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Gestational weight gain among women from low income communities: What are the associated factors and what are the subsequent weight status consequences for these women and their children?

by
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ABSTRACT

This study explored individual and interpersonal characteristics and demographic factors related to gestational weight gain (GWG) and examined the relationship between GWG and infant birth weight, child weight status at four years of age, and maternal weight status longitudinally. Data come from the Better Beginnings, Better Futures (BBBF) project, a primary prevention project conducted in economically disadvantaged communities in Ontario. A total of 562 participants provided data necessary for the calculation of GWG and were included in the study. Additional data were collected on demographic, physical, mental health and lifestyle topics at approximately three month, 1.5, 2.5, 4 and 8 year intervals.

The Social Ecological Model was used as a tool to select variables and to create a framework for examining the interconnectedness of these variables. Between 9.6% and10.8% of the variability in GWG was attributable to the women's country of birth, age, pre-pregnant BMI and the ability to afford food and living expenses. Being Canadian born significantly increased GWG by 7.17 lbs to 7.99 lbs. Increasing pre-pregnant BMI was associated with lower GWG and women classified as obese prior to pregnancy had a lower GWG by 10.88 lbs on average, compared to women with lower BMIs. Lack of money for food and living expenses was associated with a lower average GWG by 3.43 lbs to 3.59 lbs. Each year of age decreased GWG by an average of 0.22 lbs to 0.28 lbs. Pre-pregnant BMI, country of birth, age, lack of money,

taller height and smoking status were predictors of GWG above 2009 Institute of Medicine recommendations (i.e. high GWG). Women overweight or obese prior to pregnancy had more than three times the odds of having high GWG compared to underweight and normal weight women. Taller women were more likely to have high GWG (OR 1.68) as were Canadian born women (OR 2.44), women less than 20 years of age (OR 1.53), and women who were former smokers (1.48). Lack of money for food and living expenses decreased the odds of high GWG (OR 0.641).

GWG was a predictor of birth weight after controlling for pre-pregnant BMI, maternal smoking status and infant sex with each one pound increase in GWG associated with an average 0.17 lb increase in infant birth weight. Despite a significant association between GWG classification and average weight-for-height z-score and weight status among the participants' children at four years of age in bivariate analysis, GWG was not a significant predictor of childhood weight status in multivariate analysis.

Over the eight years that the women were followed average weight increased by 16.88 lbs and average BMI increased from 23.29 kg/m^2 (normal weight) prior to pregnancy to 25.34 kg/m^2 (overweight). GWG was a significant predictor of BMI at four and eight years postpartum when all of the women were examined together. When examined by pre-pregnant BMI status, GWG predicted higher BMI only among normal weight women. In both cases, GWG was attributable to only a small part of the variation in BMI.

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Chapter 1 INTRODUCTION AND STUDY OBJECTIVES

1.0 Introduction and Study Objectives

1.1 Problem Statement and Research Purpose

Overweight and obesity rates are high among Canadians of all ages; increasingly so among children. Because obesity persists throughout the lifespan, preventative measures must be determined and implemented early in the lifespan to reduce the prevalence of overweight and obesity among children and ultimately adults, and hence to reduce the rates of chronic health problems associated with excess weight. The purpose of this study is to investigate prenatal factors and maternal characteristics that may influence gestational weight gain as well as the relationship of gestational weight gain with maternal and child weight status longitudinally.

1.2 Practical Importance

Obesity has become a global epidemic. In 2008, approximately 12% of adults 20 years or older were obese (body mass index [BMI] ≥ 30 kg/m^2) and 35% of adults 20 years or older were overweight (BMI 25-29.9 kg/m^2) (1). In North America, the rates are even higher. From 2007 to 2009, the prevalence of obesity in Canada was 24.1% of adults; a lower figure than is found in the United States (34.4% of adults), but nonetheless, disturbingly high (2). This represents nearly a doubling of the rate of obesity from 1981 (3). This unfortunate trend is also affecting Canadian children. Among Canadian children and adolescents between the ages of six and 17 years, 8.6% are obese, and an even larger number are at risk for becoming obese due to excess weight and lifestyle risk factors (3). The costs of obesity for both adults and children are high, including numerous health negative health consequences such as cardiovascular problems and metabolic disorders in addition to psychosocial issues and economic stress (4).

While the trend of increasing weight appears to be widespread throughout the country, certain populations have been identified as particularly vulnerable including children, aboriginal populations and immigrants (5). Many studies have also indicated that individuals with lower incomes, lower education, and/or lower occupational class may also be at an increased risk for becoming overweight or obese. People living in the most disadvantaged neighbourhoods have been found more likely to have an increase in their BMI over a six year period compared to those in less disadvantaged neighbourhoods (6). Lower income and education have also been linked to poorer health status and health outcomes (7-9). Much of the research on the association of low income and poorer health status and the increased inclination for overweight/obesity has been conducted with adult participants. There is less information about these relationships among children. Furthermore, factors that are associated with overweight and obesity appear to be different between men and women, including relationships between weight status and income or education (10). Generally, lower income and low educational attainment have been associated with a higher risk of overweight or obesity among women more so than men, and much of this research comes from countries other than Canada (10-15). Existing Canadian studies suggest that education is a stronger determinant of obesity than income for women (10).

While few Canadian studies have found the same link between low income and education and the risk of obesity among children, the literature does indicate that living in a low income home or having parents with low educational attainment is associated with several predictors of overweight/obesity. These include lower fruit and vegetable intake, restricted access to recreation settings and disadvantaged neighbourhood conditions (which may result in less physical activity) and increased risk for smoking in the household (16-22). Most importantly, studies have consistently shown that the children of overweight or obese parents are at an increased risk of being overweight or obese themselves, and this relationship is pronounced between mothers and daughters (23-26). The current literature also suggests that children who are overweight or obese are much more likely to continue to be overweight and obese into adulthood (23, 27). As such, it is prudent to emphasize the prevention of overweight and obesity, especially among children, and as early as possible. To do this effectively requires elucidating proven and practical preventative measures. Recent studies suggest that the prenatal environment represents a potentially important influence on future weight status and hence an ideal time to begin prevention of future obesity risk (28, 29).

The prenatal environment in many ways "sets the stage" for future development, perhaps including body composition and weight status (28). Unfortunately, the high prevalence of overweight and obesity among the Canadian population translates into a high prevalence of women beginning pregnancy with a high weight. This has negative implications for the future weight status of both the mother and the child (30-32). In 2001, 10.7% of women in Nova Scotia were beginning pregnancy weighing 90 kg (198 lbs) or more (31). Having an overweight or obese BMI puts both mother and infant at risk for a number of complications during pregnancy and delivery (33). Such complications may be compounded if the mother also gains an excessive amount of weight during her pregnancy (34, 35). There is also evidence to suggest excessive gestational weight gain (GWG) perpetuates obesity in the next generation by causing high birth weight and macrosomia in infants and increasing the risk for these infants to become obese children and adults (36-38). Healthy weight gain during pregnancy, moderate physical activity and abstinence from tobacco and alcohol exposure during pregnancy are all factors that create a positive developmental environment for the infant. These factors may also have an impact on achieving a GWG within current recommendations and hence decrease the child's risk of an unhealthy weight in the future (39).

Single women, those with low educational attainment and low incomes and their children are underrepresented in the literature, especially in studies of pregnancy and the postnatal period. When these individuals are included in studies with women from a range of demographics, they are often in the minority and are more likely to be lost to follow-up in longitudinal studies. However, given that single women and lone mother families are at risk of living in a low income household, and given the link between low income or education and poorer health outcomes, it is important to examine obesity development in this population. In terms of exploring the prenatal environment, there is a need to determine factors associated with GWG specifically among women in low income communities. Smoking status, physical activity, and social support are potentially modifiable variables that could impact the odds of high GWG. It is also important to determine the long-term consequences of high GWG on future obesity risk of low income women and their children.

1.3 Research Questions

In a Canadian context, what demographic, interpersonal, and personal characteristics are predictive of GWG in a population of low income women from disadvantaged neighbourhoods? Is excessive GWG related to increased odds of weight problems among these women and their children longitudinally?

1.4 Objectives

This study involves three related objectives:

Objective 1: To determine factors associated with gestational weight gain among low income women.

Objective 2: To examine the relationship between gestational weight gain and weight status of the child at birth and at four years.

Objective 3: To examine the longitudinal relationship between pre-pregnancy BMI, gestational weight gain and maternal BMI at 4 and 8 years postpartum.

1.5 Definition of Terms

Body Mass Index: "a simple index of weight-for-height that is commonly used to classify underweight, overweight and obesity in adults. It is defined as the weight in kilograms divided by the square of the height in metres (kg/m^2)" (40).

Gestational Weight Gain (GWG): the amount of weight gained over the course of a pregnancy. GWG is typically calculated by subtracting the weight at conception or within the first few weeks of pregnancy from the last measured weight prior to delivery.

High Birth Weight (HBW): a birth weight of greater than 4000 g (8.8 lbs). HBW is a risk factor for birth injuries and is associated with higher infant mortality rates compared to mortality rates for infants weighing between 3000 g - 4000 g (41).

Low Birth Weight (LBW): a birth weight of less than 2500 g (5.5 lbs). LBW is a predictor of newborn health and survival (41).

Low Income Cut-Off (LICO): "an income threshold below which a family will likely devote a larger share of its income on the necessities of food, shelter and clothing than the average family" (42). Typically used as a measure to indicate individuals or households that are particularly disadvantaged or 'low income'.

Parity: number of children previously born.

Nulliparous: having not previously given birth.

Postpartum: the period following birth.

