]	13.5 [12.8, 14.2]	4.2 [3.8, 4.7]	4.5 [4.1, 5.0]	45.7 [44.7, 46.8]	14.3 [13.6, 15.0]
	Q2	6.1 [5.6, 6.6]	6.1 [5.6, 6.6]	13.0 [12.2, 13.7]	11.4 [10.6, 12.1]	4.7 [4.2, 5.2]	3.1 [2.7, 3.5]	19.1 [18.2, 19.9]	2.9 [2.5, 3.3]
	Q3	6.8 [6.1, 7.4]	7.2 [6.6, 7.9]	11.7 [10.8, 12.5]	10.7 [9.9, 11.5]	4.7 [4.2, 5.3]	3.2 [2.7, 3.7]	20.6 [19.6, 21.7]	3.8 [3.3, 4.3]
	Q4	6.5 [6.0, 7.0]	7.2 [6.6, 7.7]	11.7 [11.1, 12.4]	10.6 [10.0, 11.3]	4.5 [4.1, 4.9]	3.3 [2.9, 3.7]	20.1 [19.2, 20.9]	3.2 [2.8, 3.6]
	Q5 (high SES)	6.3 [5.8, 6.8]	7.0 [6.4, 7.6]	10.5 [9.9, 11.2]	9.4 [8.8, 10.1]	5.4 [4.9, 5.9]	3.5 [3.1, 3.9]	12.7 [12.0, 13.4]	2.2 [1.9, 2.5]

CI = confidence interval; n = number of cases; Q = quintiles; SES = socioeconomic status

Concentration indices by SES groups in urban and rural settings

Figure 4 shows rural (CI_{dxR}) and urban (CI_{dxU}) concentration indexes for adverse birth outcomes and related maternal factors. The majority of adverse birth outcomes and related maternal factors were unequally distributed, and concentrated in the lower SES groups except for SGA (which was concentrated in higher SES groups of rural areas; CI_{dxR} 0.03 [95% CI 0.01, 0.05]), LGA (concentrated in urban higher SES groups; CI_{dxU} 0.03 [95% CI 0.02, 0.03]) and gestational hypertension (concentrated in higher SES groups of rural areas; CI_{dxR} 0.04 [95% CI 0.01, 0.06]). There were no inequalities in the distribution of gestational hypertension by SES groups in urban areas.

The highest degrees of health inequalities across SES groups were found for substance abuse and smoking in rural areas (CI_{dxR} |0.38| and |0.23|, respectively). Medium inequalities across SES groups were identified for LGA and weight >91kg in rural areas (CI_{dxR} |0.08| and |0.07|, respectively) and for substance use (CI_{dxU} |0.15|), smoking (CI_{dxU} |0.14|), gestational diabetes (CI_{dxU} |0.10|), and SGA (CI_{dxU} |0.07|) in urban settings. A low degree of inequalities was identified in the distribution of PTB (CI_{dxR} |0.05|), SGA (CI_{dxR} |0.03|), gestational hypertension (CI_{dxR} |0.04|), and gestational diabetes (CI_{dxR} |0.04|) across SES in rural settings. LGA (CI_{dxU} |0.03|), gestational hypertension (CI_{dxU} |0.01|), and weight >91 kg (CI_{dxU} |0.03|) also had a low degree of inequalities across SES groups in urban settings.

DISCUSSION

In this cross-sectional population-based study, we used concentration indexes to examine SES gradients for adverse birth outcomes and related maternal behavioural factors in urban and rural

