

**THE ASSOCIATION OF PRETERM BIRTH WITH
AREA-LEVEL DEPRIVATION AND INDIVIDUAL-LEVEL
FACTORS IN THE VANCOUVER CENSUS
METROPOLITAN AREA**

by

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ABSTRACT

Evidence suggests area-level socioeconomic inequalities in adverse birth outcomes including preterm birth (PTB), one of the most important causes of perinatal mortality and morbidity throughout the life-course. This study analyzed inequality in PTB in live, singleton births in the Vancouver Census Metropolitan Area from 2006 to 2009 by area-level deprivation measures, and assessed the degree to which individual-level variables might indicate pathways through which area-level disparities manifest. Area-level material, but not social, deprivation was associated with higher odds of PTB. The relative odds of PTB by area-level material deprivation and known individual-level risk factors were modelled using hierarchical logistic regression. After adjusting for individual-level factors, the inequality in PTB by material deprivation was attenuated but not eliminated. Individual-level risk factors may, in part, be pathways through which this association manifests. However, future research and discussion should consider the potential interactions between individuals, environments and policies, and their possible effects on perinatal health.

Keywords: preterm birth; inequality; area-level factors; socioeconomic factors; material deprivation; individual-level factors; Vancouver Census Metropolitan Area

*Dedicated to Paron Wyatt,
for his love and support.*

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1: INTRODUCTION

Preterm birth (PTB) has been identified as the most important cause of perinatal mortality in North America and Europe (Berkowitz & Papiernik, 1993) and a key determinant of morbidity; seventy percent of neonatal mortality and 75% of neonatal morbidity in wealthy countries is attributed to PTB (Challis et al., 2001 as cited in Wen, Smith, Yang, & Walker, 2004). Some health issues have life-long consequences. The brain and lungs are particularly vulnerable at early stages of development thus PTB can cause higher rates of neurological and other health problems. Preterm infants have higher reported rates of respiratory distress, temperature instability, seizures, cerebral palsy, feeding difficulties and re-hospitalizations than babies born at full term, and in childhood have increased difficulty with motor skills, behaviour and foundational educational skills (Saigal & Doyle, 2008).

PTB is defined as being born at fewer than 37 weeks' gestation. PTB varies from 5 to 13% of all births in industrialized countries (Goldenberg, 2002; Joseph et al., 1998) and research suggests these rates have been increasing since the 1980s (Goldenberg, Culhane, Iams, & Romero, 2008; Goldenberg & Rouse, 1998; Joseph et al., 1998). The rise has been coupled with, and partially attributable to: medical advances that have improved the survival of preterm infants compared to those in decades past, such as increased obstetric intervention (Joseph et al., 1998; Slattery & Morrison, 2002); assisted

reproduction and multiple births (Joseph et al., 1998; Slattery & Morrison, 2002; Goldenberg et al., 2008); improved technology for estimating gestational age (ultrasound) (Joseph et al., 1998); increased substance use in urban areas and other reasons often attributed to poor socioeconomic circumstances (Slattery & Morrison, 2002). Despite clinical efforts and financial investments to reduce PTB, rates are still rising (Andrews, Hauth & Goldenberg, 2000).

It is common for researchers to use area-level socioeconomic measures as predictors of health outcomes (Shaw et al., 2007 as cited in CIHI, 2008). Deprivation refers to the relative disadvantage of persons or groups of people in relation to those around them, and can be divided into material and social components (Townsend, 1987). Material deprivation refers to lack of access to tangible goods and amenities, such as food and housing, and social deprivation denotes lack of “ordinary” relationships (Townsend, 1987, p.127) or poor integration into the community (Townsend, 1987; Shaw et al., 2007 as cited in CIHI, 2008).

A recent report by the Canadian Institute for Health Information (CIHI) measured the cross-sectional association between census dissemination-area (DA) level deprivation and health outcomes including low birth weight (LBW) (CIHI, 2008). Deprivation was measured using an index developed by the Institut National de Santé Publique du Québec (INSPQ). The INSPQ index uses census information to measure DA-level material and social deprivation and combines the two deprivation scores to classify areas as high, average or low socioeconomic status (SES), henceforth referred to as overall socioeconomic

deprivation (Pampalon & Raymond, 2000). CIHI identified that women who lived in areas of high overall socioeconomic deprivation more often had LBW babies than women living in areas of low overall socioeconomic deprivation. The prevalence of LBW in the Vancouver Census Metropolitan Area (CMA) ranged from 4.9 to 6.1 per 100 live births for those living in the areas with the lowest to highest overall socioeconomic deprivation respectively (CIHI, 2008). Since the overall socioeconomic deprivation measure included both material and social deprivation, it is not clear whether one of those two components contributed more greatly to the LBW gradient. We wanted to explore the INSPQ index more closely to elucidate whether there were particular area-level deprivation factors that were more predictive of poor birth outcomes, and that could become priority targets of public health interventions. This paper focuses specifically on PTB and its relationship to the components of the INSPQ deprivation index.

Numerous studies have found that gradients in PTB exist by social class and area-level measures of deprivation, and that individual-level risk factors have failed to fully account for such findings (DeFranco, Lian, Muglia, & Schootman, 2008; O'Campo et al., 2008; Luo et al., 2004; Luo, Wilkins, & Kramer, 2006; Culhane & Elo, 2005; CIHI, 2009). A cross-sectional study in Missouri, USA found that women living in counties with high poverty (measured as the percentage of the population below the American federal poverty line) more often experienced PTB than women in areas of less poverty, after adjusting for individual-level maternal age, maternal race, parental education, residence within city limits, birth sequence, marital status, medical conditions, indicators of low

income status (e.g. receipt of Medicaid or food stamps), prenatal care and risky behaviours such as smoking and alcohol use (DeFranco et al., 2008). O'Campo et al. (2008) found that PTB rates were elevated among both non-Hispanic White and non-Hispanic Black women across eight regions of four American states in areas of high neighbourhood deprivation (based on eight variables representing the socioeconomic domains of income/poverty, education, employment, housing and occupation), and that adjusting for maternal age and education only slightly attenuated the association. Canadian studies have found similar results. A Québec study found inequalities in PTB by neighbourhood income and maternal education after adjusting for infant sex, parity, plurality and maternal ethnicity, age, education and marital status. The authors concluded, however, that maternal education had a stronger and independent effect to neighbourhood income (Luo et al., 2006). Another Québec study found the odds of PTB increased with decreasing area income and immigrant density. Adjusting for maternal age, education, civil status, birth place, previous births and infant sex attenuated the association, but it remained significant. That study also examined foreign-born and Canadian born women separately. Cross-sectional odds of PTB were higher in areas of low immigrant density and in the lowest income areas for Canadian-born mothers, while foreign-born mothers had higher odds of PTB in areas of high immigrant density, before and after adjustment (Auger, Giraud, & Daniel, 2009). A study in the Canadian province of British Columbia, where the present analysis was conducted, found inequality in PTB by neighbourhood income in urban areas after adjusting for infant sex, parity,

plurality, ethnicity, maternal age, marital status, abortion history, mode of delivery, maternal illness, community size and distance to the nearest hospital with obstetricians (Luo et al., 2004). A Canadian study of four provinces and three territories found that, after adjusting for multiple births, pre-existing and gestational hypertension and diabetes, previous PTB, parity, caesarean-section, induction, maternal age, infant sex, and province/territory of residence, there were still PTB inequalities by DA-level income (CIHI, 2009).