Socioeconomic Status (SES): a relative measure that includes some combination of educational attainment, employment, income and material environment to classify individuals or families somewhere on a scale from 'low' to 'high'.

Chapter 2

LITERATURE REVIEW

2.0 Literature Review

2.1 Overweight and Obesity

The prevalence of overweight and obesity has become a serious concern globally, and especially in developed countries. In North America rates of overweight and obesity have been rapidly increasing since the 1970s (5). Data from the 2003 Canadian Community Health Survey (CCHS) revealed that of adults 18 years or older, 41% of men, and 25.7% of women were overweight, and 14.9% of the over 18 population was obese (43). In the 2007 CCHS, the rate of self-reported obesity for the over 18 population had increased to 17% (44).Overweight and obesity rates are even higher in Nova Scotia compared to the national average (43). Fifty-eight percent of Nova Scotians 18 years or older were found to be either overweight or obese in 2003, compared to 50.1% for Canada as a whole (43). In 2007, the rate of self-reported obesity in Nova Scotia was more than 20%, while in Ontario, the rate of self-reported adult obesity was approximately 17% (the same as the national average) (44).

Excess weight is strongly associated with an increased risk of developing a number of serious co-morbidities including type II diabetes, cardiovascular disease, hypertension, stroke, gallbladder disease, osteoarthritis, sleep apnoea, several types of cancer as well as depression and other psychosocial conditions (45). The rising incidence of overweight/obesity and the associated negative health consequences result in worsening health and a shorter life expectancy for Canadians, and also presents a threat to the Canadian health care system (45). In 2001, the costs associated with overweight and obesity were estimated to be $1.6 billion (5). Anis et al. (2010) estimated the costs in 2006 based on 18 weight-related comorbidities and determined that the direct cost attributable to overweight and obesity in Canada was $6 billion, representing 4.1% of total health care expenditures (45).

2.1.1 Maternal Obesity

A high prevalence of overweight and obesity in the population also means that more women are entering pregnancy with an elevated BMI which may increase health risks for both themselves and their infant (46). Heslehurst and colleagues (2007) examined obesity trends in England and found that the proportion of obese women entering pregnancy doubled from 8% to 16% over a 19 year period of study (47). Over that same period, the proportion of women entering pregnancy with an ideal BMI decreased from 66% to 44% (47). In Nova Scotia between 1998 and 2001 the mean pre-pregnant weight increased from 61.8 kg to 69.6 kg, and the mean delivery weight increased from 76.3 kg to 84.7 kg (31). Additionally, the proportion of women in Nova Scotia with a pre-pregnant weight ≥90 kg increased from 4.1% in the period 1985-1991 to 10.7% in the period 1998-2001 (31). A survey of 22 birthing facilities in the Atlantic Canadian provinces in 2008 revealed that 71% were admitting five or more obese women per month (48). One third of the facilities reporting less than 1000 births per year also reported admitting more than 10 obese women per month (48). In a study of low income women in Ontario 18% of the participants had an overweight pre-pregnant BMI, and 11% had an obese pre-pregnant BMI (32). Women with high BMIs were also found to be more likely to have a child who was obese at 48 months, although the strength of the association was weak (32).

Women entering pregnancy with an obese BMI tend to be older and are more likely to have given birth to more than one child than those entering pregnancy with a normal, underweight or overweight BMI (47, 49). Cedergren (2006) also found that obese women were more likely to be smokers than non-obese women (49). In the above mentioned study of obesity trends in England, women in all BMI groups other than normal had increased odds of living in a more deprived quintile when compared to the women with normal BMIs (47). As the level of deprivation increased, so did the level of obesity (47).

In part to address the increasing proportion of women entering pregnancy with a high BMI, the Institute of Medicine (IOM) revised guidelines for recommended GWG in 2009. The purpose of these recommendations, which are specific to a woman's pre-pregnant BMI, is to provide a range of weight gain meant to optimize the health of both the mother and infant (50). There is currently an interest in determining the effects of excessive GWG (i.e. weight gain above the upper end of the recommended range) on pregnancy outcomes. Some research suggests that many of the pregnancy complications of maternal obesity are related to not only pre-pregnancy weight but also an interaction between pre-pregnancy weight and GWG (51, 52). For example, Ihunna and colleagues (2008) found evidence of "independent and combined effects of pre-pregnant BMI and GWG on infant birth weight" (p. 563) (52). Koepp and colleagues (2012) reported that while pre-pregnancy BMI on its own is an important predictor of birth weight, GWG also has an effect independent of pre-pregnant BMI (53). Obese women also face an increased risk of developing gestational hypertension, preeclampsia and gestational diabetes mellitus (51). Additionally, there is a higher probability of caesarean delivery with the associated risks of wound infection, excessive blood loss and postpartum endometritis (51). Alanis and colleagues (2010) examined the birth outcomes of women who were classified as "super-obese" (BMI ≥ 50 kg/m^2) (54). This group of women had the highest rates of chronic hypertension, preeclampsia, pre-gestational and gestational diabetes mellitus and caesarean delivery (54). Infants born to mothers with a super-obese BMI were 3.5 times more likely to be born large for gestational age (LGA) than those born to women with lower BMIs and they also had a significantly increased risk of being born with congenital anomalies (54). Hellerstedt (1997) also found increased odds of LGA among obese women (14.1% compared to 8.0% for women with a normal BMI) (39). Conversely obese women in this study had fewer small for gestational age infants (6.2% compared to 9.1% to women with a normal BMI) (39). Both high and low pre-pregnant BMI have been shown to be predictors of pre-term delivery (46).

Attaining a BMI within the normal range before pregnancy may help in reducing the risk of numerous pregnancy complications. Unfortunately this may be difficult to achieve for many women and many pregnancies are miss-timed or unplanned. As such, further investigation into the effects of GWG is warranted as weight gain during pregnancy may represent a modifiable risk factor when achieving a normal BMI prior to pregnancy has not occurred (55). GWG is discussed further in section 2.2.

2.1.2 Childhood Overweight and Obesity

Increases in childhood overweight and obesity have been substantial, according to Belanger-Ducharme and Trembley (2005) (5). Research from the UNICEF Innocenti Research Centre shows that Canada's rates of overall childhood obesity are among the highest of the nations within the Organization of Economic Cooperation and Development (56). In North America, even very young children are affected. Eighteen percent of children between the ages of 24 and 38 months living in an urban centre in *Connecticut, USA* were obese, of which 7% were extremely obese, and an additional 12% were overweight (57). While many of the comorbidities of overweight and obesity that are seen in adulthood do not affect children with excess weight, there is now an increasing prevalence of type II diabetes at younger ages, and increasing rates of chronic disease in young adults (4). Additionally, overweight and obesity typically persist throughout childhood and they greatly increase the chances of being overweight or obese as an adult (58). As a result of these trends, it is now predicted that today's generation of children will have a shorter lifespan than their parents (4).

In Nova Scotia, childhood obesity also has a significant impact on health care costs (59). Obese children in Nova Scotia have more physician visits and more specialist health care referrals than normal weight children (59). The significantly higher health care cost for obese children begins by 3 years of age (59). It is important therefore to find ways to prevent excess weight gain in infants and children and to intervene early.

It has been suggested that the prenatal and early postnatal environment and up until the preschool years could be critical periods where long-term regulation of energy balance is programmed and these periods may play a role in the development of childhood obesity (45, 60). Gestational weight gain, discussed in section 2.2, has been shown to have an impact on both infant birth weight and later development of obesity (52, 58, 61). Low and high birth weight, which may reflect various exposures in utero, have both been shown to affect future obesity risk.

2.1.2.1 Low Birth Weight and Rapid Weight Gain

Low birth weight (LBW) has been associated with low maternal pre-pregnancy BMI, low GWG or weight losses during pregnancy as well as maternal smoking (39, 52, 62-66). Infants born preterm and LBW must gain weight to achieve optimal health (67, 68). Typically by two years of age, catch-up growth is completed, and subsequent growth follows the genetic trajectory (68). However, infants who are small at birth, and who experience rapid postnatal weight gain or rapid "catch-up" often have higher BMI in late infancy and may be more likely to develop visceral adiposity, and adult-onset metabolic disease including Type II Diabetes and cardiovascular disease, with males being at greater risk than females (67, 68). Goodell and colleagues found that infants who experienced rapid weight gain between birth and one year of age were nine times more likely to be obese and 31 times more likely to be extremely obese in early childhood compared to those who had not (57). They concluded that rapid weight gain by one year of age was a significant predictor of obesity at two to three years in low income, minority children ($P<0.001$) (57). Early rapid weight gain may be related to the introduction of formula feeding and practices associated with formula feeding, overfeeding, and/or the early introduction of solid foods (69). However, parents who provide higher calorie diets for their infants may be doing so because they accurately perceive their infant's needs, and postnatal appetite, energy intake, and obesity risk may actually be pre-programmed by in-utero factors (70).