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3 areas of Alberta. The results revealed that adverse birth outcomes and related maternal factors
4 are unequally distributed across the socioeconomic gradient in the urban-rural divide, with the
5 majority of them concentrating in lower SES groups. Specifically, the concentration indexes of
6 PTB and related maternal factors (pre-pregnancy weight > 91 kg, gestational diabetes, smoking
7 and substance abuse) demonstrated the existence of a gradient of perinatal inequalities in both
8 urban and rural areas that affected the lowest SES groups. The largest socioeconomic gradient
9 was observed for smoking and substance use during pregnancy as lower SES groups from rural
10 areas were affected the most.
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24 The pathways for the associations among area-level deprivation, maternal health, and adverse
25 birth outcomes are complex and likely multifactorial. We found that area-level deprivation and
26 geographic area of residence differentially associate with fetal growth and duration of gestation.
27 One potential explanation for these results is that women residing in rural areas are more
28 vulnerable to neighbourhood deprivation.[35] For example, there is evidence that pregnant
29 women in the younger groups living in rural areas have the highest odds for adverse pregnancy
30 outcomes compared to their counterparts living in urban settings.[36] Additionally, lower SES,
31 more unhealthy maternal behaviours, and more limited access to health care resources and
32 adequate prenatal care have been described among rural residents compared to those in urban
33 areas.[18, 37-39] The existence of synergistic deleterious influences of area-level determinants
34 and individual factors may account for these differences. Other potential explanations may be
35 linked to low health literacy in rural populations about the effects of lifestyle behaviours in
36 childbearing age and the impact on birth outcomes, and shortages in resources to stay better
37 informed than women living in more urbanized areas.[40] Systemic and structural influences
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3 such as food security, health services access may also account for the socioeconomic gradient in
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5 the urban-rural divide. Lastly, the “healthy migration” effect[41] can contribute to our study
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7 results. It is possible that healthy women living in rural and remote areas are most likely to
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9 migrate to more urbanized areas, leaving behind their counterparts at a higher risk of
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11 experiencing adverse birth outcomes.
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17 To our knowledge, few studies have evaluated SES gradients in adverse birth outcomes and
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19 related maternal factors in Canada. One study[42] evaluated socioeconomic inequality in health
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21 across the provinces in Canada over time (1998-2011) suggesting that those inequalities have
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23 widened over time, especially among women. However, in this study Alberta was merged with
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25 Saskatchewan and Manitoba to form the Prairies. A few studies have evaluated the influence of
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27 area-level SES on adverse birth outcomes in rural and urban areas using other epidemiological
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29 approaches and yielding conflicting results.[35, 43]
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34 35 **Strengths and limitations of the study**

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37 We used a well-known and robust method, the concentration index, to compare socioeconomic
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39 inequalities in perinatal health in urban and rural areas.[22, 32, 33] Compared to other
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41 approaches to the study of health inequalities, the concentration index has some advantages. For
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43 example, results are not biased by the sample size of the SES strata in the study population. The
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45 graphical display of the concentration index allows a visual representation of the dominance
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47 relationships in the distribution of the outcomes across SES strata and between urban and rural
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49 groups.
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5 Our study had some limitations that should be considered when interpreting the results. This
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7 study described the prevalence of maternal factors related to adverse birth outcomes in Alberta
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9 for a singleton birth cohort; thus, generalization of the analysis of concentration indexes to other
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11 places or populations is limited. There are other limitations in this study inherent to the cross-
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13 sectional nature of the study and the lack of detailed clinical information available in the APHP
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15 regarding maternal factors. For example, the variable pre-pregnancy maternal weight > 91 kg
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17 was used as a proxy for overweight/obesity since information on the exact weight and height is
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19 not available in the APHP to calculate body mass index. Another limitation of the study is the
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21 reliance on self-reporting of smoking and substance use during pregnancy. Self-reporting is a
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23 common problem in population studies[44] as these factors may introduce non-differential bias
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25 in the evaluation of the exposures.
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33 Another potential limitation in the study is that the SES measure incorporates area-level census
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35 information about income in the calculation. In rural areas, where farming and informal
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37 economic sectors are highly prevalent, income may not be precisely estimated and this may
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39 introduce some misclassification of the SES in the calculations. Despite this, area-level SES
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41 indicators have been used in health research as a good proxy for individual-level measures,[45,
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43 46] and our analyses were disaggregated by SES quantiles in urban and rural areas separately.
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45 This approach allowed the identification of subgroups where special attention is needed in both
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47 urban and rural areas. Area-level measures of SES gradients are important to describe
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49 inequalities in health outcomes across populations.[47, 48] There is evidence that these aggregate
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51 measures are good proxies for individual deprivation, have similar performance than individual-
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3 level SES measures, and represent a low risk of ecological bias.[49] Furthermore, we did not use
4 area-level data to impute individual values in the study cohort but rather used individual maternal
5 postal codes to assign cohort members to a dissemination area that shared particular features
6 from a census perspective. Since both the exposure (maternal postal code) and outcome were
7 measured at the individual level, the risk of ecologic fallacy is likely low.[47]
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16 We used area-level data from the 2006 Canadian census for the calculation of the socioeconomic
17 status (SES) index. The method assumed no changes in area-level deprivation between 2006 and
18 2012 and therefore, potential misclassification of the SES may occur. Other studies using area-
19 level deprivation measures have attempted to quantify changes in SES categories over time and
20 have assumed that SES remains relatively stable over time[30, 46], and that census-based
21 measures of deprivation can be used in larger comparative studies across decades without loss of
22 continuity over time.[50, 51]
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35 There is concern that area-based SES indexes are likely sensitive to urban-rural differences and
36 that variables that capture deprivation and SES in cities may not perform well in rural areas.
37 Despite these conceptual constraints, there is evidence from other studies showing that available
38 deprivation indexes can be used legitimately used in both settings, supporting the hypothesis that
39 the underlying relationship between areal-level SES and health gradients is the same in rural and
40 urban areas.[35, 52, 53]
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51 **Future perspectives**

