THE EFFECT OF AREA-LEVEL AVERAGE INCOME AND INDIVIDUAL LEVEL FACTORS ON SMALL-FOR-GESTATIONAL AGE: A POPULATION-BASED STUDY OF THE VANCOUVER CENSUS METROPOLITAN AREA, 2006-2009

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ABSTRACT

The goal of this paper was to identify area- and individual-level predictors of small for gestational age birth (SGA). This cross-sectional study analyzed live singleton births from 2006 to 2009 in the Vancouver Census Metropolitan Area. Hierarchical logistic regression models were used to model odds of SGA with deprivation. A crude model of area-level average income was compared to models adjusted by individual-level variables. A strong association was found between SGA and material deprivation, which was greatly influenced by area-level average income. Individual-level variables attenuated the association between area-level average income and odds of SGA. Maternal race/ethnicity was found to have the strongest effect in reducing the area-level association with SGA. No association was found between area-level average income and SGA except in the White group. Future research should attempt to determine if maternal race/ethnicity variable stands as a proxy for structural, biological, social, behaviour/lifestyle, and/or environmental factors.

Keywords: small for gestational age birth; deprivation; area-level variables; area-level average income; individual-level variables; Vancouver Census Metropolitan Area

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1.1 Introduction

There is increasing evidence from Canada to suggest that neighbourhoods where people live have a direct impact on their health as well as on birth outcomes (Auger, Giraud, & Daniel, 2009; CIHI, 2008; CIHI, 2009; Luo et al., 2004; Luo, Wilkins, & Kramer, 2006; Pampalon, Hamel, Gamache, & Raymond, 2009; Pampalon & Raymond, 2000). Studies have shown that areas of lower socio-economic status (SES) have higher rates of adverse birth outcomes including low birth weight (LBW), small for gestational age birth (SGA) and preterm birth (PTB) (Agyemang, et al., 2009; Auger et al., 2009; Bonellie, 2001; CIHI, 2008; CIHI, 2009; Dibben, Sigala, & Macfarlane, 2006; Elo et al., 2008; Luo et al., 2004; Luo et al., 2006; O'Campo et al., 2007; Pattenden, Dolk, & Vrijheid, 1999). Differences in the risks of adverse birth outcomes between areas in the same city can be both targets of public health policy and opportunities to identify the determinants of health outcomes. By contrasting differences between areas, both in the individual characteristics of the people living there and the characteristics of the areas themselves, we might be able to identify targets of interventions or changes in public policy to reduce both overall risks of adverse birth outcomes and disparities between population subgroups. The aim of this paper was to use available data to identify area- and individual-level predictors of SGA in the Vancouver Census Metropolitan Area (CMA), Canada.

Deprivation has been defined as 'a state of observable and demonstrable disadvantage relative to the local community or the wider society or nation to which an individual, family or group belongs' (Townsend, 1987, p. 125). In Canada, deprivation indices have been constructed from census data at different geographical resolutions and based on theoretical frameworks developed in the United Kingdom (Broadway & Jesty, 1998; CIHI, 2008; Frohlich & Mustard, 1996; Matheson, Moineddin, & Glazier, 2008; Pampalon & Raymond, 2000). The present study employed the use of the deprivation index developed by the Institut national de santé publique du Québec (INSPQ) as the measure drew upon data at the dissemination area (DA), which was the smallest geographic unit used by any of the indices developed in Canada available from the census (CIHI, 2008; Pampalon et al., 2009; Pampalon & Raymond, 2000; Statistics Canada, 2010). This deprivation index is divided into material and social components. Conceptually, material deprivation consists of access to modern conveniences, goods and services whereas social deprivation refers to relationships, customs and roles (Carstairs, 1995; Pampalon & Raymond, 2000; Townsend, 1987).

Our starting point was a recent publication from the Canadian Institute for Health Information (CIHI) that reported cross-sectional associations of declining LBW rates with increasing area-level SES across major Canadian cities (CIHI, 2008). The area-level SES measure employed was a composite score of material and social deprivation: low-SES was defined as residence in an area in the top two quintiles of both material and social deprivation, high-SES as residence in an area in the bottom two quintiles of both material and social deprivation, and average SES as residence in any other area (CIHI, 2008). Subsequent analysis by CIHI that specifically focused on small infants across Canada further explored the heterogeneity within LBW by examining PTB and SGA (CIHI, 2009). In this latter CIHI report, neighbourhood average income (defined by census DAs) was used as the aggregate measure of SES at the area-level. Across Canada (excluding Quebec), cross-sectional rates of both PTB and SGA decreased as neighbourhood average income increased, but the gradient was steeper for SGA (CIHI, 2009). The SGA gradient was partially attenuated when individual-level factors were included in the model (CIHI, 2009). Although material and social deprivation are commonly used measures in Canadian health research, the latter CIHI report only analyzed neighbourhood average income so it remains unclear whether material and social deprivation are associated with SGA. It is also unclear whether adjustment for other individual-level variables not included in their analysis but previously shown to be associated with SGA, such as smoking during pregnancy (Janssen et al., 2007; Kramer, 1987; Lang, Lieberman, & Cohen, 1996; Thompson et al., 2001) and maternal race/ethnicity (Elo et al., 2008; Lang et al., 1996; Thompson et al., 2001; Valero de Bernabé et al., 2004), can further attenuate the associations between area-level measures and SGA.

In conjunction with the CIHI reports, previous studies that looked at the association between individual- and area-level variables and LBW, PTB and SGA in Canada, the United States and Europe provide further grounding for the present study. A study of all registered births in British Columbia, Canada from 1985 to 2000 that looked at associations of multiple area - and individual-level variables with PTB and SGA found that residence in neighbourhoods with lower area-level average income was strongly associated with higher odds of adverse birth outcomes, even after accounting for important individual-level maternal and pregnancy characteristics (Luo et al., 2004). However, individual-level variables such as smoking during pregnancy and maternal race/ethnicity were not adjusted for in their models. A similar analysis in Quebec, Canada also found increasing odds of PTB and SGA associated with decreasing area-level average income; however, for this population it was concluded that individual-level maternal education was independently and more strongly associated with both birth outcomes than was area-level average income (Luo et al., 2006). Another study in Quebec focused on the differences in prevalence of PTB and SGA between Canadian and foreign-born mothers (Auger et al., 2009). It was found that

PTB was associated with foreign-born mothers that lived in areas with high poverty and low immigrant density, whereas low median household income was associated with SGA for Canadian born mothers (Auger et al., 2009). A large birth outcome study that was undertaken in eight different geographic areas in the United States found that as neighbourhood deprivation (a score comprised of income/poverty, employment, education, housing and occupation) increased, the risks of PTB (O'Campo et al., 2007) and SGA (Elo et al., 2008) also increased. This study also looked at the risk of the birth outcomes by maternal race/ethnicity. The O'Campo et al. (2007) study found that the risk of PTB was higher for non-Hispanic whites than non-Hispanic blacks, whereas the Elo et al. (2008) study found that the risk of term SGA was higher among non-Hispanic blacks than non-Hispanic whites. European studies have similarly found that adjustment for individual-level variables could partially attenuate the associations of area-level measures with birth outcomes. In the United Kingdom, studies have consistently found increasing LBW with increasing area-level deprivation after controlling for individual-level variables (Bonellie, 2001; Dibben, C., et al., 2006; Pattenden et al., 1999). Similarly, a study in the Netherlands found that as median neighbourhood income decreased, the odds of SGA increased after adjustment for individual-level factors; however, no such relationship was found with PTB (Agyemang, et al., 2009).