2.1.2.2 Smoking, Low Birth Weight and Obesity Risk

Infants born to smoking mothers are often born premature and/or LBW due to growth restrictions in utero, and often experience rapid catch-up growth, which, as previously described, is a predictor for later overweight/obesity (71). It has also been suggested that nicotine exposure in utero affects neurobehavioural impulse control which may lead to poorer satiation, increased appetite and resultant higher food consumption in childhood (72). Of Nova Scotia women aged 15 to 55 years, 30.7% reported smoking during their pregnancy or while breastfeeding or had been regularly exposed to second hand smoke during or shortly after their pregnancy (43). Several studies have determined that maternal smoking during pregnancy is associated both with LBW and with a greater likelihood of childhood obesity in the offspring (10, 39, 71, 73-75). In a study by Hellersted and colleagues (1997) the proportion of LBW and small for gestational age (SGA) was highest among the infants born to smoking mothers who had gained less than the recommendations set forth by the U.S. Institute of Medicine (IOM) (39). In a study of 4.5 year old children, maternal smoking during pregnancy, low socioeconomic status and parental overweight or obesity were the variables most significantly associated with childhood overweight (76). Similarly, children of women who smoked throughout their pregnancy were found to have higher rates of overweight (15.6%) and obesity (6.2%) at five to six years of age when compared with children whose mother had not smoked before, during or after their pregnancy (9.1% overweight and 2.8% obese) (72) . Among Greek children, maternal active and passive smoking during pregnancy increased the risk of overweight and actual overweight at three to five years of age (OR: 1.79; 95% CI: 1.13-2.82) (77). Two meta-analyses have found maternal smoking to be consistently associated with increased risk of overweight and obesity among infants and children whose mother smoked during their pregnancy, despite the differences in populations, birth year, and prevalence of overweight in each of the studies examined (75, 78). Mangrio and colleagues (2010) have suggested a synergistic effect between negative early life factors, such as smoking and parental overweight on the development of overweight and obesity in children (79). They found that children whose mother had smoked during pregnancy and who had at least one parent who was overweight had a statistically significant increase in the odds of being overweight at four years of age, but this relationship was not the same for children who had two normal weight parents (79).

Some authors have suggested that maternal smoking may increase the risk for obesity right into adulthood (73, 75). Among participants of the British Birth Cohort (born in 1958), individuals whose mother had smoked during pregnancy had a higher risk for obesity over the next three decades of their life, with a 40% increase in odds by age 33 years (73). Maternal BMI however, did not account for the elevated odds at 16, 23 or 33 years of age (73).

2.1.2.3 High Birth Weight and Obesity Risk

High birth weight (>4000 g) as well as macrosomia (>4500 g) have been associated with an increased likelihood of becoming obese in childhood (80, 81). Interestingly, Lausten-Thomsen and colleagues (2013) found a linear association between birth weight and childhood obesity, rather than the U-shaped association that has previously been reported (60). Because LGA and macrosomia have been associated with GWG above recommendations, they will be discussed, along with their consequences, in section 2.2.2 below.

2.2 Gestational Weight Gain

The amount of weight gained by a woman during her pregnancy has potential consequences for her health during pregnancy as well as for potential complications during delivery and has also been shown in a number of studies to have an impact on both her infant's birth weight and on that child's later weight status (38, 71). Some studies have found a U-shaped curve with weight gains at both the lower and higher extremes associated with a higher prevalence of offspring obesity during childhood, sometimes tracking into adolescence and adulthood (82, 83). As previously described, the IOM revised its recommendations for the amount of weight to be gained during pregnancy in 2009. The current recommendations are for a gain of 28-48 lbs for women with an underweight BMI (<18.5 kg/m^2); 25-35 lbs for women with a normal BMI (18.5-24.9 kg/m^2); 15-25 lbs for women with an overweight BMI (25-29.9 kg/m^2) and 11-20 lbs for women with an obese BMI (≥30 kg/m^2) (50).

High proportions of women continue to gain below and above the IOM recommendations with 18%-21.1% of women gaining less than recommendations, and 38%-57% of women gaining more than recommendations (39, 84-86). In Nova Scotia between 1988 and 2001 while mean pregnancy weight gain remained stable, the proportion of women gaining below and above the recommendations increased (31). The literature suggests that pre-pregnant BMI is associated with GWG. There is a trend of decreasing GWG with increasing BMI category (49, 86). Paradoxically, women with lower BMIs are more likely to gain within recommendations and women with higher BMIs are more likely to gain above recommendations (84). For instance, among participants in a 2006 study, 43.3% gained within the IOM recommendations for their pre-pregnant BMI, yet in a 2011 study with obese women as participants, only 25% of women gained within recommendations (84, 85). In another study, 62% of the overweight women gained more than the IOM guidelines, and were six times more likely to do so in comparison to women with normal pre-pregnant BMIs (86). Hellersted (1997) found that obese women gained one third less weight during their pregnancy than normal weight women with 38% actually losing weight or gaining less than seven kilograms (compared to only seven percent of normal weight women) (39). Women with the highest gains may be those with the lowest baseline BMI and the highest parity (85). This relationship may be explained by the fact that overweight women have a lower threshold of weight gain to exceed; thus while the actual amount of weight gain decreases with increasing BMI, there may be an increased propensity for the weight that is gained to exceed the lower threshold. However, up to 50% of normal weight women have also demonstrated excessive GWG (87).

In addition to pre-pregnant BMI, a number of other factors have been associated with GWG including maternal age, parity, smoking status, and physical activity levels (39, 49, 84-86). In terms of age, women at the lowest and highest ends of the spectrum may be the least likely to gain excessively. Women under 20 years of age or 40 years of age and older have been found less likely to gain above the IOM recommendations compared to women between 20 and 40 years old (84, 87).

Tobacco or cigarette smoking is typically associated with decreased weight gains or gestational weight loss although the association may be different based on BMI (85, 87). One study of obese women found that those who lost weight during pregnancy were almost two times more likely to use tobacco than the women who gain within the recommendations (85).

However, another study showed that among obese women, smoking status did not significantly influence GWG (9.3 kg for smokers versus 9.7 kg for non-smokers) (39). Smoking did affect the GWG of normal weight women however, with smokers gaining on average 13.4 kg compared to 15 kg on average for non-smokers (39). Despite smoking status apparently not affecting the GWG of obese women in this study, there were five times greater odds that the infants of these women experienced LBW, demonstrating that, “no level of GWG will eliminate the effects of cigarette smoking on birth weight” (p.595) (39). Given that smoking is still prevalent among women of child bearing age (for example, 30.7% of Nova Scotian women reporting having smoked during their pregnancy, while breastfeeding, or having been exposed to tobacco smoke during these times), further investigation into their effects on GWG is warranted (32, 43).

Interventions to control GWG utilizing physical activity have had mixed results (88). In a meta-analysis by Streuling, seven trials found decreased GWG in intervention groups involving physical activity, while five trials found no significant decreases in weight in the intervention groups compared to controls (88). Where physical activity was based on women’s perceptions of their activity, women who judged themselves as being less physically active compared to other pregnant women gained nearly two kilograms more than women who judged themselves as equally active and were also four times more likely to gain in excess of the IOM recommendations (86).

2.2.1 Excessive GWG and Pregnancy Complications

While it has been suggested that many of the complications of maternal obesity during pregnancy are attributable to pre-pregnancy weight status, some studies have demonstrated additional detrimental effects related to excessive GWG. High GWG (i.e. at the upper end of IOM recommendations or weight gain beyond recommendations) is consistently linked to increased odds of LGA birth, macrosomia and caesarean delivery (84, 87). Conversely, GWG below recommendations has been associated with increased odds of SGA (49, 87). However, among obese women, lower gains may actually be protective of other outcomes (84). Gaining less than the lower limit of the IOM recommendations has been linked to reduced risk of preeclampsia, caesarean delivery, and LGA birth among obese women (49). Cedergren (2006) observed the effects of high GWG on women of underweight, normal, overweight, obese and morbidly obese mothers and found slightly different outcomes. Underweight and normal weight women experienced doubled odds of preeclampsia and tripled odds of having a LGA infant when they had excessive GWG (49). Overweight women experienced an increased risk for requiring an instrumental delivery and obese women had an elevated risk for preeclampsia, caesarean birth and LGA infant (49). Both overweight and morbidly obese women who gained above recommendations had an increased risk of fetal distress (49). Stotland and colleagues suggest that infants born to healthy mothers may not experience the same elevated risk from SGA birth as those infants who are born small due to health problems of their mother (84). As such they propose that gaining below recommendations poses less risk than gaining beyond recommendations (84).

2.2.2 Excessive GWG/Maternal Obesity and Decreased Breastfeeding

Women with a higher BMI (i.e. those who are classified as overweight or obese) may have a decreased likelihood of initiating breastfeeding and may be more likely to terminate breastfeeding before women of normal weight (89). A review by Wojcicki in 2011 showed a pattern of lower initiation and duration rates among overweight and obese women (89). Overweight or obese women who experience complications during pregnancy or delivery have also been found less likely than normal weight women to initiate breastfeeding and regardless of complications are more likely than normal weight women to cease breastfeeding early with an 11% increased odds of terminating breastfeeding with each additional month (90).

While high BMI has been associated with a decreased intention to breastfeed, it has also been shown that women who are heavier experience more difficulty and complications with breastfeeding (91). These include physiologic complications such as polycystic ovary syndrome, diabetes, and obstetric complications which may negatively impact milk production; macrosomia; physical difficulties (i.e. large breasts) which make positioning the infant difficult and can result in a poor latching on by the infant and discomfort or poor body image (91, 92). Caesarean deliveries have also been suggested as a possible reason behind these lower initiation rates as this type of delivery can result in delayed mother-infant contact and delayed milk production (91). This can lead to negative psychological consequences if a woman had hoped to breastfeed her child as well as resulting in the mother missing out on benefits of breastfeeding such as delayed menses and enhanced postpartum weight loss (74). Additionally, the infant does not receive the many benefits of breast milk and some studies suggest that infants not fed breast milk have an increased likelihood of developing overweight or obesity in childhood (93-95).