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3 Studies about socioeconomic gradients in health provide a way to identify gaps that characterize
4 the health (or ill health) of socioeconomic groups,[7] helping health authorities to evaluate the
5 performance of health care systems, policies, and interventions.[54] Our evaluation of
6 inequalities in perinatal health and influential factors across urban and rural areas have important
7 implications. First, improving accessibility and adequate and high-quality prenatal care,
8 especially for the lower SES groups may reduce socioeconomic-related inequalities in maternal
9 and perinatal health in both rural and urban areas. Particularly, the most disadvantaged groups
10 are concentrated in rural areas in terms of their perinatal outcomes. Interventions targeting these
11 rural populations in terms of increasing perinatal health and income can be a cost-effective tool
12 to tackle these health inequalities.
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28 **Conclusion**

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30 In summary, using a concentration index approach, we identified SES-related inequalities in the
31 distribution of adverse birth outcomes and related maternal factors, with a major impact in rural
32 areas. Future research is needed on the underlying mechanisms driving the observed different
33 patterns of socioeconomic inequalities in health distribution across the rural–urban spectrum.
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44 None.

45 **COMPETING INTERESTS**

46
47 None.

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10 Children's Health Research Institute. The study sponsors had no role in the design and conduct
11 of the study; in the collection, management, analysis and interpretation of data; and in the
12 preparation, review, or approval of the manuscript.
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28 **DATA AVAILABILITY STATEMENT**

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30 The custodian of the data is the provincial program called Alberta Perinatal Health Program.
31 After they review our research protocol, we obtained anonymized data exclusively for this work
32 without authorization to share them or to do secondary analysis. Births and maternal data are
33 available upon formal request to the Alberta Perinatal Health Program.
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35 The data related to the SES index is available from Policy Wise (<http://www.policywise.com>).
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FIGURE LEGENDS

Figure 1. Study population flow diagram.

Figure 2. Period prevalence (with 95% confidence interval) of preterm birth (PTB), small for gestational age (SGA), large for gestational age (LGA), and gestational hypertension (GH) across SES quintiles in urban and rural settings.

Footnote: The linear gradient for the prevalence by health outcome across the SES quintiles was tested using regression analysis. The p-value for the linear gradient was incorporated into the graph when it was statistically significant ($p < 0.05$). Note that the y-axis scaling (%) differ among the different panels.

Figure 3. Period prevalence (with 95% confidence interval) of maternal weight > 91 kg, gestational diabetes (GD), smoking, and substance use during pregnancy across SES quintiles in urban and rural settings.

Footnote: The linear gradient for the prevalence by health outcome across the SES quintiles was tested using regression analysis. The p-value for the linear gradient was incorporated into the graph when it was statistically significant ($p < 0.05$). Note that the y-axis scaling (%) differ among the different panels.

Figure 4. Concentration index (CIdx) of adverse birth outcomes and related maternal factors among urban and rural populations in Alberta (2006 – 2012). Horizontal lines indicate 95%