Following on the previous research, our goal was to build a model of the predictors of SGA in the Vancouver CMA using both area- and individual-level variables. We first investigated area-level material and social deprivation (and their components) to identify if there were area-level measures that were most strongly associated with SGA. We then adjusted our model using individual-level variables that were previously identified risk factors for SGA to investigate to what extent their addition to the model would attenuate the association between area-level variable(s) and SGA.

SGA was the birth outcome of interest for the present study and, in Canada, is often defined using a Canadian standard of infants in the bottom 10^{th} percentile of birthweight for their gestational age and sex, derived from national population birthweight data (excluding Ontario) (Kramer et al., 2001). There are multiple known determinants of growth restriction leading to SGA, such as smoking during pregnancy (Janssen et al., 2007; Kramer, 1987; Lang et al., 1996; Thompson et al., 2001), maternal age (CIHI, 2009; Clausson, Cnattingius, & Axelsson, 1998; Janssen et al., 2007; Lang et al., 1996), parity (CIHI, 2009; Janssen et al., 2007; Lang et al., 1996; Thompson et al., 2001), pre-pregnancy body mass index (BMI) (Clausson et al., 1998), height (Clausson et al., 1998; Thompson et al., 2001), diabetes (Valero de Bernabé et al., 2004), hypertension (Ananth, Peedicayil, & Savitz, 1995; Clausson et al., 1998; Janssen et al., 2007; Valero de Bernabé et al., 2004), maternal infections (Casey et al., 2000; Lang et al., 1996; Valero de Bernabé et al., 2004), maternal education (Luo et al., 2006) and maternal race/ethnicity (Elo et al., 2008; Lang et al., 1996; Thompson et al., 2001; Valero de Bernabé et al., 2004). SGA has also been linked to increased morbidity and mortality throughout the life course, such as impaired cognitive function, decreased insulin sensitivity and increased risk of metabolic syndrome (Gillman & Rich-Edwards, 2000; Indredavik et al., 2005; Janssen, 2007; Varvarigou, 2010; Veening, Van Weissenbruch, & Delemarre-Van de Waal, 2002).

Because previous research showed that a composite measure of material and social deprivation derived from the INSPQ deprivation index was associated with LBW (CIHI, 2008), we wanted to explore the association with SGA and determine which of the underlying area-level measures (material and social deprivation and their components) were most strongly associated with SGA. We then focused on the single most strongly associated measure, area-level average income, and explored whether its association with SGA was attenuated after adjustment using available individual-level determinants of SGA. We finish with an interpretation of our findings and some thoughts about the next steps needed in this area of research.

1.2 Methods

This cross-sectional study analyzed pregnancy and birth outcome data for live singleton births in the Vancouver CMA for the period 1 January 2006 through 17 September 2009, the latest date for which complete birth data were available from hospitals. Multiple births and stillbirths were not included in the dataset. Data were provided by the BC Perinatal Health Program capturing approximately 99 percent of the births occurring during the study period in provincial health care facilities from maternal medical records and infant birth certificates collected by physicians and midwives, excluding home births (BC Vital Statistic Agency et al., 2007; British Columbia Reproductive Care Program, 2003). All data were linked to the INSPQ deprivation index at the census DA by maternal residential postal code on the birth record. For postal codes that spanned more than one DA, a DA was randomly assigned according to the proportions of the population in the postal code living in the different overlapping areas (Pampalon & Raymond, 2000). The BC Perinatal Health Program anonymized data by removing all identifying information of the mothers and infants, including postal code, prior to when the research team received the data for analysis. The study protocols were approved by the research ethics boards of Simon Fraser University as well as Women's and Children's Hospital in Vancouver, Canada.

We used the INSPQ deprivation index to define material and social deprivation as described previously (Pampalon & Raymond, 2000). Briefly, the INSPQ defined several area-level variables at the census DA to create the material and social deprivation measures (CIHI, 2008; Pampalon et al., 2009; Pampalon & Raymond, 2000; Statistics Canada, 2010). The variables used in the measures (for material: *% persons with no high-school diploma, % persons employed,* and *average income*; for social: *% persons living alone, % persons separated, divorced or widowed* and *% single parent families*) were selected by the INSPQ based on their relationships to health, their associations with either material or social deprivation, and their availability from census data at the DA (Pampalon & Raymond, 2000). The INSPQ performed principle component analysis to combine the above subcomponents into composite measures of material and social deprivation (Pampalon & Raymond, 2000). All area-level variables were divided into quintiles defined at the level of the Vancouver CMA.

Individual-level determinants were chosen based on their association with SGA as reported in the literature, as well as their availability in our dataset. Smoking during pregnancy (Janssen et al., 2007; Kramer, 1987; Lang et al., 1996; Thompson et al., 2001) was defined as 'yes' for women whose records indicated they smoked during all or part of their pregnancy. Former smokers were defined as not smoking during pregnancy. Smoking status was also defined as not smoking for the 61% of participants who had missing data on smoking. A previous study of randomly selected charts determined that 90% contained data about smoking during pregnancy, but many non-smokers were left blank in the BC Perinatal Database Registry. In the 90% with smoking data in their charts in that random sample, recoding missing data as non-smokers led to 75% specificity and 98% sensitivity in smoking status classification (M. Brauer, personal communication to S. Venners, January 23, 2009). Mother's age at the time of delivery (CIHI, 2009; Clausson et al., 1998; Janssen et al., 2007; Lang et al., 1996) was categorized as less than 20 years, greater than or equal to 20 years and less than 35 years, and greater than or equal to 35 years. Parity (CIHI, 2009; Janssen et al., 2007; Lang et al., 1996; Thompson et al., 2001) was defined as one or more previous pregnancies delivered at or equal to 20 weeks of gestation or 500 grams, regardless of the outcome, versus no previous pregnancy. Pre-pregnancy BMI (in kg/m^2) (Clausson et al., 1998) was the ratio of the mother's mass to height squared pre-pregnancy or up to 12 weeks gestation. BMI was categorized as underweight (BMI<18.5), normal weight ($18.5 \leq BMI < 25$), overweight ($25 \leq BMI < 35$) and obese (≥ 35). Height (Clausson et al., 1998;

Thompson et al., 2001) was modelled as a continuous variable to the nearest centimetre. Diabetes (Valero de Bernabé et al., 2004) and hypertension (Ananth et al., 1995; Clausson et al., 1998; Janssen et al., 2007; Valero de Bernabé et al., 2004) were modelled together in four categories where the mother had: neither diabetes nor hypertension, diabetes only, hypertension only, or both diabetes and hypertension. Diabetes included pre-existing or gestational diabetes. Hypertension included having a blood pressure reading of ≥140/90 mmHg on two consecutive readings prior to pregnancy, pregnancy induced hypertension, and mothers who had hypertension from any cause other than renal disease; all other mothers (94.3%) were coded as not having hypertension. ICD-10 codes were used to define maternal clinical conditions including oligohydramnios (O41021, O41031, P012 and P013) (Casey et al., 2000) and placental disorders (O43001, O43101, O43201, O43881, O43901, O44001, O44101, O44103, O45801, O45901, P020, P021 and P022) (Lang et al., 1996; Valero de Bernabé et al., 2004); all other mothers were coded as not having one of the clinical conditions (97.5% for oligohydramnios and 97.7% for placental disorders).