Similar results have been found outside of North America in other wealthy countries. A study of over 7000 singleton very PTBs (VPTBs, defined as <32 weeks' gestation) in the Trent health region of the United Kingdom found that incidence of VPTB between 1994 and 2003 increased with deprivation from 8.5 VPTBs per 1000 births in the least deprived areas to 16.4 VPTBs per 1000 births in the most deprived areas, after adjusting for changes in socioeconomic differences over time. Deprivation was based on the percentage of children younger than 16 years in each area living in low income families. The analysis did not adjust for any individual-level factors (Smith, Draper, Manktelow, Dorling & Field, 2007). Conversely, a study in Amsterdam, The Netherlands found that cross-sectional rates of PTB increased with decreasing neighbourhood income after adjustment for maternal age and parity, but that the relationship became statistically insignificant after maternal education, ethnicity, smoking status and body mass index (BMI) were added to the multilevel logistic regression model (Agyemang et al., 2009).

Our study differed from previous work by examining the effects of neighbourhood deprivation on the Vancouver CMA population using the Canadian-developed INSPQ deprivation index. We built on the information presented by CIHI (2008) by exploring the material and social components and sub-components of the INSPQ index, and by focusing our analyses on inequalities in PTB, which is one potential contributor to LBW rates. The present study considered a number of individual-level risk-factors for PTB that have been identified in previous research: maternal infection (Berkowitz & Papiernik, 1993; Goldenberg et al., 2008; DeFranco et al., 2008), polyhydramnios (DeFranco et al., 2008), oligohydramnios (DeFranco et al., 2008), placental conditions (Berkowitz & Papiernik, 1993; Goldenberg et al., 2008; CIHI, 2009), anaemia (Luo et al., 2004), BMI (Agyemang et al., 2009), parity (Agyemang et al., 2009; Luo et al., 2006; Luo et al., 2004; CIHI, 2009), smoking during pregnancy (DeFranco et al., 2008; Agyemang et al., 2009), hypertension and diabetes (DeFranco et al., 2008; Luo et al., 2004; CIHI, 2009), age (DeFranco et al., 2008; Agyemang et al., 2009; O'Campo et al., 2008; Luo et al., 2006; Luo et al., 2004; Auger et al., 2009; CIHI, 2009) and infant sex (Luo et al., 2006; Luo et al., 2004; Auger et al., 2009; CIHI, 2009). We also had access to more recent data, from 2006 to 2009, than the previously mentioned studies. By comparison, Luo et al.'s (2004) study of births in British Columbia ranged from 1985 to 2000. This paper offers various potential explanations for PTB inequalities considering individual and distal factors, and discusses the potential difficulty in separating the two.

The goals of public and population health are not only to reduce PTB rates overall, but also to eliminate disparities in PTB rates between subgroups within populations, such as those of differing SES (Kindig, 2007). The two main objectives of our study were to build on previous research to 1) determine the best area-level indicator of PTB in the Vancouver CMA, based on the INSPQ index, and 2) investigate the extent to which known individual-level risk factors might be pathways through which the area-level association might manifest. We further explain some of the inherent difficulties associated with this methodological approach. We investigated the associations between PTB and DA-level overall socioeconomic deprivation, social and material deprivation, and their sub-components using chi-square tests. Material deprivation was most strongly associated with PTB. To investigate whether known individual-level risk factors might elucidate pathways through which PTB inequality by material deprivation manifests (and would therefore attenuate the association between PTB and the area-level measure), we added available individual-level covariates to a hierarchical logistic regression model of material deprivation and PTB.

2: METHODS

2.1 Data

This cross-sectional study analyzed pregnancy characteristics and birth outcomes of live, singleton births in the Vancouver CMA that occurred between January 1st, 2006 and September 17th, 2009 inclusive. The date range was selected because 1) we used data from the 2006 census, which corresponded to the January 1st, 2006 start date and 2) September 17th, 2009 was the latest date for which complete birth data were available from hospitals. Multiple births and stillbirths were not included in the dataset.

We received our data from the British Columbia Perinatal Database Registry. The Registry provides epidemiologic and clinical data on approximately 99% of births in the province based on forms completed in physician and midwife offices and at delivery locations (BC Vital Statistics Agency et al., 2007; British Columbia Reproductive Care Program, 2003). It has built-in validation rules and data quality checks are performed regularly (BC Vital Statistics Agency et al., 2007). The Registry data were linked to DA-level census data and the INSPQ index using the residential postal code of the mother at the time of delivery, as recorded on the birth record. If the postal code of a participant covered more than one DA, one of the included DAs was randomly selected and assigned. The probabilities of selection were weighted proportionally to the percentage of the population within that postal code who lived in each DA (Pampalon & Raymond,

2000). To protect mother/baby anonymity, postal codes and identifying information were removed before we received the dataset. Our study protocols were approved by the research ethics boards of Simon Fraser University and the University of British Columbia - Children's and Women's Health Centre of British Columbia.

2.2 Variables

A major impetus for our research was a study that found an association between LBW and overall socioeconomic deprivation across Canada (CIHI, 2008). CIHI (2008) reviewed four deprivation indices frequently used in Canada for health research – Frohlich and Mustard, 1996; Broadway and Jetsy, 1998; Pampalon and Raymond, 2000 (INSPQ); and Matheson, Moineddin and Glazier, 2008 – and selected the INSPQ index (Pampalon & Raymond, 2000) for their study on health outcomes. They chose the INSPQ index because of its incorporation of both material and social factors, and its level of geographic measurement: the INSPQ index links census data to Statistics Canada DAs, the smallest unit of the four Canadian indices (CIHI, 2008; Pampalon & Raymond, 2000; Pampalon, Hamel, Gamache, & Raymond, 2009). A DA is comprised of one or more neighbouring blocks of houses and a total population of 400 to 700 people (Statistics Canada, 2010).