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3 confidence interval around the Concentration Index (CIdx). Degrees of inequalities were
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5 interpreted based on the absolute value of the concentration index as low ($\leq |0.05|$), medium
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7 ($|0.06$ to $0.19|$), and high ($\geq |0.20|$).
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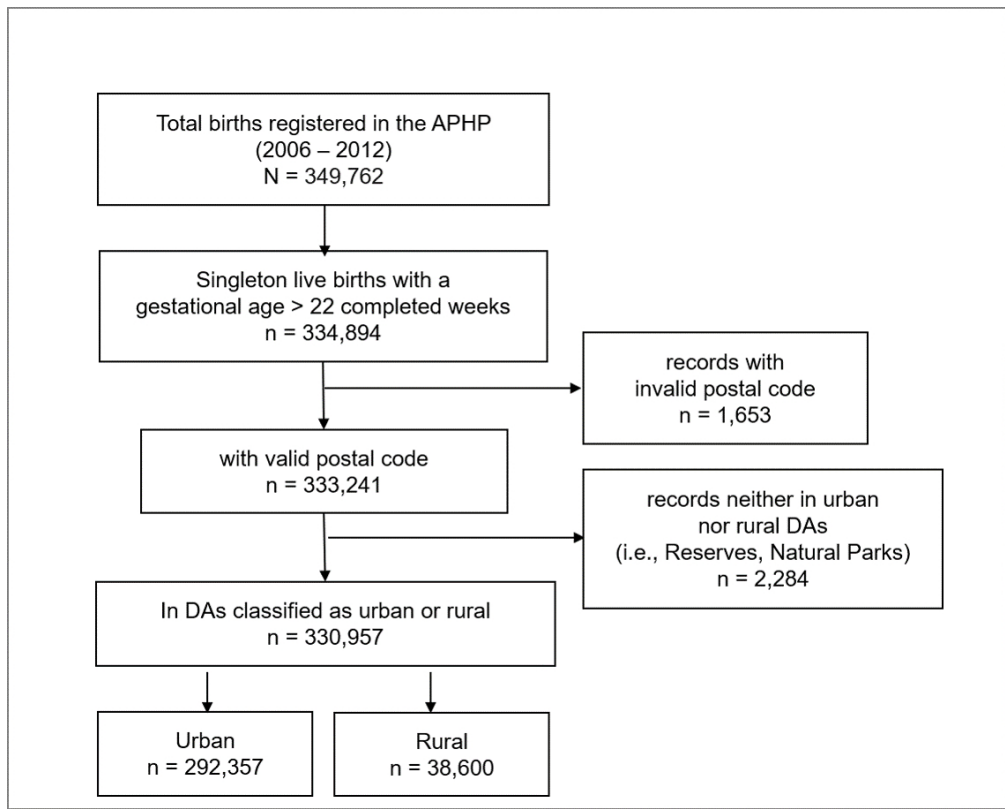


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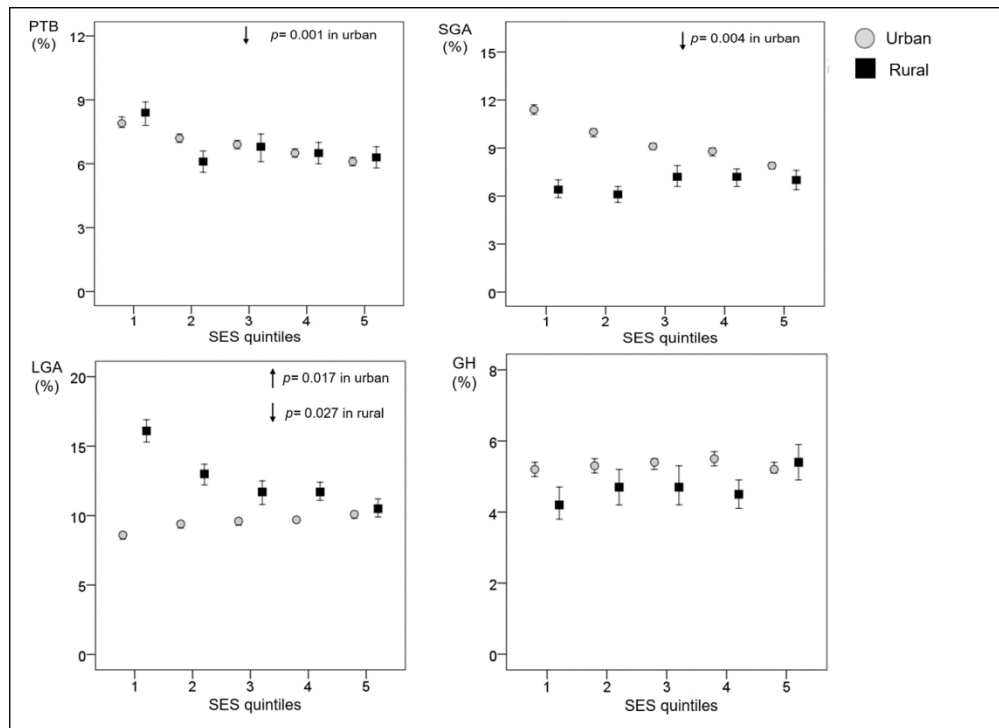