2.2.3 Excessive GWG and Long Term Weight Consequences

Excessive GWG has been associated with increased odds of postpartum weight retention or becoming overweight (96-98). While a number of factors including breastfeeding duration and smoking status have also been implicated, it seems that GWG beyond IOM recommendations in addition to pre-pregnancy BMI may be the strongest predictors of weight retention or postpartum overweight/obesity risk (97, 98).Walker (2009) clustered study participants based on their pre-pregnancy weight, GWG and weight retention. Out of the five clusters created, only one averaged no retention at 12 months postpartum (96). The individuals in this cluster were predominantly normal weight before pregnancy and had gained a low amount of weight during pregnancy (96). The highest weight retention was among the cluster of women who had been overweight before pregnancy and had very high gains during pregnancy (average amount of weight retained at 12 months postpartum was 22.8 kg) (96). Gunderson and colleagues (2000) found that close to 11% of their participants whose GWG was beyond the IOM recommendations had become overweight by the time of their second pregnancy (97). These women had three times greater odds of being overweight than the women who had gained less than or within the IOM recommendations (97).

Additional factors such as low age at menarche, short interval between menarche and first pregnancy, and maternal age have been associated with increased odds of postpartum weight retention (97, 98). For instance women between 24-30 years of age were shown to have increased odds of becoming overweight between pregnancies, with no difference in odds between women 18-23 years and 30 years or older (97). These factors are however less amenable to intervention (especially in the case of unplanned pregnancy). Breastfeeding has been suggested as a factor that may decrease the odds of postpartum weight retention, but Gore and colleagues (2003) suggest that for long term benefits, lactation may need to be maintained for a longer duration than is common among most breastfeeding mothers (98). Women who quit smoking during and after pregnancy may also have increased odds of postpartum retention or postpartum gains as smoking cessation is frequently associated with weight gains indicating that special attention or counselling may be required for these women (98).

Ramachenderan has summarized the potential effect of GWG on longer term weight status well, noting that, “multiplied over decades of post-reproductive life, this impact of pregnancy-associated weight gain will cause a substantial elevation of long-term risk, particularly of cardiovascular disease" (p.230) (33).

2.2.4 Effects of Excessive GWG on the Child

Studies of GWG have generally found that gaining more than the recommended amount of weight during pregnancy increases the offspring's odds for development of overweight or obesity. Macrosomic birth has been proposed to be related both to maternal pre-pregnant weight and to weight gained in pregnancy (33). Heude and colleagues (2005) found that maternal BMI and weight were associated with the child's adiposity at birth, decreased somewhat over the first several years and then remained stable throughout childhood and following puberty (99). They suggest that the correlations between parental and child adiposity are due to shared genes and environmental factors including foods eaten, eating habits and physical activity patterns (99). Stotland and colleagues (2006) argue that high maternal weight gains during pregnancy have adverse effects for neonates even after controlling for birth weight stating, "excessive weight gain is not simply a marker for macrosomia related adverse outcomes" (p. 639) (84).

A significant positive association has been demonstrated between GWG and weight in the offspring at birth, in adolescence and in adulthood (82). While most studies have consistently found that GWG above the recommendations increases the odds of later overweight or obesity in the offspring, there is research to suggest that the effect is more prominent for some maternal BMI categories than for others (37, 83, 100, 101). Among Portuguese children aged 6-12 years, there was a significant association between birth weight and GWG and childhood overweight, with increasing odds of childhood overweight with increasing GWG (36). The odds ratio for children whose mother gained >16 kg during pregnancy was 1.53 compared to those whose mothers gained <9k g, and this remained after adjustment for various cofounders (although the odds ratio was reduced to 1.27) (36). Wrotniak and colleagues (2008) similarly examined the relationship in seven year old children and determined that children whose mothers gained more than the recommendations had a 48% increase in the odds of being overweight (101). The relationship was strongest for those women who had an underweight pre-pregnancy BMI (101). Olson and colleagues (2009) found however that excessive GWG increased the odds of childhood obesity at age three years most prominently among the children of overweight and obese women (37). Forty-seven point five percent of the children of overweight mothers who had gained beyond recommendations were overweight at three years compared to 23.7% of the children of normal or underweight mothers who had gained more than recommendations (37). For women with a normal early pregnancy BMI, a net GWG of 30 lbs (thus exceeding IOM recommendations with the added weight of a normal sized term infant) resulted in a four times greater odds of their child being overweight at three years compared to a normal weight woman who's total gain was within recommendations (37). In comparison, obese women who gained within the recommendations had children with no increased odds of overweight at three years. However, if women in this category gained more than the recommendations, their child's odds increased six times that of the reference (37). For each one unit of increase in maternal BMI, the odds of childhood obesity (at three years) increased by approximately 10% (37). Stuebe and colleagues (2009) examined retrospectively collected data and determined that a GWG either above or below 15-19 lbs was associated with an increased odds of offspring obesity at both 18 years and in adulthood (36-46 years of age) (83). This association was modest among the normal weight mothers and stronger among those with higher pre-pregnant BMIs (83). The lowest prevalence of adverse birth outcomes among very obese women (BMI ≥40) may actually result from women losing weight, which is counter to current recommendations (82).

High GWG may affect future obesity risk in the offspring by exerting some effect on the developing physiology of the fetus as well as impacting fetal adipose deposition which then results in further consequences downstream in childhood and potentially adulthood (38, 82, 83). Stuebe and colleagues (2009) have also noted that because maternal BMI is often more strongly related than paternal BMI to obesity in the female offspring it can be suggested that, “the intrauterine environment acts synergistically with genetic factors to influence obesity risk” (p.751) (83). Therefore, GWG represents a potentially modifiable risk factor for metabolic disease of future generations (83)

Chapter 3

THEORETICAL FRAMEWORK

3.0 Theoretical Framework

The theoretical framework selected to guide this research was the Social Ecological Model (SEM). This model considers individual factors in addition to factors at the interpersonal and environmental levels in influencing individual behaviour. The SEM assists in the classification of these factors into levels or spheres of influence (e.g. the individual, peer groups, community, etc) and the model can be used to examine their relationships/interconnectedness. It is a useful model for this study because it provides a way to consider how the relationships between variables found among this study's unique, economically disadvantaged population are similar to or different than those found among populations previously studied in the literature.

3.1 The Social Ecological Model

The SEM provides a framework for examining the relationships between the multiple levels of influence in an individual's life. The model is based on the belief that the behaviour of individuals is influenced not only by personal characteristics but by the social and physical environment as well, and that individual behaviour and the environment are interconnected through reciprocal causation (102, 103). Behaviours and exposures in turn influence an individual's health status. Different users of this model have identified varying levels of influence, the most common being the intrapersonal level reflecting individual characteristics, knowledge, skills and beliefs; the interpersonal level involving relationships and social support including interactions with family and peers and; the community level, made up of the environment and structural factors such as policies and community resources (103). The model used by the Centres for Disease Control (CDC) describes four levels; individual, relationship, community and societal (104).

As described above, the SEM can provide a research framework to identify what variables should be examined as well as how to view the interconnectedness of those variables (103). Cassel for instance describes the SEM as an organizing framework which can be used to explore factors related to obesity (105). Cassel used the framework to identify "intervention points". For example the obesogenic environment represents an intervention point between social disparities and health disparities, and individual behaviour represents an intervention point between obesity disparities and health disparities (105). Examining the relationships between various levels of influence can also help identify protective factors that exist and which can be promoted in intervention programs at both the individual level to change behaviour and environmentally focused efforts to improve the physical or social setting (105, 106).

Physical and social conditions affect one's physiologic, emotional and social well-being which in turn drives behaviours that affect health (106). Stokols (1996) notes that the efforts of an individual to change their behaviour can be impeded by numerous constraints such as economic (lack of money or education), social, or cultural in addition to lack of time and energy or by chronic exposure to an environment or social/familial group where negative health behaviours or factors are prevalent (106). In this study, household income, educational achievement, health problems, social support and marital status are considered as potential predictors of GWG. While in the past many interventions have focused on the individual and attempted behaviour change directly, using the SEM may reveal important environmental or social conditions that are actually driving individual factors, especially in an economically disadvantaged population. Stokols describes how a stressful job and lengthy commute may be the reasons why an individual smokes and drinks (to deal with stress) and does not engage in physical activity (lack of time and energy) (106). Hence, certain factors exert a disproportionate influence on health. Through examining this relationship it may become clear that to improve the other lifestyle behaviours (e.g. smoking, drinking, lack of physical activity), the more influential ones (e.g. a new job and less stressful working situation) may be most beneficial (106). Similarly, in this study, modifiable characteristics such as physical activity, alcohol consumption and smoking status are examined as potential predictors of GWG while controlling for environmental and interpersonal factors to determine which variables lead to the best predictive model. Hence, the model is used to determine which levels of influence have the greatest association with GWG and if GWG itself is associated with maternal and child weight outcomes after accounting for other characteristics.

Because the model allows for a way of interpreting and understanding the "dynamic interplay among persons, groups, and their sociophysical milieu", it can also be used to explain why relationships established in one population may be different in another (p.283) (106). Given that the community level factors within an economically disadvantaged neighbourhood are different from those of more affluent neighbourhoods and that demographic factors such as country of birth and LICO status and intrapersonal characteristics such as educational achievement or smoking status are known to be different among individuals in economically disadvantaged neighbourhoods, it can also be expected that the way these factors interact could be different between lower and higher SES populations. Theoretically, because a population made up of women living in economically disadvantaged neighbourhoods, who are primarily of low SES is a fairly homogeneous group it may be more difficult to find significant relationships. Conversely, examining such a specific and unique population may illuminate different associations or relationships than have been previously identified among more heterogeneous groups or among women of higher SES. This in turn can be useful for elucidating recommendations for policy or interventions to meet the needs of economically disadvantaged women. Addressing specific factors (including those at the highest level of influence) that lead to GWG outside of recommendations among economically disadvantaged women is important because, as Cassel points out, interventions that fail to alter the environmental variables that contribute to unhealthy behaviours are unlikely to be effective or sustainable (105).