The INSPQ index is based on two components, material and social deprivation, as described previously (Pampalon et al., 2009; Pampalon & Raymond, 2000). To summarize, INSPQ selected potential indicators based on four criteria: their established links to health, associations with material or social

deprivation, availability by DA-level and “previous use as geographic proxies” (Pampalon et al., 2009, p.179). INSPQ performed a principle component analysis to construct the material and social deprivation indices and divided areas into quintiles of each measure. Quintile 1 represents DAs with the least deprivation and quintile 5 represents DAs with the most deprivation. Material deprivation is composed of the DA-level average income, percentage of persons with no high school diploma, and employment to population ratio. Social deprivation encompasses the DA-level percentage of persons living alone; percentage separated, widowed or divorced; and percentage of single parent families (Pampalon et al., 2009; Pampalon & Raymond, 2000). In their study, CIHI (2008) defined high overall socioeconomic deprivation areas as those in one of the two most deprived quintiles of both social and material deprivation, low overall socioeconomic deprivation areas as those in one of the two least deprived quintiles of both material and social deprivation, and average overall socioeconomic deprivation as all areas that did not meet either the high or low criteria. In our study, we used the same definitions of overall socioeconomic deprivation, material and social deprivation at the DA-level.

We situated our research within the field by completing a systematic literature review in Medline using a combination of keywords and subject terms such as: obstetric labour, birth, infant, premature, preterm, residence characteristics, neighbourhood, socioeconomic factors, deprivation and disadvantage. We limited our search to articles published in the year 2000 and later. The search returned 136 articles. We did not review articles specific to

less-wealthy countries or those that focused primarily on race/ethnicity because our study examined the overall Vancouver CMA population and we did not have complete sample data on race and/or ethnicity. During the research process, we expanded our literature background by reviewing articles referenced in other papers and conducting other keyword searches as we found necessary.

We used literature to identify individual-level risk factors for PTB. Hypertension and diabetes (CIHI, 2009; Berkowitz & Papiernik, 1998; Meis et al., 1998; Goldenberg et al., 2008; DeFranco et al., 2008; Luo et al., 2004) were modelled together in four categories: neither condition, hypertension only, diabetes only, and both conditions. The hypertension category was comprised of mothers recorded as having had any of the following conditions: blood pressure measurements $\geq 140/90$ mmHg in at least two consecutive readings during pregnancy, pregnancy-induced hypertension, or hypertension due to any cause other than renal disease. The diabetic variable included only women with pre-existing or gestational diabetes. Women were coded dichotomously for whether or not they smoked during pregnancy (Berkowitz & Papiernik, 1993; Goldenberg et al., 2008; CIHI, 2009; DeFranco et al., 2008; Agyemang et al., 2009). A study of the British Columbia Perinatal Database Registry, in which original clinical records were compared to data coded in the database, found that non-smokers were often entered into the database with blank information for this variable. Recoding those with missing data as non-smokers resulted in 75% specificity and 98% sensitivity for the smoking status variable (MacIntyre et al., 2006). We therefore coded the 61% of women for whom smoking status was missing as

non-smokers. Former smokers were also defined as non-smokers. Women recorded as smoking during any or all of their pregnancy were analyzed as smokers. We grouped BMI (Goldenberg et al., 2008; Agyemang et al., 2009) into four categories: underweight ($<18.5 \text{ kg/m}^2$), normal weight ($\geq 18.5 \text{ kg/m}^2$ and $<25 \text{ kg/m}^2$), overweight ($\geq 25 \text{ kg/m}^2$ and $<30 \text{ kg/m}^2$) and obese ($\geq 30 \text{ kg/m}^2$). Maternal age (Goldenberg et al., 2008; Berkowitz & Papiernik, 1993; CIHI, 2009; DeFranco et al., 2008; Agyemang et al., 2009; O'Campo et al., 2008; Luo et al., 2006; Luo et al., 2004; Auger et al., 2009) was analyzed in three categories: <20 years, 20 to 35 years and >35 years. Parity (Agyemang et al., 2009; Luo et al., 2006; Luo et al., 2004; CIHI, 2009) was a binary variable defined as either nulliparous, or one or more previous pregnancies carried to 500g birth weight or 20 weeks' gestation, regardless of outcome. We coded infant sex (Berkowitz & Papiernik, 1993; CIHI, 2009; Luo et al., 2006; Luo et al., 2004; Auger et al., 2009) as male or female. ICD-10 codes were combined to create dichotomous variables that encompassed related complications for the following categories: infection (ICD-10 codes O23001, O23101, O23301, O23401, O23501, O23901, O41121, O41131, O41139, O41191, O98101, O98201, O98301, O98302, O98801, O98802, O98901, P359, P360, P361, P362, P363, P364, P368, P369, P027, P028) (Berkowitz & Papiernik, 1993; Goldenberg et al., 2008; DeFranco et al., 2008), polyhydramnios (ICD-10 codes O40021, O40031, O40091) (Goldenberg et al., 2008; DeFranco et al., 2008), oligohydramnios (ICD-10 codes O41021, O41031, P012, P013) (Goldenberg et al., 2008; DeFranco et al., 2008), placental conditions (ICD-10 codes O43001, O43101, O43201, O43881,

O43901, O44001, O44101, O44103, O45801, O45901, P020, P021, P022) (Berkowitz & Papiernik, 1993; Goldenberg et al., 2008; CIHI, 2009) and anaemia (ICD-10 codes O99001, O99002, O99004) (Scholl, 2005; Scholl, Hediger, Fischer, & Shearer, 1992; Luo et al., 2004). Since the Registry only recorded information for women who had ICD-10 coded conditions and hypertension, we coded those without data as not having these conditions.

The original sample consisted of 82,720 birth records. We dichotomously coded each birth for PTB, defined as <37 weeks' gestation. Babies born at a gestational age of less than 22 weeks (255 births) were excluded so we could compare our sample to a Canadian standard of mean birth weights for sex and gestational age that covers 22 to 43 weeks' gestation (Kramer et al., 2001). The remaining births ranged from 22 to 43 weeks inclusive. To eliminate unlikely birth weights for gestational age (likely due to miscoding of gestational age), we excluded outlier birth weights of greater than four standard deviations from the Canadian mean (120 births) (Kramer et al., 2001), as done in previous studies (Wen et al., 2003). This left 82,345 births records. We only included individuals in our study with complete data for all covariates used in the final model. We excluded women missing BMI (21,559) and DA-level deprivation (1707), leaving 59,039 mother-infant pairs in our study sample (71% response rate).