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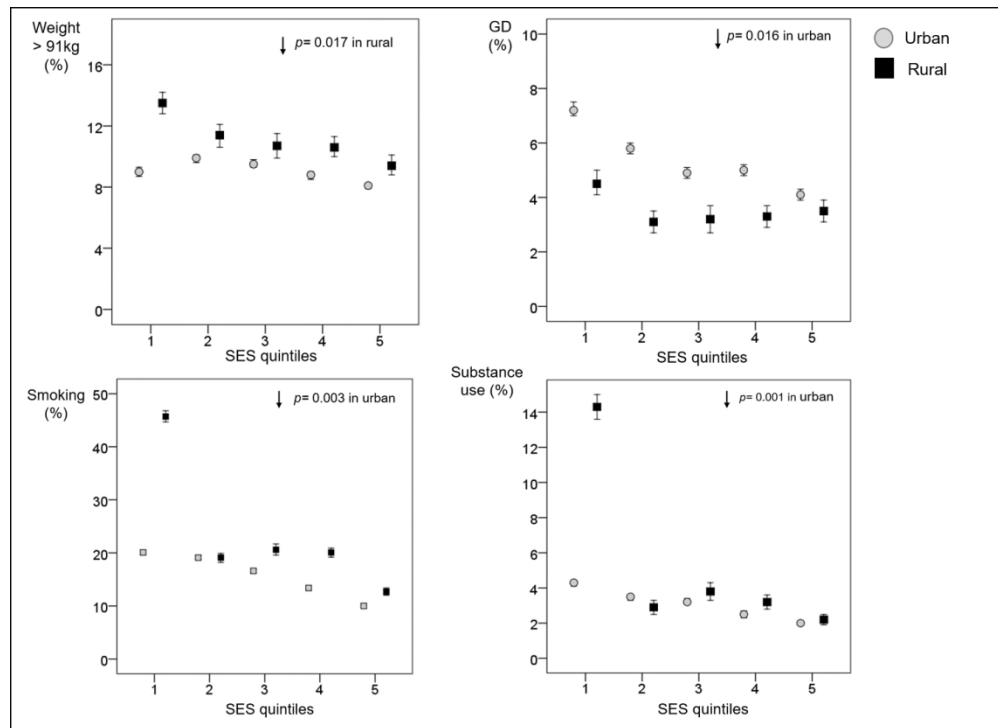


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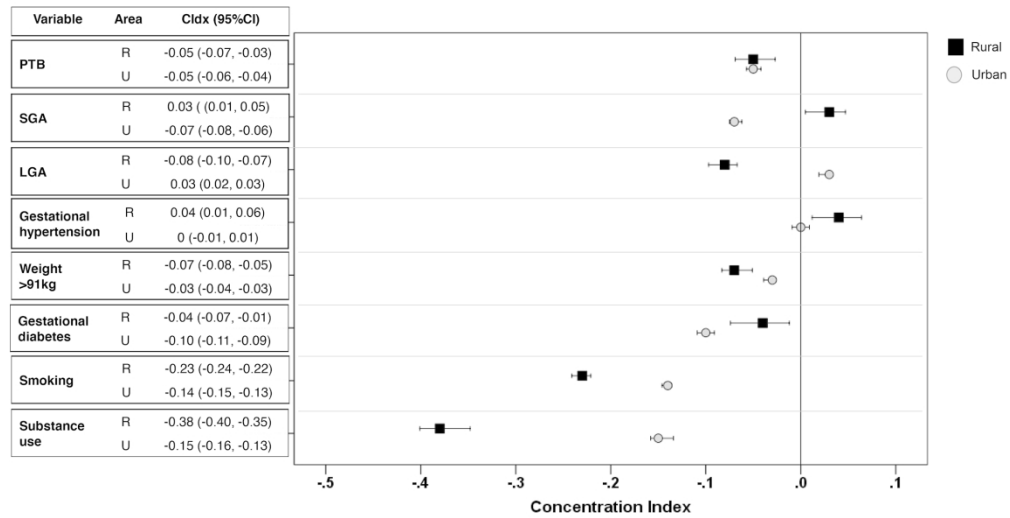


Figure 4. Concentration index (Cidx) of adverse birth outcomes and related maternal factors among urban and rural populations in Alberta (2006 – 2012). Horizontal lines indicate 95% confidence interval around the Concentration Index (Cidx). Degrees of inequalities were interpreted based on the absolute value of the concentration index as low ($\leq |0.05|$), medium ($|0.06$ to $0.19|$), and high ($\geq |0.20|$).

198x103mm (300 x 300 DPI)

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6-7
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	7, 10 Patient Involvement Statement
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-9
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	Population data
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	9-10
		(b) Describe any methods used to examine subgroups and interactions	
		(c) Explain how missing data were addressed	
		(d) If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	Figure 1
		(c) Consider use of a flow diagram	Figure 1

Descriptive data	14	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-11
		(b) Indicate number of participants with missing data for each variable of interest	Table 1
Outcome data	15*	Report numbers of outcome events or summary measures	Table 1
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 1. Figures 2 and 3
		(b) Report category boundaries when continuous variables were categorized	
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	14 and Figure 4
Discussion			
Key results	18	Summarise key results with reference to study objectives	14-15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16-17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-18
Generalisability	21	Discuss the generalisability (external validity) of the study results	17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19-20