The BC Prenatal Genetic Screening Program, a separate program within the BC Perinatal Health Program where the above individual data were drawn from, provided individual-level data on maternal race/ethnicity (Lang et al., 1996; Thompson et al., 2001; Valero de Bernabé et al., 2004). This is a voluntary screening program that tests for the possibility of Down syndrome, trisomy 18 or an open neural tube defect during pregnancy (BCPGSP, 2009a). The program is open to all residents of British Columbia, Canada but as it is voluntary it is only able to capture the segment of the population who utilize these specific clinical services. The BC Prenatal Genetic Screening Program collected the maternal race/ethnicity data on standardized forms from a question on 'racial origin'. However, during the period included in our data, the 'racial origin' groups on the forms underwent revisions. Prior to revision, the form contained a possibly confusing use of 'Oriental' to indicate individuals of East Asian origin and 'Asian' to indicate individuals from South Asia. Some misclassification based on these labels may have occurred if some East Asian individuals had been recorded as Asian. The revised form utilized different categories including Caucasian, East Asian (eg. Chinese, Japanese, Filipino, Vietnamese, Korean), South Asian (eg. Indian, Pakistani, Sri Lankan), First Nations, Black and Other (BCPGSP, 2009b). Our data included records from both versions of the form leading to 16 maternal race/ethnicity classifications: Asian, Black, Caucasian, Chinese, East Asian, Filipino, First Nations, Hispanic, Japanese, Korean, Multiple, Oriental, Other, Semitic, South Asian and Not Specified. We defined six maternal race/ethnicity categories for analysis as follows: (1) East Asian (Oriental, Chinese, East Asian, Filipino, Japanese or Korean); (2) South Asian (Asian or South Asian); (3) White (Causasian); (4) First Nations; (5) Black and (6) Other (all groups with size less than 1% of the original sample including Multiple, Other, Not Specified, Semitic and Hispanic). White was used as the reference group for this analysis because it was the largest group. We could not determine which mothers had self-reported their race/ethnicity and which were observer-identified. It is also important to note that race and ethnicity have both been used as biological, social and cultural variables in research (Ellison, 2005; Oppenheimer, 2001). Therefore, to embrace the complexity of both of these terms, the combined 'race/ethnicity' will be used throughout the analysis and is conceptualized as a multifaceted variable that may stand as a proxy for other area- or individual-level variables that were unavailable for analysis as well as structural characteristics of social and political phenomena. We conceive of maternal race/ethnicity as a multiplicity of social constructs that are defined differently and often nebulously by various individuals and institutions. In this study, we utilize maternal race/ethnicity as a construct to help us begin describing population stratification of SGA rates and developing hypotheses for future research about why such stratification exists. Such hypotheses will likely require research to clarify uncertainties caused by the general non-homogeneity of maternal race/ethnicity categories, specific inclusion of multiple cultural groups within single categories, and exclusion of multiple categories that intersect with maternal race/ethnicity such as gender, class, sexual orientation, immigration history, as well as among others.

The original sample obtained from the BC Perinatal Health Program contained 82,720 birth records. Consistent with previous work (Kramer et al., 2001), births less than 22 weeks (n = 255) were excluded from the sample and remaining gestational ages ranged from 22 to 43 weeks inclusive. We removed infants with birthweights less than or greater than four standard deviations from the mean birthweight for gestational age and sex (n = 120) using a Canadian reference as these may be the result of gestational age misclassification (Kramer et al., 2001; Wen et al., 2003). Each birth was dichotomously coded for SGA, defined as less than the 10th percentile for gestational age and sex based on the same Canadian birthweight reference (Kramer et al., 2001). Only birth records with complete data for area-level average income and individual-level variables included in the final hierarchical logistic regression model were analyzed. We excluded those who were missing data on maternal race/ethnicity (n = 29,802), pre-pregnancy BMI (n = 13,807) and area-level average income (n = 1,069). The final sample was comprised of 37,667 live singleton births. Compared to those who were excluded, the sample analysed was slightly more likely to be in the lower income quintiles (19.5% vs. 20.6%), first time mothers (46.9% vs. 49.6%) over 35 years old (24.1% vs. 31.6%) as well as non-smokers (6.3% vs. 4.8%) (all at p<0.01). However, the risk of SGA was similar in both groups (7.4% vs. 7.2%; p=0.1336).

Based on previous studies that showed an association between LBW and area-level SES (CIHI, 2008), we separated SES into material and social deprivation to model their association with SGA. We used SAS PROC GLIMMIX to conduct hierarchical logistic regression modelling with a random intercept of DAs, which included a variable for material deprivation and a variable for social deprivation each divided into quintiles using four dummy variables, to determine the relative odds of SGA.

We next conducted hierarchical logistic regression modelling with a random intercept of DAs to determine the relative odds of SGA within quintiles of the subcomponents of material deprivation, which included *% persons with no high-school diploma, % persons employed* and *area-level average income*. Because area-level average income was the only subcomponent of material deprivation significantly associated with SGA (2-sided alpha = 0.05), we focused on this area-level SES measure for the remainder of the analyses.

The association of area-level average income and SGA was modelled by hierarchical logistic regression with a random intercept of DAs. To investigate whether known individual-level determinants of SGA might be confounders or intervening variables in the association between area-level average income and SGA, we compared the crude model to models adjusted for individual-level factors. All individual-level SGA determinants listed above that had bivariate associations ($p<0.20$) with SGA were added to the model and backwards elimination was used as required. We added each individual-level factor to a base model of area-level average income to investigate its specific impact on the association between area-level income and SGA (data not shown). The significant associations were plotted against SGA as well as area-level average income and chi-squared tests were used to further model the associations. All analyses were completed using SAS 9.2 (SAS Inc., Cary, NC).

1.3 Results

A statistically significant increase (at 2-sided alpha = 0.05) in SGA with increasing material deprivation was found (Table 1). Social deprivation was not significantly associated with SGA at 2-sided alpha = 0.05, so it was no longer considered in the analysis. When the three subcomponents of material deprivation were modelled together, area-level average income was the only subcomponent that had a statistically significant association with SGA at 2-sided alpha = 0.05. The percent of SGA in the sample decreased from the lowest to the highest area-level average income quintile (Table 2 and Figure 1).