2.3 Statistical Methods

Unless otherwise indicated, associations were considered significant at 2-sided $\alpha=0.05$. To test for potential selection bias, we compared women included and excluded from the study using chi-square tests. To find the best

area-level predictor of PTB based on the INSPQ index, we used chi-square tests to examine the relationship between PTB and overall socioeconomic deprivation, material and social deprivation. While social deprivation was not associated with PTB, material deprivation was strongly associated with the birth outcome. We constructed figures to show the percentage of PTB in the Vancouver CMA, and the percentage of all PTBs in the Vancouver CMA, by material deprivation quintile. As a sub-analysis, we tested for inequalities in PTB by the sub-components of material deprivation (described earlier) using chi-square tests in case the composite measure was masking underlying relationships.

A hierarchical logistic regression model using SAS PROC GLIMMIX, a random intercept for the DA-level and an unstructured covariance structure was developed to estimate the unadjusted odds ratios (ORs) for PTB in each quintile of material deprivation, using the lowest deprivation quintile as the reference. To investigate whether known individual-level risk factors might be pathways through which the association between material deprivation and PTB manifests, we added available individual-level covariates to that model and compared the adjusted to unadjusted ORs. We included covariates in our hierarchical logistic regression model associated with PTB in chi-square tests at 2-sided $\alpha=0.20$, and used backwards stepwise elimination as required until all variables were associated with PTB in the model at 2-sided $\alpha=0.05$. All analyses were performed using SAS 9.2 (SAS Inc., Cary, NC).

3: RESULTS

There were 59,039 live, singleton births in the Vancouver CMA within the study timeframe that met our selection criteria (71% of total). Of these, 4377 (7.4%) were preterm. Compared to women excluded from the study, those included differed slightly in levels of material deprivation, placental conditions, anaemia, BMI, parity, smoking during pregnancy, presence of hypertension and/or diabetes and maternal age. The prevalence of most characteristics differed by <1%. However, women included in the study were slightly less likely to be over 35 years of age (26.2% vs. 30.9%, $p<0.0001$), more likely to be overweight or obese (19.5% vs. 15.9% and 9.7% vs. 7.5% respectively, $p<0.0001$) and more likely to be nulliparous (50.0% vs. 43.5%, $p<0.0001$) than those excluded. PTB prevalence was 1% lower among women included in the study (7.4% vs. 8.4%, $p<0.0001$) (data not shown).

Table 1 displays the prevalence of PTB and DA-level overall socioeconomic deprivation (defined using a combination of material and social deprivation, as described previously), material deprivation and social deprivation separately and examines their bivariate associations with PTB. PTB inequality by overall socioeconomic deprivation was observable, but the association was not statistically significant ($p=0.0959$). When DA-level material and social deprivation were modelled individually, there was a monotonic association with

PTB for material deprivation (6.7% in quintile 1 to 7.9% in quintile 5, $p=0.0073$), but there was no association for social deprivation ($p=0.7598$).

We conducted a sub-analysis on the sub-components of material deprivation. There were generally monotonic associations of higher PTB prevalence with both decreasing DA-level average income ($p=0.0006$) and decreasing percent with a high school education ($p=0.0007$). The association between percent employed and PTB was neither monotonic nor statistically significant ($p=0.15$) (data not shown). Since two of the three sub-components of material deprivation were strongly associated with PTB, we determined that material deprivation as a whole was the best area-level predictor of PTB and consequently included it in our regression model.

Figure 1 shows graphically the monotonic association between higher area-level material deprivation (by quintile) and higher PTB prevalence, as described in Table 1. Figure 2 shows the relative percent of all PTBs that occurred in different quintiles of material deprivation. There was a monotonic association between higher deprivation and higher percent of all PTBs occurring in each quintile of material deprivation.

Table 2 shows the bivariate associations between PTB status and all variables considered for regression modelling. There was a modest dose-response relationship between material deprivation and PTB. Relative to term births, PTBs more often occurred in the top two quintiles of material deprivation and less often in the bottom three quintiles ($p=0.0073$). Compared with mothers of term births, mothers of preterm babies had more infections during pregnancy

($p < 0.0001$), more often smoked during pregnancy ($p < 0.0001$) and were more often diagnosed with diabetes, hypertension or both conditions ($p < 0.0001$). Mothers of preterm babies were less often of a normal weight (as defined by BMI) ($p < 0.0001$) or aged 20 to 34 years at time of delivery ($p < 0.0001$). Preterm infants were more often male ($p < 0.0001$).

The final hierarchical logistic regression model initially included all variables shown in Table 2 since each was significantly associated with PTB in bivariate analyses at 2-sided $\alpha = 0.20$, which was our a priori criterion for initial inclusion in the model. All of the variables remained in the model because they were significantly associated with PTB at 2-sided $\alpha = 0.05$. Table 3 displays the unadjusted and adjusted ORs of the associations between quintiles of DA-level material deprivation and PTB. In the unadjusted model, the odds of PTB increased with increasing material deprivation relative to the least deprived quintile. Those in the two quintiles with the most material deprivation had 1.2 times (95% CI=1.1-1.3) the odds of PTB than those in the least deprived quintile. The inequality in PTB by DA-level material deprivation was attenuated when individual-level risk factors were added to the model; however, a modest association remained after adjustment relative to the least deprived quintile. Mothers in the two quintiles with the most material deprivation had 1.1 times (95% CI=1.0-1.3) the odds of PTB compared to those in the least deprived quintile after adjustment. Conditions of the placenta increased the odds of PTB by 7.2 times (95% CI=6.3-8.1) and smoking by 1.6 times (95% CI=1.4-1.8). Having diabetes, hypertension or both conditions relative to neither condition also

increased the odds of PTB (OR (95% CI) =1.4 (1.3-1.5), 3.0 (2.7-3.3), and 4.8 (3.9-5.8), respectively). Relative to those with normal weight, those who were underweight (OR (95% CI) =1.3 (1.2-1.5)), overweight (1.1 (1.0-1.2)) or obese (1.2 (1.0-1.3)) had higher odds of PTB, however the association with overweight was not statistically significant at 2-sided alpha=0.05. Oligohydramnios (OR (95% CI) =3.2 (2.8-3.7)) and polyhydramnios (2.0 (1.4-2.8)) both increased the odds of PTB. The relative odds of PTB were modestly elevated with other variables as well including male baby (OR (95% CI) =1.2 (1.1-1.3)), maternal age >35 years (1.1 (1.0-1.2)), parity ≥ 1 (1.1 (1.0-1.2)) and anaemia (1.2 (1.1-1.4)).