Figure 1 shows how the variables for this study were classified into three spheres of influence, the individual level, household level and community level. Figure 2 provides a model to predict how these variables influence each other as well as identifying potential intervention points. This SEM served as tool for the selection of BBBF survey questions and variables to use and these models created from those variables were utilized again during the shaping of the discussion and conclusions of this study.

Figure 1. A Social Ecological Model to Predict Variables Related to GWG

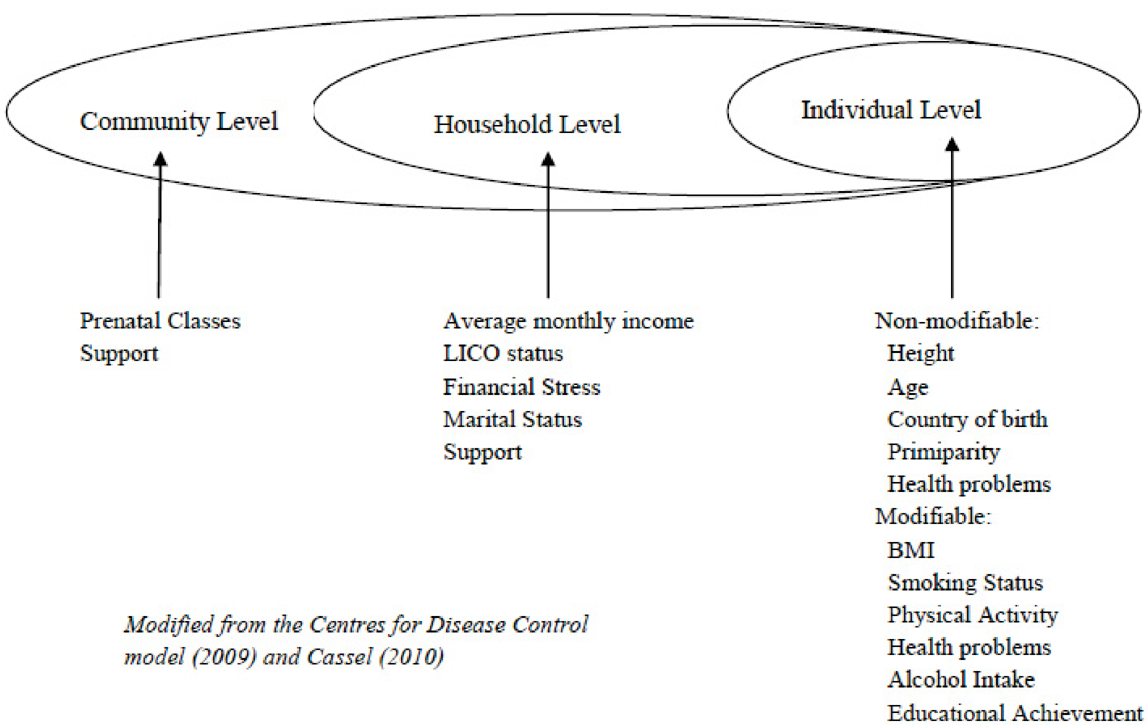
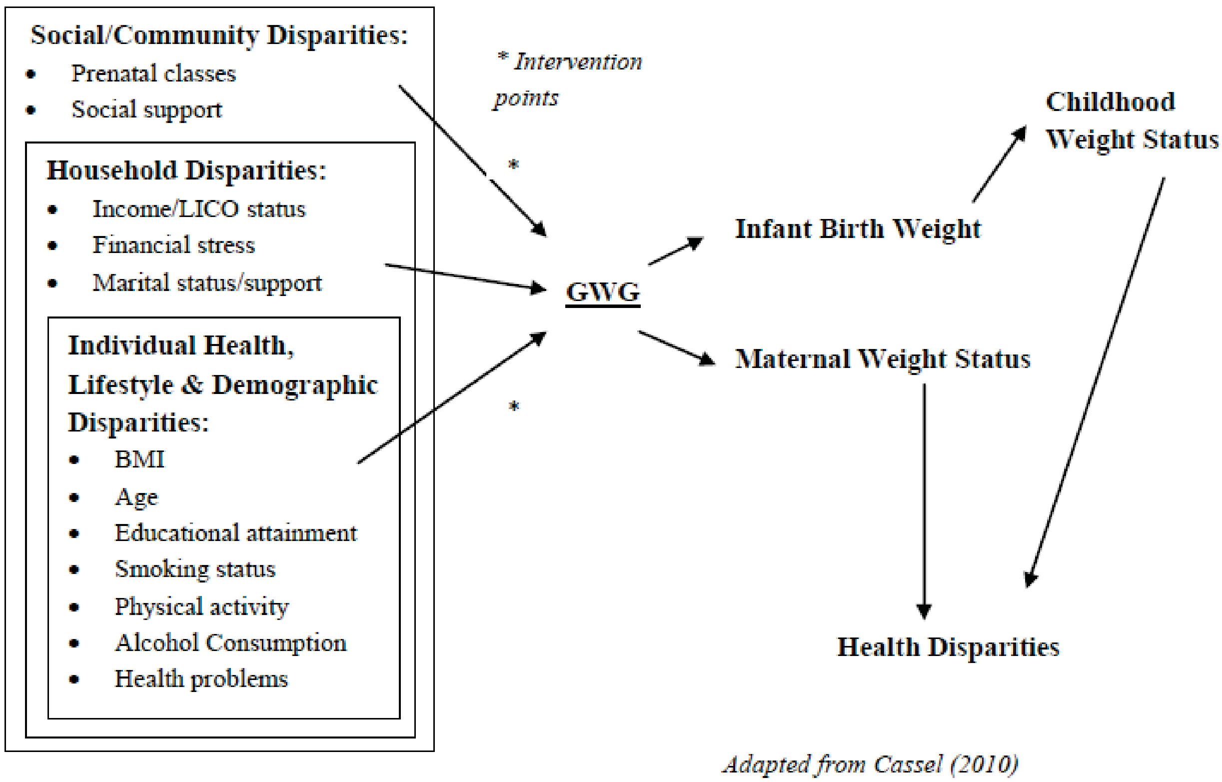


Figure 2. Relationships between Community, Household and Individual Disparities and Weight and Health Outcomes



Chapter 4

METHODS

4.0 Methods

The data for this study were collected through the Better Beginnings Better Futures (BBBF) Project, which took place in several economically disadvantaged communities in Ontario, Canada. The communities which took part in BBBF were funded to provide primary prevention programs with a focus on children belonging to one of two categories: birth to four years (younger cohort) and ages four to eight years (older cohort). The younger cohort communities, from which the data for this study will come, included Guelph, Kingston, Toronto and Ottawa, as well as Peterborough which was a comparison site. All individuals living in these communities and who had given birth to an infant in 1994 were eligible to participate as were families who later moved into any of the communities and had a child born in 1994. The invitation to participate was presented by a public health nurse or social worker.

The intention of BBBF was not to provide an evaluation of participation in the programs, but rather to provide universal access of services to the community with the aim of primary prevention. The study used two quasi experimental designs, (1) a baseline-focal design and; (2) a longitudinal comparison site design. Baseline data was collected in 1992-93 prior to the program implementation. The baseline data collected included a variety of variables including information on socioeconomic status, family characteristics and health measures, infant characteristics and neighbourhood characteristics.

The goals of BBBF were to (1) reduce emotional and behavioural problems and promote healthy development of young children; (2) strengthen parents', families' and neighbourhoods' ability to respond to children's needs; (3) develop local organizations to provide programs to children birth to four or four to eight years of age and their families that respond effectively to local needs; (4) to encourage parents/citizens to participate as equal partners in developing and carrying out the programs and; (5) to establish partnerships with existing and new service providers and schools (107).

In 1994, the longitudinal phase of BBBF began. There was an emphasis placed on community participation, and members of the BBBF communities were invited to attend planning and steering committee meetings and were also given volunteer positions or hired on as employees to run the program. This involvement was intended to provide appropriate community support and to give the community participants knowledge, confidence and self-efficacy to improve their lives and the lives of their children (108).

As previously described, all families with a child born in 1994 and living within the BBBF communities or the comparison site communities were eligible to participate in the research. Families were initially approached by a public health nurse or social worker while in hospital after the birth of their infant. If they showed an interest in participating, follow-up in their home was completed by project research assistants who gave further information on the study and obtained signed consent. The first set of data was collected around the time the infant was three months old. Families who moved into one of the communities and had an infant three months old or older were also recruited. Additional data were collected when the child was approximately18, 33, and 48 months old, and eight years after the initial survey. The interviews and child testing were conducted in the participants' home with the infant's primary care provider, which most often was the infant's mother.

4.1 Variables

The parent interviews were divided into sections which focused on various aspects of the participants' background, living situation and interactions with their children, family and community. Survey questions that were used for this study are listed in Appendix I.

At the three month and 18 month parent interviews participants were asked how much they had weighed prior to their pregnancy and how much they had weighed at the end of their pregnancy and this was recorded in pounds. At each parent survey participants were also asked to report their height and current weight, recorded in inches and pounds respectively. For the purposes of this study a new height variable was also created to express height in centimeters for comparison with a previous study. GWG was calculated by subtracting pre-pregnancy weight from weight at the end of pregnancy and pre-pregnancy BMI was calculated by dividing pre-pregnancy weight by height-squared, multiplied by 703 to give a value equivalent to kg/m^2. BMI was further classified into four categories; underweight, normal, overweight and obese (table 1). GWG was then classified as below, within or above IOM recommendations according to each participant's pre-pregnant BMI (table 1). Weight losses were considered "below recommendations" and were grouped into this category as has been done in previous research (55).