SGA births accounted for 7.2% (n = 2697) of all births during the study period (Table 2). Risk of SGA differed by maternal race/ethnicity ($p<0.0001$). Compared to non-SGA births, SGA births were less often born to mothers who were classified as White (30.1% vs. 47.8%) but more often to those classified as South Asian (35.6% vs. 23.3%) or East Asian (25.2% vs. 20.5%). The risk of SGA differed by smoking status of the mother during pregnancy ($p=0.0102$). Mothers of SGA babies had higher rates of smoking during pregnancy than mothers of non-SGA babies (5.8% vs. 4.7%). Compared to non-SGA births, SGA births had more mothers aged 20-35 years (70.8% vs. 67.2%) but fewer over 35 years (28.2% vs. 31.8%) ($p=0.0006$). Sixty-four percent of SGA babies were the mother's first pregnancy resulting in a live birth while non-SGA babies were the mother's first pregnancy in approximately 50% of the births ($p<0.0001$). The mothers of non-SGA babies had higher rates of overweight and obesity than mothers of SGA babies ($p<0.0001$). Mothers of SGA babies had a lower mean height than mothers of non-SGA babies (160.8 cm vs. 163.6 cm; $p<0.0001$). Hypertension was more common in mothers of SGA babies than mothers of non-SGA babies (9.5% vs. 4.1%; $p<0.0001$). Of the maternal clinical conditions analyzed, mothers of SGA babies had higher prevalence of oligohydramnios than those of non-SGA babies (8.8% vs. 2.0%; p<0.0001) as well as higher prevalence of placental disorders (3.5% vs. 2.2%; p<0.0001).

Area-level average income was associated with SGA at 2-sided alpha = 0.05 in the unadjusted hierarchical logistic regression model (Table 3). While this relationship was only statistically significant for the three highest average income quintiles, there was a clear decreasing stepwise trend in odds of SGA with increasing area-level average income. A histogram of percent SGA by area-level average income quintiles was plotted to further visually depict this relationship (Figure 1). The model was subsequently adjusted using all of the individual-level variables found to be significantly associated with SGA at 2-sided alpha = 0.2 in bivariate analyses, which greatly attenuated the association between area-level average income and SGA. All individual-level variables remained in the model at 2-sided alpha = 0.05 except mother's age, which we left in the model because it had a 2-sided p value close to our alpha level of 0.05 and has been shown to be a risk factor for SGA in previous studies (CIHI, 2009; Clausson et al., 1998; Janssen et al., 2007; Lang et al., 1996). Compared to mothers classified as White, those classified as South Asian had the highest relative odds of SGA (odds ratio (OR) 1.9, 95% confidence interval (CI) 1.7-2.2) in the sample. Mothers classified as Black had the second highest relative odds (OR 1.8, 95% CI 1.2-2.7) of SGA followed by those classified as Other (OR 1.5, 95% CI 1.3-1.8) and East Asian (OR 1.4, 95% CI 1.2-1.6). While mothers classified as First Nations had a lower odds of SGA (OR 0.7, 95% CI 0.4-1.2) compared with mothers classified as White, the association was not statistically significant at 2-sided alpha = 0.05. Smoking during pregnancy was associated with greater odds of SGA (OR 1.8, 95% CI 1.5-2.1) while having had one or more previous pregnancies was associated with decreased odds of SGA (OR 0.5; 95% CI 0.5-0.6). Mothers who were underweight had greater odds of SGA (OR 1.6, 95% CI 1.4-1.9) than those of normal weight, and as BMI increased, the odds of SGA decreased. As mother's height increased, the odds of SGA lowered. Having only diabetes and not hypertension was associated with lower odds of SGA (OR 0.9, 95% CI 0.8-1.0). Having hypertension only and not diabetes (OR 2.4, 95% CI 2.0-2.8) or both diabetes and hypertension (OR 1.5, 95% CI 1.1-2.1) was associated with higher odds of SGA. Oligohydramnios (OR 4.1, 95% CI 3.5-4.8) and occurrence of placenta disorders (OR 1.5, 95% CI 1.2-1.9) were also associated with higher odds of SGA in the model. After adjustment for individual-level variables, the association between area-level average income and SGA was no longer significant at 2-sided alpha = 0.05 and odds ratios were close to 1.

Although the strongest attenuation of the area-level average income-SGA association was observed when all individual-level variables were included in the model, when we added the individual-level variables to the model separately, maternal race/ethnicity was the only individual-level variable found to greatly attenuate the association between area-level average income and SGA when modeled alone with area-level average income. We therefore next investigated the associations of maternal race/ethnicity with both area-level average income and SGA. To investigate these associations, maternal race/ethnicity was plotted against percent SGA (Figure 2) as well as area-level average income (Figure 3).

As shown in Figure 2, we found that mothers classified as First Nations had the lowest percent of SGA (3.7%) followed by mothers classified as White (4.6%). The highest percentage of SGA (10.5%) occurred among mothers classified as South Asian. Figure 3 shows the distribution of maternal race/ethnicity by quintiles of area-level average income. The number of mothers classified as White increased from the lowest to the highest income quintile, but the opposite trend was found for the other five maternal race/ethnicity groups. When we examined the association between area-level average income and SGA within each maternal race/ethnicity group, the statistically significant gradients in the association of area-level average income and SGA shown in Figure 1 were no longer statistically significant at 2-sided alpha = 0.05 for any maternal race/ethnicity groups except White (Figure 4). The statistically significant relationship (2-sided p=0.005 by hierarchical logistic regression) with area-level average income found among mothers classified as White appeared to be the result of a threshold effect, where those in the lowest area-level average income quintile experienced a higher odds of SGA than the four higher quintiles.

1.4 Discussion

In this analysis, we found a strong association between increasing area-level material deprivation and increasing SGA. Further analysis revealed that the association of material deprivation with SGA was primarily due to the association of SGA with area-level average income, one of the three components comprising the measure of material deprivation used in our study. Our findings are consistent with results of previous studies that showed declining SGA from the lowest to the highest area-level average income quintiles (Agyemang et al., 2009; CIHI, 2009; Luo et al., 2004; Luo et al., 2006). Furthermore, we found that after adjusting for individual-level variables that were each independently associated with SGA, the association between area-level average income and SGA was no longer statistically significant at 2-sided alpha = 0.05. Further analysis revealed that when maternal race/ethnicity was added alone to the hierarchical logistic regression model with area-level average income, the maternal race/ethnicity variable greatly reduced the area-level average income association with SGA. None of the other individual-level variables attenuated the association between area-level average income and SGA as much as maternal race/ethnicity when modelled alone. When we stratified our analysis by maternal race/ethnicity, we found that the crude associations between area-level average income and SGA were no longer statistically significant at 2-sided alpha = 0.05 in any maternal race/ethnicity group other than White, although there were non-significant trends of decreasing SGA with increasing area-level average income for the East Asian and Other groups. Among mothers classified as White, those in the lowest quintile of area-level average income had higher odds of SGA compared to the higher four groups.