4: DISCUSSION

Our study found that material deprivation was the best area-level predictor of PTB among the socioeconomic measures examined. The inequality in PTB was observable as the prevalence of PTB and DA-level material deprivation increased in tandem. Individual-level factors found to be associated with PTB in previous studies were also risk factors in our study population. When we added individual-level covariates to a hierarchical logistic regression model, the inequality in PTB by material deprivation was attenuated but remained. These findings are consistent with previous research documenting area-level socioeconomic inequalities in birth outcomes (DeFranco et al., 2008; Slattery & Morrison, 2002; Berkowitz & Papiernik, 1993; Goldenberg et al., 2008; O'Campo et al., 2008; Luo et al., 2004; Luo et al., 2006). Other Canadian studies found that neighbourhood income and high school completion were predictive of PTB risk (both of which are components of our measure of material deprivation); however, the study examining high school completion used individual- rather than area-level education (Luo et al., 2004; Luo et al., 2006). Conversely, Agyemang et al. (2009) found that, in Amsterdam, inequality in PTB by neighbourhood income did not persist after adjustment for individual-level factors. Their study adjusted for ethnicity (defined by country of origin) and individual-level education, which ours did not, and used two independent components of

area-level deprivation (neighbourhood unemployment/social security benefit and income), rather than a composite deprivation measure.

Our study used individual-level factors previously shown to be associated with PTB that were not present in other Canadian studies (Urquia, Frank, Moineddin, & Glazier, 2010; Luo et al., 2004; Luo et al., 2006; Auger, Luo, Platt & Daniel, 2008a; Auger et al., 2009), including BMI (Goldenberg et al., 2008; Agyemang et al., 2009), smoking during pregnancy (Berkowitz & Papiernik, 1993; Goldenberg et al., 2008; CIHI, 2009; DeFranco et al., 2008; Agyemang et al., 2009) and maternal conditions such as infection (Berkowitz & Papiernik, 1993; Goldenberg et al., 2008; DeFranco et al., 2008).

Our study was unique in its use of INSPQ-defined material deprivation as an area-level measure to predict PTB. Many studies use single indicators to represent and explore the effects of neighbourhood socioeconomic disadvantage (Luo et al., 2004; Luo et al., 2006; Agyemang et al., 2009; DeFranco et al., 2008; Smith et al., 2007). An analysis of the development of neighbourhood deprivation indices using principal component analysis found that indicators of deprivation – including occupation, education and income – associated with perinatal health tend to be strongly correlated due to their interconnected nature (Messer et al., 2006). Researchers contend that the correlation between these predictors warrants the use of an index that encompasses multiple aspects of deprivation, and that such an index is more robust against issues associated with single indicators (Messer et al., 2006). A study examining an index specific to PTB across eight cities and counties in the USA found that indices combining

education, employment, occupation and poverty indicators are robust and useful for predicting PTB (Messer et al., 2008). The INSPQ index incorporates three of these four domains.

The use of secondary data may be considered a limitation of our study. We used census data to define area-level deprivation. Census data are based on self-reports and interpretation of questions may vary by individual. Our results were also influenced by the timescale of our study. Researchers have speculated that historic or multi-generational phenomena might influence birth outcomes (Hennessy & Alberman, 1998; Emanuel, Alberman, & Evans, 1992; Porter, Fraser, Hunter, Ward, & Varner, 1997), that exposures may accumulate throughout one's life (Singh-Manoux, Ferrie, Chandola, & Marmot, 2004) and that there may be critical exposure times during development that impact individual health as well as future offspring (Camacho, 2008). It may not be adequate therefore to investigate only those potential causes of PTB (regardless of whether at individual or area levels) that are observable at the time of pregnancy and birth. An example of this is the well-known phenomenon that recent immigrants to some countries tend to have better health outcomes than those in the new country, but over time and generations their health status deteriorates to match that of the new country (Chen, Ng & Wilkins, 1996; Stephen, Foote, Hendershot, & Schoenborn, 1994). A mother's exposures during childhood, throughout her lifecourse or during her own development in utero may have greater or additional effects on the birth outcomes of her future children than her socioeconomic circumstances at the time she gives birth (Macintyre & Ellaway,

2003 as cited in Culhane & Elo, 2005; Hennessy & Alberman, 1998). We would have preferred to have had data on neighbourhood environments throughout the mothers' and their ancestors' lifecourses instead of only postal codes at the time of giving birth (Macintyre, Ellaway, & Cummins, 2002; Macintyre & Ellaway, 2003 as cited in Culhane & Elo, 2005), but these data were not available for this study. Although we hypothesized that current area-level exposure (deprivation) could have an immediate effect on PTB, our analysis methods were not chosen to suggest this is the only important period of exposure.

Within the British Columbia Perinatal Database Registry, clinical infant measures such as birth weight and gestational age were nearly 100% complete. There were some variables in the Registry that we would have wanted to include in our study, based on their associations with birth outcomes in previous research, but did not because over 40% of the study sample were missing information. Those variables include alcohol use (Goldenberg et al., 2008), drug use (Berkowitz, Blackmore-Prince, Lapinski, & Savitz, 1998), lone-parent status (Berkowitz & Papiernik, 1993; Wen et al., 2004; Goldenberg et al., 2008) and individual-level maternal education (Wen et al., 2004; Goldenberg et al., 2008). We did exclude 28% of our mother-infant pairs because they were missing BMI and/or material deprivation information. We felt it was inappropriate to exclude BMI due to its association with PTB in previous studies (Goldenberg et al., 2008; Wen et al., 2004) whereas material deprivation was one of the main variables of interest. Hypertension and ICD-10 conditions were recorded in the Registry only for women who had the risk factors. As discussed previously, a recent study

found that non-smokers were often entered into the Registry database with blank information for this variable and that recoding those records as “no” for the smoking variable had relatively high sensitivity and specificity (see methods) (MacIntyre et al., 2006). We therefore coded any observations with missing data for ICD-10 conditions, hypertension or smoking as negative for the risk factor. Some information may simply have been missed or miscoded in the database, however, and our decision may have resulted in some misclassification. Since there were subtle but significant differences between the women included in and excluded from our study, there may also have been differences in the relationships between risk factors and PTB in the two populations.