Table 1: IOM Recommendations for Gestational Weight Gain (50)

Pre-pregnant BMI category	**Recommended Total Weight Gain (range in pounds)**
Underweight (<18.5 kg/m^2)	28-40
Normal weight (18.5-24.9 kg/m^2)	25-35
Overweight (25-29.9 kg/m^2)	15-25
Obese (≥30 kg/m^2)	11-20

Participants reported their child's birth weight and this was recorded in pounds and ounces. For the purposes of this study a single variable for birth weight, expressed as pounds, was created using these existing pounds and ounces variables. Following established guidelines height and weight were measured twice for each child at approximately 48 months (four years) of age (109). Height was measured to the nearest 0.1 cm using a modified tape measure

(Microtoise, CMS Weighing Equipment, London, UK); weight to the nearest 0.5 lb with a strain-gauge digital scale (Wonderscale, Health-o-meter, Inc., Bridgeview, Illinois). A third measure was taken if the first two measures differed by 0.5 cm or 0.5 lb respectively; the average of the two closest measures was then recorded. Weight-for-height z-scores were calculated using Epi Info, version 5.01 (USD, Incorporated, Stone Mountain, GA), based on National Center for Health Statistics reference data (110, 111). Z-scores close to the median (zero) and those within one standard deviation above or below zero are considered within the normal range (table 2). These z-score lines are derived from the measurements of children in the WHO multicentre Growth Reference Study (112). Z-scores far from the median in either direction indicate potential growth problems. For the purposes of this study, three categories of growth problem indicators were created; wasted/normal, possible risk for overweight, and overweight/obese, as indicated by the shading in table 2.

Table 2: Z-score Indicators of Growth Problems (112)

Z-score	Weight-for-Height Growth Problem Indicator
Above 3	Obese
Above 2	Overweight
Above 1	Possible Risk for Overweight (A trend towards the 2 z-score line shows a definite risk)
0 (Median)	Normal range
Below -1	Normal Range
Below -2	Wasted
Below -3	Severely Wasted

Demographic questions asked of the participants included the country of the participants' birth, their birth date (year, month, day), educational achievement, average monthly household income, and marital status. Additional topics asked about with respect to the prenatal period included smoking status and the presence of other smokers in the home, physical activity, attendance at prenatal classes, whether or not participants experienced health problems, if participants had support from friends or family and if participants had consumed alcohol. Participants were also asked about their infant (referred to in survey guides as the focal child) including the infant's birth weight, if the infant had been breastfed and if so, for how long. A complete list of variables for this study is found in table 3.

Table 3: List of Variables

Variable Name	Definition	Response Categories
3 Month or 18 Month Interview		
Pre-pregnancy weight	Self-reported	lbs
Height	Self-reported	cm
End of pregnancy weight	Self-reported	lbs
Stature	Categorization of self-reported height	157cm or taller = 0; Less than 157 cm tall = 1
Gestational weight gain	End of pregnancy weight – pre-pregnancy weight	lbs
Gestational weight gain classification	GWG classified according to pre-pregnant BMI and IOM recommendations. See table 1	Within recommendations = 0; Below recommendations (low) = 1; Above recommendations (high) = 2
High gestational weight gain	GWG above recommendations	No = 0; Yes = 1
Low gestational weight gain	GWG below recommendations (including weight loss during pregnancy)	No = 0; Yes = 1
Pre-pregnant BMI	(Pre-pregnancy weight in lbs / height in inches^2) x 703 ǂ	kg/m^2
Pre-pregnant BMI classification	See table 1	Normal = 0; Underweight = 1; Overweight = 2; Obese = 3

Smoking Status	Non-smokers did not smoke in the month before pregnancy or during pregnancy. Former smokers smoked the month before pregnancy but quit before or during pregnancy. Smokers smoked throughout pregnancy.	Non-smoker = 1; Former smoker = 2; Smoker during pregnancy = 3
Age	Age at child's birth calculated by: child's birth year – mother's birth year and adjusted by month of child's and mother's birth	Years
Age classification	Age at child's birth	20-29 years = 0; < 20 = 1; ≥30 =2
Physical activity (PA)	Any type of activity to increase heart rate or breathing for 15-20 minutes during the first 7 months of pregnancy	On average 0 times per week = 0; On average, at least once per week = 1
Frequency of physical activity	Rate of participation in any type of activity to increase heart rate or breathing for 15-20 minutes during the first 7 months of pregnancy	Less than four times per week = 0; Four or more times per week = 1
Prenatal classes	Attendance at prenatal classes one or more times during pregnancy	Did not attend = 0; Attended = 1
Nulliparity	Self-reported number of previous pregnancies	One or more previous pregnancies = 0; No previous pregnancies = 1
Health problems during pregnancy	Self-report of any health problems during pregnancy	No = 0; Yes = 1
Country of birth	Participant's birth place	Outside of Canada = 0; Within Canada = 1
Educational achievement	Highest level of schooling completed at time of interview	No high school diploma = 0; High school diploma or more educational achievement = 1
Low income cut-off status	Value of average monthly income x 12 months in relation to the low income cut-offs. An indicator of the sufficiency of household income to provide necessities given the number of people in the household	At or above cut-off = 0; Below cut-off = 1

Monthly household income	Average total monthly household income from all sources before taxes or other deductions	$
Marital status	At time of interview: married participants are those living with their husband; partnered participants are those who live with their partner but are not married; lone or single participants are those who never married or are separated and do not live with a partner	Married = 0; Partner = 1; Lone or separated = 2
Support during pregnancy	Received support or help from people or groups (friends, relatives, parent groups) during pregnancy	No = 0; Yes = 1
Other smokers in the household	Other members of the household smoking during the participant's pregnancy	No = 0; Yes = 1
Alcohol consumption	Consumption of alcohol by the participant during pregnancy	No = 0; Yes = 1
Financial stress	Not enough money for food and living expenses in the previous 3 months from the time of the interview	False = 0; True = 1
Birth weight of child	Reported by mother	lbs
Birth weight classification of child	Normal birth weight is 5.5 to 8.8 lbs; low birth weight is less than 5.5. lbs, high birth weight is more than 8.8 lbs	Normal = 0; Low = 1; High = 2
Breastfed status	Breastfed status of the child. If the child was breastfed at least once he or she is considered "ever breastfed"	Never breastfed = 0; Ever breastfed = 1
Duration of breastfeeding	Length of time the participant reported breastfeeding the child.	Months
48 Month Parent Interview		
Weight-for-height z-score	48 month measure of participant's focal child. Measured and calculated by trained research staff.	standard deviation units

Weight-for height z-score classification	See table 2	Normal/wasted = 1; possible risk of overweight = 2; overweight/obese = 3
4-year postpartum monthly household income	Average total monthly household income from all sources before taxes or other deductions	$
4-year postpartum smoking status	Current smoking status. Non-smokers reported smoking 0 cigarettes per day, smokers reported smoking less than half a pack or more per day	Non-smoker = 0; Smoker = 1
4-year postpartum weight	Self-reported weight of participant	Lbs
Grade 3 [8 year] Parent Interview		
8-year postpartum monthly household income	Average total monthly household income from all sources before taxes or other deductions	$
8-year postpartum smoking status	Current smoking status. Non-smokers reported smoking 0 cigarettes per day, smokers reported smoking less than half a pack or more per day	Non-smoker = 0; Smoker = 1
8-year postpartum weight	Self-reported weight of participant	Lbs

ǂ This formula is a variant of the formula [BMI = weight in kg / height in $m^{2]}$ and was used because respondents reported height in feet and inches and weight in pounds. BMI is reported as kg/m^2 throughout the study.

4.2 Ethical Considerations

This study received ethical approval from the Mount Saint Vincent University Research Ethics Board prior to initiation of data analysis. Secondary analysis poses minimal risk to the participants. All identifiers have been removed from the data and thus are not available to the researcher, nor were they made available in the analysis or written thesis. All confidential BBBF information is contained on a password protected computer and data stick. Hard copies of data and information relating to BBBF are stored in a locked filing cabinet in the office of Dr. Melissa Rossiter PhD, PDt. at the Mount Saint Vincent University campus. Confidential information is made available only to the researcher and supervisor (Dr. Melissa Rossiter) and other members of the thesis committee. Upon completion of this project, any confidential materials will be destroyed.

4.3 Data Analysis

Data were analysed using SPSS statistical analysis software (versions 20.0 and 21.0 SPSS Inc., Chicago, Illinois). Statistical analyses include Chi-Square test for independence, analysis of variance (ANOVA), correlation, multiple linear regression and binary logistic regression. Differences were considered statistically significant at the $p < 0.05$ level unless otherwise stated.

Univariate analyses were conducted to describe the characteristics of the participants (average BMIs, age, GWG, monthly household income) and their children (birth weight, duration of breastfeeding, weight-for-height z-scores), as well as the frequencies of the study variables among the participants (BMI classifications, GWG classifications, smoking status, physical activity, nulliparity, health problems, country of birth, educational achievement, LICO status, marital status, support, other smokers in the home, alcohol consumption, and financial stress) and the participants' children (birth weight classification, weight-for-height z-score classification, breastfed status). Frequencies of demographic variables were compared between the communities. Some significant differences emerged, notably, differences in the proportion of participants born in Canada and the proportion of participants living below the low income cut-offs. These differences have been described previously (113). Because all of the communities were selected due to their being considered "disadvantaged" and because the main interest of this study was to explore factors associated with GWG rather than effects of living in a certain community, the participants were analysed together for all further analyses.