Area-level average income stratification by maternal race/ethnicity was stark in this analysis. The proportion of the population categorized as White increased with increasing area-level average income quintiles, with the greatest proportion of White women in the highest area-level average income quintile. The opposite trend was found for all other maternal race/ethnicity categories, with the greatest proportion of each population in the lowest area-level average income quintile. Mothers classified as a race/ethnicity other than White also had higher odds of SGA than those classified as White, except for mothers classified as First Nations. The lower odds of SGA among mothers classified as First Nations may be the result of higher rates of diabetes found in this subpopulation (Young et al., 2000). This also corresponds with our analysis where mothers having diabetes only had lower odds of SGA.

Given that no relationship between SGA and area-level average income was found for any of the other maternal race/ethnicity groups, this first of all may infer that area-level average income does not affect SGA for maternal race/ethnicity groups other than those classified as White. This may mean that area-level average income affects maternal race/ethnicity groups differently than mothers classified as White. Secondly, due to the smaller sample sizes for all other maternal race/ethnicity groups other than White, the association between area-level average income and SGA for these groups may not have been revealed in this analysis. Therefore, as two different narratives of the area-level average income and SGA association have emerged for mothers classified as White versus all other maternal race/ethnicity groups, the question of whether area-level average income affects SGA in the Vancouver CMA remains open. In light of this, it would be interesting to determine why there is an association between area-level average income and SGA for mothers classified as White, and if there really is no association for all other maternal race/ethnicity groups, why that is. However, should it be found that the smaller sample sizes and the potential misclassification of maternal race/ethnicity groups (see Methods) have clouded the association between area-level average income and SGA, it would be interesting to determine if there are different factors that impact the association for different maternal race/ethnicity groups so that the most effective public health measures may be used.

The data analysed for this study were from validated and well-established federal and provincial agencies. However, area-level average income was extracted from census data. Because census data are based on self-reported information, individuals may interpret questions differently from one another, which could lead to potential misclassification. Furthermore, while the BC Perinatal Health Program has built-in validation rules and regular data quality checks (BC Vital Statistic Agency et al., 2007), 61% of the sample were coded as non-smokers due to lack of data on smoking status during pregnancy. This recoding may not have adequately adjusted for smoking in the association between area-level average income and SGA; however, a previous analysis found recoding of this variable to have adequate sensitivity and specificity (see Methods). The data were further limited by the pre-pregnancy BMI and maternal race/ethnicity variables as 26% and 36% of the sample respectively were missing, which led us to exclude these individuals from our analysis leading to a potential increase in selection bias. However, sensitivity analyses (data not shown) demonstrated that the main effect of the area-level average income and SGA association was the same between the sample with all the subjects, the sample that was not missing maternal race/ethnicity and the final sample, which had neither maternal race/ethnicity nor pre-pregnancy BMI missing. Therefore, given that the analyzed sample was limited based on the inclusion criteria, the main association of interest between area-level average income and SGA was not biased due to selection on complete data.

As previously discussed, the BC Prenatal Genetic Screening Program is a voluntary program from which the maternal race/ethnicity data was obtained. Therefore, the results of this study are limited to women who participated in the program and might therefore be biased due to selection into the study. As Canada operates under a public health care system, prenatal services are accessible to whoever chooses to utilize them. As discussed earlier, we found that compared to those excluded from the analysis, the sample analyzed was slightly more likely to be in the lower income quintiles (19.5% vs. 20.6%), first time mothers (46.9% vs. 49.6%) over 35 years old (24.1% vs. 31.6%) as well as non-smokers (6.3% vs. 4.8%) (all at $p<0.01$), but had a similar percentage of SGA (7.4% vs. 7.2%; $p=0.1336$). To further explore the possibility of selection bias, we compared the main association of area-level average income and SGA in the entire group (including those who were missing values for maternal race/ethnicity and pre-pregnancy BMI) versus those included in the analysis and found that the associations were of identical magnitude (data not shown). We also compared the magnitude of associations in the two groups between individual-level variables and SGA in the full model (excluding maternal race/ethnicity and pre-pregnancy BMI). The associations were all similar with the exception of maternal height, which had a stronger association with SGA in the analyzed group than in the entire group. Although these analyses suggest that selection bias should not be a major problem in our analysis, it may be practical only to generalize our results to the subset of the population in the Vancouver CMA who take part in prenatal genetic screening.

There are also several important limitations with regard to the maternal race/ethnicity variable. First, it was possibly subject to misclassification due to the how the data were collected on the BC Prenatal Genetic Screening Program standardized forms throughout the study period (see Methods). Another limitation was the small sample sizes within several categories, most notably for First Nations and Black mothers. Both of these groups had less than five counts per cell in the chi-square tests for the higher area-level average income quintiles. The small cell sizes made some statistical analyses of these categories impossible, but also highlight that these are minority populations in Vancouver that have small proportions of women living in areas with the highest average incomes. Finally, we were only able to analyze maternal race/ethnicity; however, we hypothesize that paternal race/ethnicity would also be an important variable in the investigation of population stratification of SGA.

It is also important to recognize that maternal race/ethnicity-specific birthweight phenomena are not static, but are conditioned by external, structural factors over time. This claim is supported by studies that have found that foreign-born mothers have heavier babies than native-born mothers of the 'same' race/ethnicity group in the same country (Buekens, Notzon, Kotelchuck, & Wilcox, 2000; Cabral, Fried, Levenson, Amaro, & Zuckerman, 1990; Fuentes-Afflick, Hessol, & Pérez-Stable, 1998; Harding, Santana, Cruickshank, & Boroujerdi, 2006). These findings may be the result of the 'healthy migrant effect' where immigrants experience favourable health outcomes due to the immigration selection process (Urquia, Frank, Moineddin, & Glazier, 2010) even when foreign mothers were found to experience socioeconomic disadvantage when compared to non-immigrant mothers of the same race/ethnic background (Fuentes-Afflick et al., 1998). However, the association with the 'healthy migrant effect' and adverse birth outcomes has been found to differ by migrant subgroup as well as by country of migration (Urquia et al., 2009). This supports that race/ethnicity groups are not homogeneous. While the utilization of large groupings in the present study helps to elucidate differences in SGA between groups, a study of Asian women in the United States documented differences in perinatal outcomes by national origin (Fuentes-Afflick & Hessol, 1997). This would mean that further refinement of subgroups of populations would be necessary as there may be differences in the downstream health outcomes as well.

It is also important to note that the interpretation of our results depends upon whether the higher odds of SGA that we observed in some maternal race/ethnicity categories indicates higher odds of later adverse health consequences of reduced fetal growth. However, we do not have data that would allow us to make this conclusion. Being born small is not a pathology in itself. Rather it is a marker of increased risk of later or concurrent pathology (Gillman & Rich-Edwards, 2000;

Indredavik et al., 2005; Janssen, 2007; Varvarigou, 2010; Veening et al., 2002). We do not know if downstream risks of babies classified as SGA based on overall population birth distributions are equal among babies in different maternal race/ethnicity groups. As mentioned, our findings demonstrated very large differences in area-level average income distributions among maternal race/ethnicity groups, suggesting similarly large differences in living conditions among these groups. In addition to socioeconomic variability, our maternal race/ethnicity groups are likely highly heterogeneous in regards to immigrant and generational status, as well as religion and culture.