Census-based definitions of neighbourhoods may differ from perceived neighbourhood boundaries of inhabitants, and residents may experience the same neighbourhood differently as a consequence (Culhane & Elo, 2005; Diez-Roux, 1998). Such inconsistency, or misclassification of resident exposure to area deprivation, could result in erroneous conclusions about the effects of neighbourhoods on health (Culhane & Elo, 2005). DAs are relatively small geographic units and previous studies suggest that smaller neighbourhood units are more likely to share characteristics (Culhane & Elo, 2005). However it may be more appropriate to use knowledge of the region rather than geographic census boundaries to designate neighbourhood groups (Culhane & Elo, 2005; Morenoff, 2003). Few studies have examined whether different methods of creating area boundaries provide different information on the impact they have on health (Culhane & Elo, 2005).

Our results suggest that individual-level factors may be pathways along which inequality in PTB by material deprivation manifest. We describe them as pathways as per researchers who contest that, rather than confounding results, these factors provide insight into mechanisms which may create inequality (Anderson & Mortensen, 2006; Macintyre et al., 2002). Accepting this claim, it is possible to approach explaining the results or considering potential interventions from multiple angles. The observed PTB inequality by DA-level material deprivation could have been further attenuated by including other individual- or area-level factors in our model, and so our results do not elucidate all potential targets of public health interventions. Some studies have suggested that race/ethnicity (defined various ways including country of origin (Janevic et al., 2010; Agyemang et al., 2009) and being of “black” ancestry (Slattery & Morrison, 2002; Wen et al., 2004; DeFranco et al., 2008)), having periodontal disease (Madianos, Bobetsis, & Kinane, 2002; Radnai et al, 2009), working during pregnancy (Meis et al., 1998; Goldenberg et al., 2008), being unmarried or living without a partner (Berkowitz & Papiernik, 1993; Wen et al., 2004) and experiencing anxiety or stress-inducing life events (Kramer et al., 2009; Dole et al., 2003; Berkowitz & Papiernik, 1993) can affect PTB risk. These variables were not included in our model and may have changed our results.

Although attenuation of associations between area-level variables and health outcomes by addition of individual-level variables to regression models may indicate pathways through which area-level effects manifest, it may also be helpful to consider other ways of conceptualizing health inequalities. Some

argue that interventions that focus on “populations at risk” and individual-level risk factors fail to address the conditions that lead to risk exposure. In other words, such approaches may not prevent new people from becoming at risk even if they are successful at decreasing PTB among those currently identified as part of high-risk groups (Frohlich & Potvin, 2008). Meanwhile, interventions that focus on entire populations without considering particularly vulnerable sub-populations risk exacerbating health inequalities, even if they reduce overall population mean levels of risk exposure. This phenomenon may occur because groups with more material and social resources are often better able to take advantage of interventions and therefore benefit faster and to a greater extent than less wealthy populations (Frohlich & Potvin, 2008). For example, interventions to promote smoking cessation in pregnant women have had greater success in higher income groups (Mullen, 1999; Lumley et al., 2001 as cited in Bull, Mulvihill & Quigley, 2003), potentially because they failed to address the greater stress and poorer mental health and social support reported by lower income women (Mullen, 1999) as well as the distal factors that contributed to these differing experiences. These critiques of risk-factor/behaviour and population-wide interventions encourage other conceptualizations of how to effectively reduce PTB inequality. One potential option is to incorporate strategies that target vulnerable populations, as well as factors and policies that contribute to vulnerability, into population-based interventions (Frohlich & Potvin, 2008). Such interventions could combine both individually focused approaches to help women vulnerable to PTB, such as counselling for low-income pregnant women who

smoke to help them with issues such as stress (Mullen, 1999), with social policies to reduce the number of women in low-income groups. It is difficult to measure the effect of, or to attribute, reduced inequalities to interventions and social policies since so many factors and sectors contribute to health outcomes (Rychetnik, Frommer, Hawe, & Shiell, 2002). Additionally, there may be unintended adverse outcomes to approaches that target vulnerable populations, including stigmatization and being less effective at reducing overall negative birth outcomes in the population as a whole (Frohlich & Potvin, 2008). Still, many advise that individual-level interventions should be accompanied by social policies that support vulnerable populations in particular (Frohlich & Potvin, 2008; Commission on Social Determinants of Health, 2008).

We think it is important to consider different frameworks for understanding socioeconomic inequalities in PTB, particularly those that elucidate interactions among individuals, environments and policies. While place effects may be overemphasized in the absence of controlling for individual-level factors, it is also possible that individual-level factors will be overstated without exploration of the effects of more distal structures (Duncan, Jones, & Moon, 1999). Either approach of failing to consider different levels of influence can be inadequate.

One framework that may be useful for considering overlapping structures is the ecosocial framework (Krieger, 2001). Krieger (2001) uses the term “embodiment” to describe how our material and social environments are biologically incorporated into our bodies. Our individual behaviours and health

status are influenced by the environments in which we live and grow, social norms and exposures (e.g. physical, social and service-related), and how we as individuals respond to them (Krieger, 2001; Culhane & Elo, 2005). Therefore attempting to explain inequalities in PTB using area-level or individual-level factors without consideration of policies, environments and lived experiences seems insufficient for gaining a deeper understanding of the problem and for meeting the public health goal of eliminating disparities between subgroups of the population (Kindig, 2007).

The following example provides a basic illustration of inseparable interactions among individual factors, environments and policies. The city of Vancouver has one of the highest costs of living of major Canadian cities, yet British Columbia has the lowest minimum wage in the country (\$8.00 per hour). Someone working a minimum wage job in the city is constrained in their housing choices by their finances. A low-income Vancouverite may therefore end up in sub-standard housing in a neighbourhood of high crime due to lack of affordability. Lack of perceived neighbourhood security could contribute to stress (Auger et al., 2008b), which has been associated with poorer birth outcomes in previous research (Kramer et al., 2009; Dole et al., 2003; Berkowitz & Papiernik, 1993). It may be an individual choice for one to live in a particular home and neighbourhood, but that choice is heavily constrained by a region's availability of employment, decent wages and affordable housing. Employment opportunities, conditions and housing affordability are similarly influenced by the political and economic climate, and by social policies surrounding remuneration and housing

strategies. If factors such as stress increase risk of PTB (Kramer et al., 2009; Dole et al., 2003; Berkowitz & Papiernik, 1993), then the combination of individual, environmental and structural influences could have an impact on the options available to, and behaviours of, a mother and those around her, and on the future health and development of her offspring. Future research should examine downstream effects of policies that affect factors such as housing availability and conditions, wages and crime as they pertain to birth outcomes. For example, a recent study in the city of Montréal, Canada found that women living in areas they perceived to be high in crime were at increased risk of having a small for gestational age child (Auger et al., 2008b).