4.3.1 Objective 1 Analyses

As described previously, the purpose of the first objective was to investigate variables hypothesized to have a relationship with gestational weight gain and to determine an equation to predict gestational weight gain as a continuous variable. First, bivariate analysis was conducted to identify variables associated with gestational weight gain. Analysis of variance (ANOVA) was used to compare mean gestational weight gain between classifications of all prenatal variables that could be classified into two or more categories. To test the assumption of homogeneity of variance, Levene's test of equality of variances was included with each ANOVA test. In cases where the null hypothesis for equal variances of the dependent variable across groups was rejected a, (i.e. where the Levene statistic was <0.05), a Kruskall Wallis test was conducted. In each case there were no major discrepancies between the results of the ANOVA and the Kruskall Wallis test. The p-value, R-square and R-square adjusted values are reported for each ANOVA test in addition to the mean GWG for each classification. In cases where the independent variable had more than two categories and a significant difference in mean GWG was found, a post-hoc Tukey test was conducted to identify which categories of the dependent variable had significantly different average GWG values.

The IOM recommends different ranges of weight gain during pregnancy based on a woman's pre-pregnant BMI as previously described. As such GWG was also explored as a categorical variable identified as GWG classification. To determine if any of the demographic and prenatal variables were related to a difference in the proportion of women gaining below, within or above IOM recommendations, Chi-square tests were conducted. The Chi-square test statistic, degrees of freedom (df) and p-value are reported for each test.

Following the bivariate analysis, linear regression models were built with the purpose of identifying the best model to predict GWG. The first model to be tested included all of the potential predictor variables examined in the bivariate analysis, regardless of the significance demonstrated through ANOVA or Chi-square tests. Variables that were not found to be significant and which did not contribute to the predictive ability of the model were dropped one-by-one sequentially in order of least significance/least contribution to the model until a model with the least number of significant variables making a contribution remained. Once these variables were identified the model was again entered into SPSS using the "Enter" method to maximize the number of participants included in the analysis. As previously described, variables such as GWG/GWG classification or BMI/BMI classification that could be expressed both continuously or categorically were included in the model in their continuous form. The final model to predict GWG included pre-pregnant BMI, country of birth, age and financial stress. A second model was entered into SPSS using pre-pregnant BMI classification in place of pre-pregnant BMI to determine if the BMI cut-points identified by the World Health Organization (i.e. underweight, normal weight, overweight, obese) could be used to predict increased GWG.

Once the models best able to predict GWG were established (one using the continuous version of pre-pregnant BMI and the other using the categorical version) the models were checked for linearity, collinearity, and outliers. Linearity was assessed by examining bivariate scatterplots of each predictor variable with the dependent variable (GWG) and confirming a significant F-statistic. Collinearity was assessed by examining correlation matrices, Variance inflation factors (VIFs), and Condition indices (CIs; less than 30 was considered to indicate that collinearity was not an issue). A case analysis was also performed; any cases with outliers beyond 3 standard deviations were removed from the model and the regression run without them. The significance of the variables as well as the above mentioned plots were then examined to see if there were any differences due to removal of the outliers. The assumptions of normality and homoscedasticity were also checked. To assess normality, histograms of standardized residuals and normal P-P plots of regression standardized residuals were examined. Homoscedasticity was checked by creating a plot of standardized predicted values versus standardized residuals for each model. Plots where the residuals were randomly scattered around a horizontal line drawn at zero on the y-axis were considered to meet the assumption of equality of variances.

To explore the relationship between demographic/prenatal variables and GWG further, binary logistic regression models were built to predict high GWG (a category of GWG classification). The initial model included all predictor variables examined in the bivariate analysis and as previously described any variable that could be expressed continuously was used in that form. As was done for the linear regression models, variables that were not found to be significant and which did not contribute to the predictive ability of the model were dropped one-by-one sequentially in order of least significance/least contribution to the model until a model with the least number of significant variables making a contribution remained. Once these variables were identified the model was again entered into SPSS using the "Enter" method to maximize the number of participants included in the analysis. Logistic regression models were also assessed for fit by examining the Hosmer and Lemeshow statistic and significance and examining bivariate scatterplots.

4.3.2 Objective 2 Analysis

As previously described, the purpose of the second objective was to examine the relationship, if any, between GWG and birth weight controlling for demographic variables and maternal characteristics. These variables included the mothers' pre-pregnant BMI and smoking status during pregnancy, the presence of other smokers in the house during the child's gestation, monthly household income, the mothers' educational attainment and the mothers' age at their infant's birth. To determine if any of these variables had a bivariate relationship with birth weight, ANOVA tests were used. The same methods described for ANOVA in objective 1 were used to find differences in average birth weight, including the use of Kruskall-Wallis tests and post-hoc Tukey tests. P-values, R-square and R-square adjusted values for each ANOVA test are reported in the Results section.

Differences in the proportion of infants born low, normal or high birth weight by demographic and maternal characteristics were investigated using Chi-square tests. The Chi-square values, df and p-value for each test are reported in the Results section.

Following bivariate analysis, multiple linear regression models were constructed to determine if a model using the variables examined in the bivariate analysis could be found to predict birth weight. The procedure described above for creating a linear regression model was used again here and as per the procedures described in objective 1 the final model was assessed for linearity, normality, homoscedasticity, collinearity and outliers.

Binary logistic regression models were built in an attempt to predict high birth weight and, through separate model construction, low birth weight. However, a significant model could not be found to predict either high or low birth weight using the variables examined in the bivariate analysis including GWG.

4.3.3 Objective 3 Analysis

As previously described, the purpose of the third objective was to examine the longitudinal relationship of GWG and BMI, examining BMI at pre-pregnancy, four years postpartum and eight years postpartum and controlling for monthly household income, smoking status, age and educational attainment. First, BMI at four years post partum was analyzed with monthly household income, age, and pre-pregnant BMI to look for correlations. The same analysis was conducted for BMI at eight years postpartum and the relationship between BMI at four and eight years postpartum was also analyzed to determine if there was a correlation. Scatter plots were created for each correlation to examine the shape of the relationship and to look for outliers.

Next, ANOVA was used to look for differences in average BMI at four years, and then at eight years postpartum based on educational attainment and smoking status. An F-statistic for the Levene's test of equality of variance was generated and in each case the null hypothesis was retained, negating the need for a Kruskall-Wallis test. Because there were only two categories of educational attainment (less than high school and high school or above) and smoking status (smoker and non-smoker) post-hock Tukey tests were not required.

Following the bivariate analysis described above, multiple linear regression models were built with either BMI at four years postpartum or BMI at eight years postpartum as the dependent variable. To predict BMI at four years postpartum an initial model was constructed which included GWG, pre-pregnant BMI, educational attainment, monthly household income, age and smoking status. Only pre-pregnant BMI and GWG were found to be significant predictors, so the other variables were dropped from the model one at a time in the following order, (1) monthly household income, (2) smoking status, (3) age. To determine if either low or high GWG could be a predictor of BMI at four years postpartum an additional linear regression model was created with the variables high GWG and low GWG in place of GWG (continuous). Only pre-pregnant BMI and high GWG were found to be significant predictors. The details of these regressions are reported in the Results chapter.

Linear Regression models were also built to predict BMI at eight years postpartum and began with the same set of variables used to predict BMI at four years postpartum with the addition of four-year postpartum BMI. The variables which were found to not be significant contributors to the model were educational attainment and age and they were dropped one at a time in that order. The final model included pre-pregnant BMI, GWG, BMI at four years postpartum, monthly household income and smoking status. When the variables high GWG and low GWG were substituted for GWG (continuous), they were not found to be significant predictors.

Because previous research has indicated that the relationship between GWG and weight retention or BMI longitudinally may be mediated by pre-pregnant BMI, additional linear regression models were built to predict four year postpartum BMI for each pre-pregnant BMI classification (i.e. underweight, normal weight, overweight, and obese). Each model began with the full set of variables used to predict four-year postpartum BMI as described above. Of the participants with data available at four years postpartum, only 47 had pre-pregnant BMIs classified as underweight and only 38 had pre-pregnant BMI classified as obese and it was not possible to obtain a linear regression model to predict BMI for either group.

There were 220 women with a normal pre-pregnant BMI. The only variable found to be a significant predictor of BMI at four years postpartum was GWG. Age, monthly household income, smoking status and educational attainment were not found to be significant predictors and were dropped from the model in this order.

There were 75 women with an overweight pre-pregnant BMI. The first non-significant variable to be removed from the model was monthly household income, followed by GWG and then educational attainment. The final model contained only two predictors: age and smoking status.

The final linear regression models for four year post partum BMI (all participants), eight year postpartum BMI (all participants), and four year post partum BMI of participants with normal and overweight pre-pregnant BMIs were all assessed as previously described for linearity, normality, homoscedasticity, collinearity and outliers to ensure that the use of linear regression was appropriate.

Chapter 5

RESULTS

5.0 Results

5.1 Objective 1

5.1.1 Characteristics of the Participants

Data required to calculate gestational weight gain were collected at the three month and 18 month parent interviews. Of the 720 participants interviewed at these survey times, data on gestational weight gain (GWG) were available for 562 women (78.1%). Three hundred sixty-five women (64.9%) were from one of the four BBBF communities and 197 (35.1%) were from the comparison community. Additional data required to classify GWG as within, below, or above Institute Of Medicine's (IOM) recommendations (based on pre-pregnant BMI) were available for 547 women (tables 4 and 5).