In summary, our finding of a statistically significant association of SGA by area-level average income quintile was consistent with previous birth outcome studies that looked at odds of SGA across Canadian cities (Auger et al., 2009; Luo et al., 2006) and provinces (CIHI, 2009; Luo et al., 2004). However, in contrast to these studies, our dataset included individual-level variables that have previously been shown to be associated with SGA, such as smoking during pregnancy (Janssen et al., 2007; Kramer, 1987; Lang et al., 1996; Thompson et al., 2001) and maternal race/ethnicity (Elo et al., 2008; Lang et al., 1996; Thompson et al., 2001; Valero de Bernabé et al., 2004). While smoking during pregnancy was associated with greater odds of SGA in our fully adjusted model, maternal race/ethnicity was the only individual-level variable found to greatly attenuate the association between area-level average income and SGA when modelled alone with area-level average income. Our subsequent analyses of area-level average income and SGA with maternal race/ethnicity have therefore proved to be the inaugural look at these associations in the Canadian context.

1.5 Implications for public health practice and policy

The association between area-level average income and SGA found in this analysis is consistent with previous Canada-wide studies (CIHI, 2009). Therefore, it is likely that the results obtained would be consistent across Canada, but replication would be necessary to make conclusions across the country, especially due to the ethnic diversity between cities. However, in order to understand the public health implications of this study, it is first of all important to know whether groups that experience higher rates of SGA also experience higher rates of the downstream health effects. Secondly, it is important to assess whether these differences in the levels of SGA between groups persist in city and country comparisons, as well as over time. As previously discussed, maternal race/ethnicity birthweight phenomena are not static, but are conditioned by external, structural factors. Therefore future research should attempt to determine if the maternal race/ethnicity variable stands as a proxy for structural (such as immigration policies, smoking regulations), biological (such as pre-existing disease, inherited disorders), social (such as stress, access to employment, discrimination, access to appropriate health information), behaviour/lifestyle (such as smoking, access to nutritious foods, physical activity), and/or environmental factors (such as pollutants in water, air and soil). It would be important to develop or utilize existing methods to be able to accurately capture population-level data of these external factors and assess if there is a strong causal link to SGA to them. If a link was established, then appropriate public health interventions could be developed and targeted at reducing the differences in levels of SGA, as well as other health outcomes, between groups. As found in the present analysis, the stark area-level average income divide between maternal race/ethnicity groups may be an important area to focus future public health interventions. For example, the differences in SGA between groups may be the result of structural factors. Should this be the case, then public health interventions should emphasize that in order to decrease the differences in percentages of SGA between groups living in the Vancouver CMA that average income should be increased as the area-level average income divide may be an important determinant of health inequity between maternal race/ethnicity groups.

SGA is an important birth outcome measure to study because of its known link to increased morbidity and mortality throughout the life course. However, it is also important to assess whether SGA is the appropriate measure to look at given that not only are birthweight distributions natural in populations but also subject to changes over time. SGA is currently defined as the bottom 10th percentile in birthweight for sex and gestational age; however, if population birthweights change over time it may be important to change the percentile cut-off periodically to prevent misdiagnosis of infants as SGA and the subsequent subjection to monitoring, testing, high health care costs and parental anxiety that may in fact be unnecessary (Janssen et al., 2007). Therefore, there may be a need for greater sensitivity to ensure for the appropriate diagnoses of infants that are truly growth restricted for their sex and gestational age, which may be based on individual monitoring throughout gestation rather than in comparison to the overall population.

1.6 Self reflection

In the research, analysis and composition of the present paper, I have had the opportunity to apply the wide range of research methods and knowledge that I have gained throughout my Master in Public Health. In conjunction with the coursework that I have completed, this process has solidified the importance of reliable data in making assertions about population health and the dissemination of information to the public in an appropriate and meaningful way.

While working through the present analysis, there were occasions where the reliability of the data for some of the variables was brought into question, even though they were obtained from a validated and quality-checked sources. The greatest concern surrounded the maternal race/ethnicity variable as the inclusion of this variable eliminated 36% of the available dataset. In addition to this drastic reduction in the available sample, this variable was of concern because we were uncertain of the reliability of the collected data as the maternal race/ethnicity groups underwent revisions over the period of analysis. As well, it was unclear how these data were recorded (self-reported, outsider-reported, or a combination). This experience will thus influence how I practice public health by forcing me to always question the source of the data and their collection methods so that I may be able to produce high quality work that is founded on strong sources and not merely because the data were available for use. However, should I feel confident in the data sources and that the analysis was delivered in an effective and sensitive manner where time was taken to ensure that the interpretation of the analysis was appropriate, I would not hesitate to share the obtained results if they were to help in pushing forward an important public health goal.

In the composition of this paper, I attempted to use cautionary language and to present the data as objectively as possible. However, the problem that can be encountered is what happens to the work after it is published if it is not disseminated properly. As information is so readily accessible once it is released, the greatest concern I am presented with is the interpretation by the public. For example, if the media were to release a generalization of mothers of SGA babies in the Vancouver CMA based on the present findings, unnecessary concern by individual mothers could be possible, instead of the message being viewed as population (and not individual-level) trends. This work is a starting point that greatly lends itself towards more focused research in the future. This experience has therefore motivated me to strongly consider the dissemination of research so that it may hopefully be interpreted correctly and used appropriately.

Ultimately, the experience of working on the capstone has further engrained in me that all public health problems are multifaceted and complex. There is not one right solution to a problem and it all has to do with the process of how we, as public health practitioners, choose to look at the issues and from what angle. I therefore feel strongly about the importance of working in collaborative teams so that the strengths and insights that each of us have of the world can work towards the benefit of the public health issue at hand.

1.7 Figures

Figure 1 **Percent small for gestational age birth (SGA) by census area-level average income quintile, Vancouver CMA, 1 January 2006 to 17 September 2009.**