In conclusion, our study demonstrated area-level socioeconomic inequalities in PTB in the Vancouver CMA that were specific to material deprivation measures, and demonstrated that the individual-level factors we explored attenuated but did not eliminate these PTB disparities. We would encourage further research and discussion on the potential effects of, and interactions among, individual biology and behaviour, social and material environments and policies, and the effects they may have on the perinatal health of future generations.

5: SELF REFLECTION

The process of completing this research and capstone has been one of the most valuable experiences of my MPH degree. I appreciated working so closely with Scott and Irene, and the discussions that we were able to have on an almost daily basis. Our meetings often resulted in self-reflection on the way I viewed the world as well as challenging me to think critically about our data. We had many conversations about how to interpret our results once we determined our focal question. For me, providing a meaningful discussion about our results was the most important and difficult part of this project. I wanted to present our results in a fashion that situated individuals, their conditions and choices within a broader social and political context. Sometimes I was sidetracked by these attempts and had to remind myself (or be reminded) to comment on individual-level explanations too. I think I sometimes was so focused on the external factors that I removed individuals from being part of society and forgot that individuals affect society as well as the converse, and that politics and policies do not exist in isolation of people.

I struggle with how deprivation is defined and how we can ever parse out the most important causes of inequalities. This struggle, however, implies that there is some definitive solution. Perhaps what is more important is opening the dialogue, or contributing to the conversation, about inequities and factors that influence how we behave. This was one of the parts I really had difficulty with in

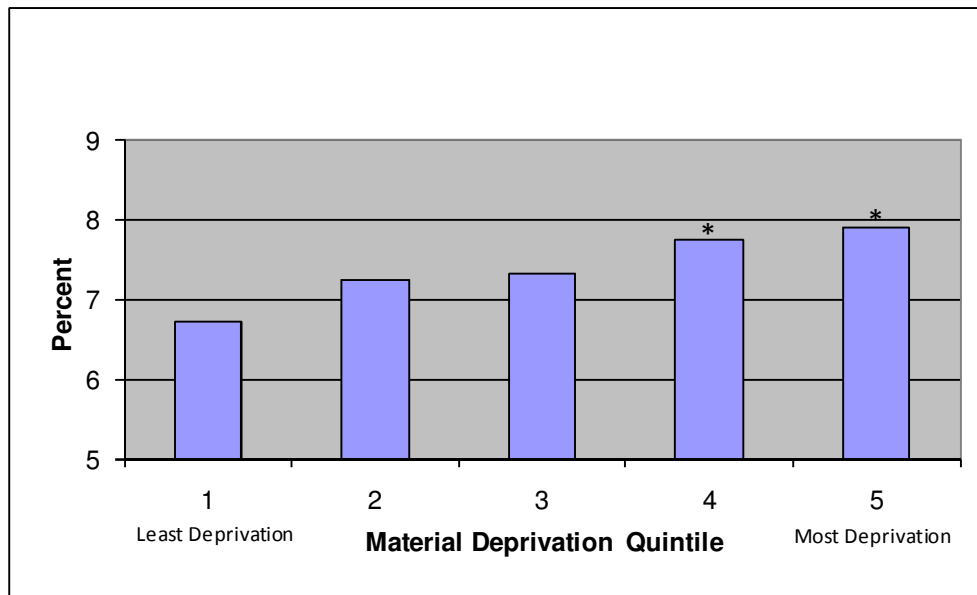
my discussion. I wanted to be able to explain what was really going on, but what I thought was most important was strongly influenced by how I, as an individual, viewed the world. I needed to consider other possible explanations or discourses around the gradients we identified. Scott in particular helped me to realize that.

I do not know how all of this work might translate into practice. I was frustrated with reading so many studies that agreed with our findings, and seeing so few policies that reflected the recommendations of those papers. There seem to be so many layers to these issues, and the worse inequalities become, the more it seems it will take to remedy them. But I suppose that change is slow and at least the conversation is taking place.

Overall, this project improved my epidemiological skills and, more importantly, gave me the opportunity to work closely with people who had many ideas and different approaches to addressing research problems. The process of running tests, reading the literature and discussing the meaning of results challenged many of my assumptions of what certain variables may reflect and expanded my understanding of social determinants of health.

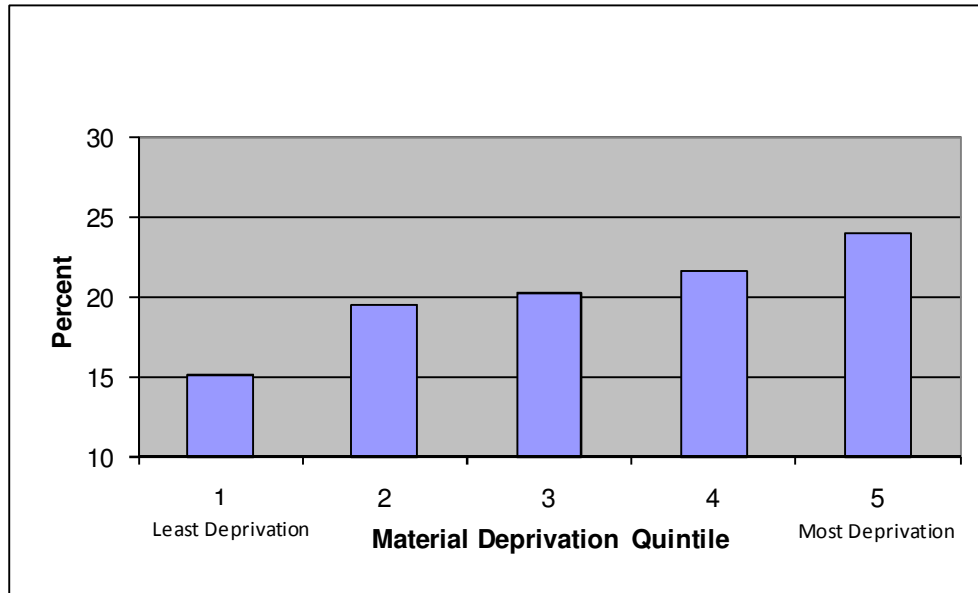
6: FIGURES

Figure 1 Percent preterm birth by census dissemination-area material deprivation quintiles among live, singleton births (n=59,039): Vancouver Census Metropolitan Area, January 1, 2006 to September 17, 2009.