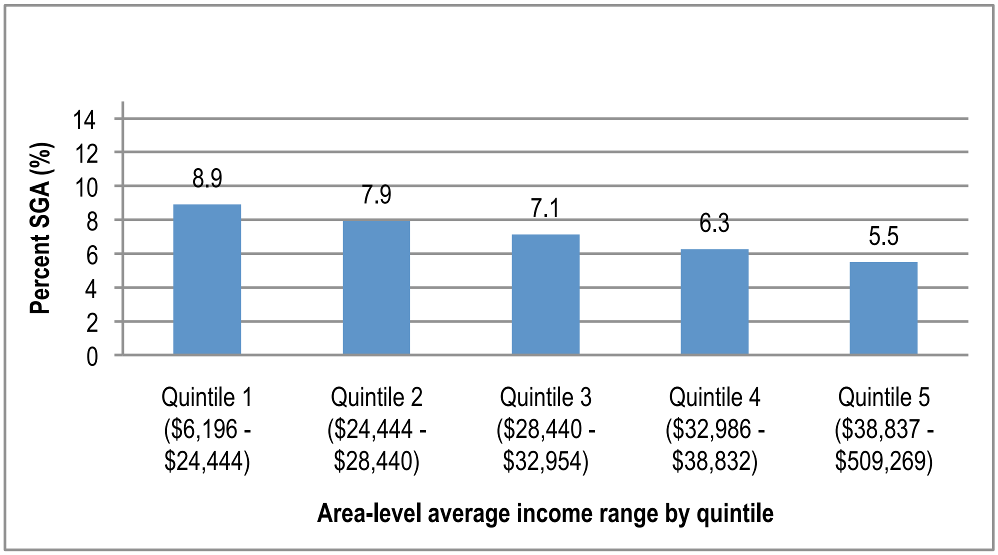
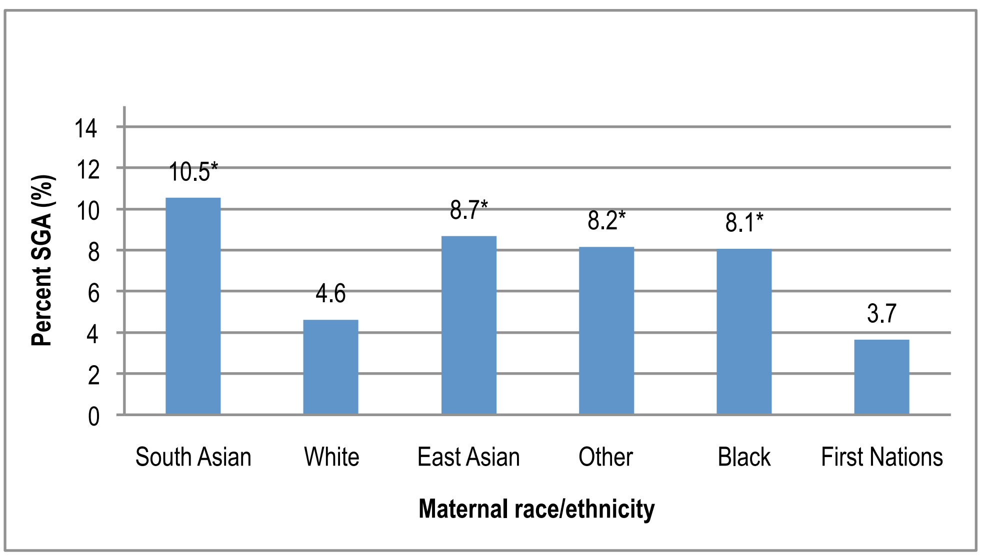


Figure 2 **Percent small for gestational age birth (SGA) stratified by maternal race/ethnicity, Vancouver CMA, 1 January 2006 to 17 September 2009.**



* Odds of SGA significantly different than maternal race/ethnicity White at 2-sided alpha = 0.05

Figure 3 **Small for gestational age births (SGA) by area-level average income quintile, stratified by maternal race/ethnicity, Vancouver CMA, 1 January 2006 to 17 September 2009.**

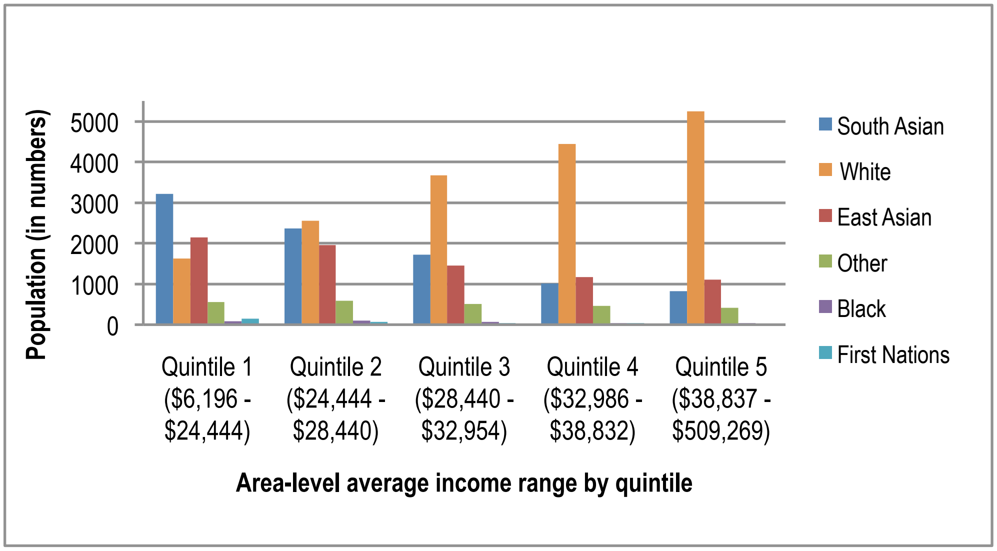
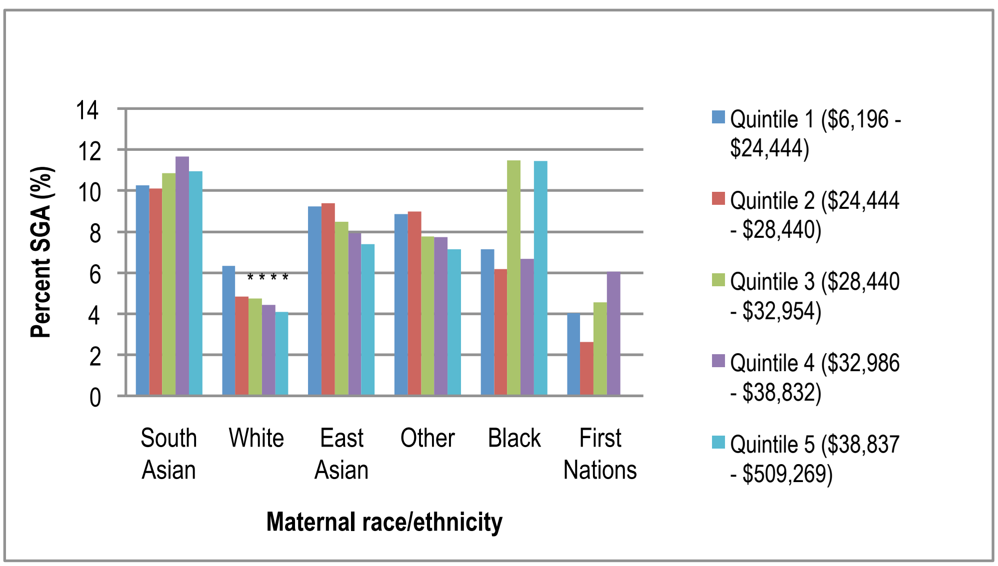


Figure 4 **Percent small for gestational age birth (SGA) by census area-level average income quintile, stratified by maternal race/ethnicity, Vancouver CMA, 1 January 2006 to 17 September 2009.**



* Significantly different than lowest income quintile at 2-sided alpha = 0.01 by chi-square test

1.8 Tables

Table 1 Hierarchical logistic regression models of small for gestational age birth (SGA) by census dissemination area-level material and social deprivation (modelled together), and components of material deprivation (modelled together), Vancouver CMA, 1 January 2006 to 17 September 2009.

		Material and social deprivation together	*Components of material deprivation together*
	n	OR (95% CI)	OR (95% CI)
Material deprivation			
1 (least deprived)	13324	Reference	
2	15438	1.2 (1.0-1.3)	
3	16210	1.2 (1.1-1.4)**	
4	16655	1.4 (1.2-1.7)***	
5 (most deprived)	18217	1.7 (1.5-2.0)***	
Social deprivation			
1 (least deprived)	14256	Reference	
2	16234	0.9 (0.8-1.0)	
3	16970	0.9 (0.8-1.0)	
4	16876	0.9 (0.8-1.0)	
5 (most deprived)	15508	0.9 (0.8-1.1)	
% Persons with no high-school diploma			
1 (highest)	15993		Reference
2	15953		1.0 (0.8-1.1)
3	15960		1.0 (0.8-1.1)
4	15985		1.1 (0.9-1.3)
5 (lowest)	15953		1.2 (1.0-1.3)
% Persons employed			
1 (lowest)	15957		Reference
2	15964		1.0 (0.9-1.2)
3	15988		1.0 (0.9-1.2)
4	15976		1.0 (0.9-1.1)
5 (highest)	15959		1.0 (0.8-1.1)
Average income			
1 ($6,196 – $24,444)	15990		Reference
2 ($24,444 – $28,440)	15937		0.9 (0.8-1.0)
3 ($28,440 – $32,954)	15975		0.8 (0.7-1.0)*
4 ($32,986 – $38,832)	15952		0.7 (0.6-0.9)**
5 ($38,837 - $509,269)	15990		0.7 (0.6-0.8)***

*p<0.05; ** p<0.01; *** p<0.0001

Table 2 **Bivariate associations of small for gestational age birth (SGA) with maternal characteristics and census dissemination area-level average income quintiles, Vancouver CMA, 1 January 2006 to 17 September 2009.**

	SGA N (%)	Non-SGA N (%)	*P**
Total sample	**2697 (7.2)**	**34970 (92.8)**	
Income Quintiles			<0.0001
1 ($6,196 – $24,444)	691 (25.6)	7075 (20.2)	
2 ($24,444 – $28,440)	605 (22.4)	7012 (20.1)	
3 ($28,440 – $32,954)	532 (19.7)	6920 (19.8)	
4 ($32,986 – $38,832)	449 (16.7)	6727 (19.2)	
5 ($38,837 - $509,269)	420 (15.6)	7236 (20.7)	
Maternal race/ethnicity			<0.0001
South Asian	961 (35.6)	8156 (23.3)	
White	811 (30.1)	16718 (47.8)	
East Asian	680 (25.2)	7157 (20.5)	
Other	207 (7.7)	2326 (6.7)	
Black	26 (1.0)	296 (0.9)	
First Nations	12 (0.4)	317 (0.9)	
Smoking during pregnancy			0.0102
No	2541 (94.2)	33330 (95.3)	
Yes	156 (5.8)	1640 (4.7)	
Maternal age			0.0006
<20	28 (1.0)	336 (1.0)	
20-35	1908 (70.8)	23512 (67.2)	
≥ 35	761 (28.2)	11122 (31.8)	
Parity			<0.0001
0	1762 (65.3)	16937 (48.4)	
≥ 1	935 (34.7)	18033 (51.6)	
Pre-pregnancy BMI (kg/m^2)			<0.0001
Underweight (<18.5)	318 (11.8)	2256 (6.5)	
Normal weight (18.5-25)	1795 (66.6)	22579 (64.6)	
Overweight (25-30)	413 (15.3)	6845 (19.6)	
Obese (≥30)	171 (6.3)	3290 (9.4)	
Height (cm) (mean (SD))	160.8 (6.7)	163.6 (7.0)	<0.0001
Diabetes/hypertension			<0.0001
Neither	2126 (78.8)	29337 (83.9)	
Diabetes only	270 (10.0)	3804 (10.9)	
Hypertension only	255 (9.5)	1448 (4.1)	
Diabetes & hypertension	46 (1.7)	381 (1.1)	
Oligohydramnios			<0.0001
No	2461 (91.3)	34276 (98.0)	
Yes	236 (8.8)	694 (2.0)	
Placenta disorder			<0.0001
No	2604 (96.6)	34205 (97.8)	
Yes	93 (3.5)	765 (2.2)	

*χ^2 test for categorical variables and analysis of variance (ANOVA) for continuous variable (height)

Table 3 Hierarchical logistic regression models of small for gestational age birth (SGA) for area-level average income only, area-level average income with all individual-level variables, and area-level average income and maternal race/ethnicity, Vancouver CMA, 1 January 2006 to 17 September 2009.

		Income only	*Income and all individual-level variables*	*Income and maternal race/ethnicity*
	n	OR (95% CI)	OR (95% CI)	OR (95% CI)
Income quintiles				
1 ($6,196 – $24,444)	7766	Reference	Reference	Reference
2 ($24,444 – $28,440)	7617	0.9 (0.8-1.0)*	1.0 (0.9-1.1)	1.0 (0.9-1.1)
3 ($28,440 – $32,954)	7452	0.8 (0.7-0.9)**	1.0 (0.9-1.1)	0.9 (0.8-1.1)
4 ($32,986 – $38,832)	7176	0.7 (0.6-0.8)***	0.9 (0.8-1.1)	0.9 (0.8-1.0)
5 ($38,837 - $509,269)	7656	0.6 (0.5-0.7)***	0.9 (0.8-1.0)	0.8 (0.7-0.9)**
Maternal race/ethnicity				
South Asian	9117		1.9 (1.7-2.2)***	2.3 (2.1-2.6)
White	17529		Reference	Reference
East Asian	7837		1.4 (1.2-1.6)***	1.9 (1.7-2.1)***
Other	2533		1.5 (1.3-1.8)***	1.7 (1.1-2.6)**
Black	322		1.8 (1.2-2.7)**	1.8 (1.5-2.1)***
First Nations	329		0.8 (0.4-1.4)	0.7 (0.4-1.3)
Smoking during pregnancy				
No	35871		Reference	
Yes	1796		1.8 (1.5-2.1)***	
Maternal age				
<20	364		0.8 (0.6-1.3)	
20-35	25420		Reference	
≥ 35	11883		1.1 (1.0-1.2)	
Parity				
0	18699		Reference	
≥ 1	18968		0.5 (0.5-0.6)***	
Pre-pregnancy BMI				
Underweight (<18.5)	2574		1.6 (1.4-1.9)***	
Normal weight (18.5-25)	24374		Reference	
Overweight (25-30)	7258		0.8 (0.7-0.9)***	
Obese (≥30)	3461		0.7 (0.6-0.8)***	
Height			0.9 (0.9-1.0)***	
Diabetes/ Hypertension				
Neither	31463		Reference	
Diabetes only	4074		0.9 (0.8-1.0)	
Hypertension only	1703		2.4 (2.0-2.8)***	
Diabetes & hypertension	427		1.5 (1.1-2.1)*	
Oligohydramnios				
No	36737		Reference	
Yes	930		4.1 (3.5-4.8)***	
Placenta disorder				
No	36809		Reference	
Yes	858		1.5 (1.2-1.9)**	

* p<0.05; ** p<0.01; *** p<0.0001

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