*Significantly different than quintile 1 at 2-sided $\alpha=0.05$ by hierarchical logistic regression (see Table 3).

Figure 2 Percent of all (n=4377) live, singleton preterm births by census dissemination-area material deprivation quintiles (totals to 100%): Vancouver Census Metropolitan Area, January 1, 2006 to September 17, 2009.



7: TABLES

Table 1 Prevalence of preterm births among live, singleton births by area-level socioeconomic measures: Vancouver Census Metropolitan Area, January 1, 2006 to September 17, 2009.

Area-level socioeconomic measures	Total singleton births - n	Preterm births - n (%)**	p ***
Overall socioeconomic deprivation*			0.0959
Low (least deprived)	7766	537 (6.9)	
Average	42446	3152 (7.4)	
High (most deprived)	8827	688 (7.8)	
Material deprivation (quintiles)			0.0073
1 (least deprived)	9779	657 (6.7)	
2	11775	851 (7.2)	
3	12058	881 (7.3)	
4	12182	942 (7.7)	
5 (most deprived)	13245	1046 (7.9)	
Social deprivation (quintiles)			0.7598
1 (least deprived)	10756	802 (7.5)	
2	12151	893 (7.4)	
3	12635	941 (7.5)	
4	12194	877 (7.2)	
5 (most deprived)	11303	864 (7.6)	

*See methods for explanation of low, average and high overall socioeconomic deprivation.

**Birth at gestational age <37 completed weeks.

***Chi-square test, 2-sided p-value.

Table 2 Bivariate associations of area-level material deprivation and individual-level characteristics with preterm birth status: Vancouver Census Metropolitan Area, January 1, 2006 to September 17, 2009.

	Preterm births - n (%)	Term births - n (%)	p*
n	4377	54662	
Material deprivation (quintiles)			0.0073
1 (least deprived)	657 (15.0)	9122 (16.7)	
2	851 (19.4)	10924 (20.0)	
3	881 (20.1)	11177 (20.5)	
4	942 (21.5)	11240 (20.6)	
5 (most deprived)	1046 (23.9)	12199 (22.3)	
Infection (Yes)	226 (5.2)	1182 (2.2)	<0.0001
Polyhydramnios (Yes)	41 (0.9)	225 (0.4)	<0.0001
Oligohydramnios (Yes)	291 (6.7)	1092 (2.0)	<0.0001
Placental conditions (Yes)	444 (10.1)	807 (1.5)	<0.0001
Anaemia (Yes)	359 (8.2)	2883 (5.3)	<0.0001
Body mass index			<0.0001
Underweight (<18.5)	345 (7.9)	3753 (6.9)	
Normal weight (≥ 18.5 , <25)	2588 (59.1)	35130 (64.3)	
Overweight (≥ 25 , <30)	893 (20.4)	10601 (19.4)	
Obese (≥ 30)	551 (12.6)	5178 (9.5)	
Parity (≥ 1)	2142 (48.9)	27401 (50.1)	0.1296
Smoking during pregnancy	387 (8.8)	3091 (5.7)	<0.0001
Hypertension/Diabetes			<0.0001
Neither	3238 (74.0)	46925 (85.9)	
Diabetes only	504 (11.5)	5111 (9.4)	
Hypertension only	474 (10.8)	2179 (4.0)	
Both	161 (3.7)	447 (0.8)	
Mother's age			<0.0001
<20 years	81 (1.9)	846 (1.6)	
20-35 years	3037 (69.4)	39638 (72.5)	
>35 years	1259 (28.8)	14178 (25.9)	
Sex (male)	2444 (55.8)	27949 (51.1)	<0.0001

* Chi-square test, 2-sided p-value.

Table 3 Hierarchical logistic regression models of preterm birth by area-level material deprivation and individual-level risk factors: Vancouver Census Metropolitan Area, January 1, 2006 to September 17, 2009.

	Material Deprivation only			Material Deprivation and Individual Risk Factors	
	n	OR (95% CI)	p	OR (95% CI)	p
Material deprivation (quintiles)					
1 (least deprived)	9779	Ref	Ref	Ref	Ref
2	11775	1.1 (1.0-1.2)	0.0913	1.1 (1.0-1.2)	0.1728
3	12058	1.1 (1.0-1.2)	0.0646	1.1 (1.0-1.2)	0.2649
4	12182	1.2 (1.1-1.3)	0.0025	1.1 (1.0-1.3)	0.0473
5 (most deprived)	13245	1.2 (1.1-1.3)	0.0005	1.1 (1.0-1.3)	0.0311
Infection					
No	57631			Ref	Ref
Yes	1408			2.3 (2.0-2.7)	<0.0001
Polyhydramnios					
No	58773			Ref	Ref
Yes	266			2.0 (1.4-2.8)	0.0001
Oligohydramnios					
No	57656			Ref	Ref
Yes	1383			3.2 (2.8-3.7)	<0.0001
Placental conditions					
No	57788			Ref	Ref
Yes	1251			7.2 (6.3-8.1)	<0.0001
Anaemia					
No	55797			Ref	Ref
Yes	3242			1.2 (1.1-1.4)	0.0007
Body mass index					
Underweight (<18.5)	4098			1.3 (1.2-1.5)	<0.0001
Normal weight (\geq 18.5, <25)	37718			Ref	Ref
Overweight (\geq 25, <30)	11494			1.1 (1.0-1.2)	0.0929
Obese (\geq 30)	5729			1.2 (1.0-1.3)	0.0074
Parity					
0	29496			Ref	Ref

≥1	29543		1.1 (1.0-1.2)	0.0305
Smoking during pregnancy				
No	55561		Ref	Ref
Yes	3478		1.6 (1.4-1.8)	<0.0001
Hypertension/Diabetes				
Neither	50163		Ref	Ref
Diabetes only	5615		1.4 (1.3-1.5)	<0.0001
Hypertension only	2653		3.0 (2.7-3.3)	<0.0001
Both	608		4.8 (3.9-5.8)	<0.0001
Mother's age				
<20 years	927		1.2 (1.0-1.5)	0.1259
20-35 years	42675		Ref	Ref
>35 years	15437		1.1 (1.0-1.2)	0.0258
Sex				
Female	28646		Ref	Ref
Male	30393		1.2 (1.1-1.3)	<0.0001

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