Table 4: Pre-Pregnant BMI Classification of Women (n = 547)

Pre-pregnant BMI classification	**n**	**%**
Underweight (<18.5 kg/m^2)	74	13.5
Normal weight (18.5-24.9 kg/m^2)	313	57.2
Overweight (25-29.9 kg/m^2)	101	18.5
Obese (≥30 kg/m^2)	59	10.8

Table 5: Gestational Weight Gain Classification of Women by Pre-Pregnant BMI Classification (n=547)

Pre-pregnant BMI Classification	Gestational Weight Gain Classification		
	Within Recommendations n (%)*	Below Recommendations (Low GWG) n (%)*	Above Recommendations (High GWG) n (%)*
Underweight (<18.5 kg/m^2)	23 (31.1)	27 (36.5)	24 (32.4)
Normal Weight (18.5-24.9 kg/m^2)	103 (32.9)	95 (30.4)	115 (36.7)
Overweight (25-29.9 kg/m^2)	21 (20.8)	15 (15.8)	64 (63.4)
Obese (≥30 kg/m^2)	10 (16.9)	13 (22.0)	36 (61.0)

* Row percentage

Among the 157 women who gained within IOM recommendations, 103 (65.6%) had a normal pre-pregnant BMI, 23 (14.6%) had an underweight pre-pregnant BMI, 21 (13.4%) had an overweight pre-pregnant BMI and 10 (6.4%) had an obese pre-pregnant BMI. Women with low GWG (151 in total) had slightly lower proportions of overweight and normal pre-pregnant BMIs and slightly higher proportions of obese and underweight pre-pregnant BMIs compared to women with GWG within recommendations. Of the women with low GWG, 16 women (10.6%) had overweight pre-pregnant BMIs and 95 women (62.9%) had normal pre-pregnant BMIs, while 13 women (8.6%) had obese pre-pregnant BMIs, and 27 women (17.9%) had underweight pre-pregnant BMIs. There were 239 women who had high GWG and this group had the highest proportions of overweight and obese pre-pregnant BMIs. A normal pre-pregnant BMI was the highest proportion for women with high GWG (115 women, 48.1%), followed by overweight pre-pregnant BMI (64 women, 26.8%), obese pre-pregnant BMI (36 women, 15.1%) and finally underweight pre-pregnant BMI (24 women, 10.0%).

A total of 11 women (2%) lost weight during their pregnancy. Characteristics of these 11 women (all of whom have data available on pre-pregnant BMI) are displayed in Table 6.

Table 6: Characteristics of all Women with Data on GWG Who Lost Weight (n=11)

Characteristics	n	%
Site		
BBBF communities	8	72.7
Control community	3	27.3
Pre-pregnant BMI classification		
Underweight	0	0.0
Normal	2	25.0
Overweight	3	37.5
Obese	3	37.5
Smoking status		
Non smoker	2	33.3
Current smoker	4	66.6
Former smoker	0	0.0
Activity during first 7 mo of pregnancy		
Yes	5	45.5
No	6	54.5
Prenatal classes		
Yes	4	36.4
No	7	63.6
Nulliparous		
Yes	2	18.2
No	9	81.8
Health problems during pregnancy		
Yes	4	36.4
No	7	63.6
Country of Birth		
Canada	7	63.6
Outside of Canada	4	36.4
Education		
< High school	3	27.3
≥ High school	8	72.7
LICO status "a"		
< LICO	7	87.5
≥ LICO	1	12.5
Support during pregnancy		
Yes	9	90.0
No	1	10.0

Others in home smoke during pregnancy		
Yes	6	66.7
No	3	33.3
Alcohol during pregnancy		
Yes	2	25.0
No	6	75.0
Age at birth of focal child		
< 20 years	0	0.0
20-29 years	8	72.7
≥ 30 years	3	27.3
Marital status		
Married	5	45.5
Partner	0	0.0
Lone/separated	6	54.5
Stature		
< 157cm	0	0.0
≥ 157 cm	11	100.0
Not enough money for food/daily living expenses in last 3 months		
True	7	63.6
False	4	36.4

Average GWG for all 562 women was 31.5 lbs (±17.1). When the data from women with missing pre-pregnancy BMI values were excluded the average GWG was 31.7 lbs (±17.2), and when women who lost weight during pregnancy were excluded the average GWG became 32.7 lbs (±15.7).

The average pre-pregnancy BMI was 23.3kg/m^2 and the average height was 162 cm (5 feet, 3 inches). Two hundred, thirty-nine women (43.7%) gained weight beyond the IOM recommendations during their pregnancy (high GWG); while 157 women (28.7%) gained within the IOM recommendations and 151 women (27.6%) gained less than the IOM recommendations (low GWG). More than half of the women had given birth at least once before (64.5%) and nearly half were married (49.5%). The average age of the women at delivery was 26.3 years (±5.8). The majority of the women were born in Canada (70.5%) and were living below the low income cut-offs (71.3% at the first interview).The average monthly income was \$1,972.22 ± \$1,348.00. More than half of the women had at least at high school education (62%). Characteristics of all the women with data on GWG are presented in table 7.

Table 7: Characteristics of all Women with Data on GWG (n=562)

Variables	n	%
Better Beginnings Better Futures site		
Yes	365	64.9
No	197	35.1
First Interview		
Time point "a"	498	88.6
Time point "b"	64	11.4
Lost weight during pregnancy		
Yes	11	2.0
No	551	98.0
Gestational weight gain classification		
Within recommendations	157	28.7
Below recommendations	151	27.6
Above recommendations	239	43.7
(missing)	15	
Nulliparous		
Yes	199	35.5
No	361	64.5
(missing)	2	
Country of Birth		
Canada	396	70.5
Outside of Canada	166	29.5
Education		
< High school	213	38.0
≥ High school or more	347	62.0
(missing)	2	
LICO status at time point		
At or above LICO	129	28.5
Below LICO	323	71.3
(missing)	109	
Marital Status		
Married	276	49.5
Partner	107	19.2
Lone/Separated	175	31.4
(Missing)	4	

Age at focal child's birth		
< 20 years	82	14.6
20 to 29 years	310	55.2
≥ 30 years	170	30.2
Smoking status during pregnancy		
Non smoker	315	59.1
Former smoker	57	10.7
Current smoker	161	30.2
Activity during first 7 months of pregnancy		
Yes	317	56.8
No	241	43.2
(Missing)	4	
Frequency of PA during first 7 months of pregnancy		
0-3 times per week	400	73.0
4 or more times per week	148	27.0
Attendance at prenatal classes		
Yes	204	36.3
No	358	63.7
Health problems during pregnancy		
Yes	204	36.5
No	355	63.5
(Missing)	3	
Received support during pregnancy		
Yes	482	86.5
No	75	13.5
(Missing)	5	
Others smoking in home during pregnancy		
Yes	245	45.5
No	294	54.5
(Missing)	23	
Alcohol consumption during pregnancy		
Yes	116	22.4
No	402	77.6
(Missing)	44	
Stature		
< 157cm	98	17.9
≥ 157 cm	448	82.1
(Missing)	16	
Not enough money for food/daily living expenses in last 3 months		
True	172	31.3
False	378	68.7

5.1.2 Bivariate Relationships between GWG and Maternal/Prenatal Factors

The purpose of the first objective was to determine which demographic variables or other maternal characteristics were associated with differences in average GWG and the size of the differences. As such, the independent variables described above were included in separate ANOVA tests with GWG as the dependent variable (tables 8 and 9).

Table 8: Gestational Weight Gain by the Women's Characteristics

Variables (n)	**Average Weight Gain (lbs) ± s^{+}**	**F**	**d*f***	***$P^{\ddagger}$***
Pre-pregnant BMI classification		8.000	3, 543	**p<0.001**
Underweight (74)	35.7 ± 16.9			
normal (313)	32.7 ± 16.9			
Overweight (101)	31.3 ± 16.9			
Obese (59)	22.2 ± 16.9			
Country of Birth		26.356	1, 560	**p<0.001**
Canada(396)	33.8 ± 16.8			
Outside of Canada (166)	25.9 ± 16.8			
Education		1.113	1, 557	p=0.292
< High school (213)	32.5 ± 17.2			
≥ High school (346)	30.9 ± 17.2			
LICO status		1.530	1, 451	p=0.217
< LICO (324)	31.4 ± 16.9			
≥ LICO (129)	33.6 ± 16.9			
Marital Status		2.820	2, 555	p=0.060
Married (276)	30.5 ± 17.1			
Partner (107)	35.0 ± 17.1			
Lone/separated (175)	30.9 ± 17.1			
Nulliparous		7.720	1, 557	**p=0.006**
Yes (199)	34.3 ± 17.0			
No (360)	30.1 ± 17.0			
Age		10.125	2, 559	**p<0.001**
< 20 years (82)	39.1 ± 16.9			
20-29 years (310)	30.7 ± 16.9			
≥ 30 years (170)	29.2 ± 16.9			
Prenatal Classes		9.268	1, 559	**p=0.002**
Yes (204)	34.4 ± 17.0			
No (357)	29.9 ± 17.0			

Smoking status during pregnancy		3.884	2, 529	**p=0.021**
Non smoker (315)	30.7 ± 16.8			
Current smoker (160)	32.4 ± 16.8			
Former smoker (57)	37.3 ± 16.8			
Others smoke in home during pregnancy		0.116	1, 536	p=0.733
Yes (244)	32.1 ± 17.2			
No (294)	31.6 ± 17.2			
Active during first 7 months of pregnancy		4.785	1, 555	**p=0.029**
Yes (317)	29.7 ± 17.1			
No (240)	32.9 ± 17.1			
Frequency of PA during first 7 months of pregnancy		3.161	1, 545	p=0.076
0-3x/week (399)	30.7 ± 17.2			
≥4x/week (148)	33.6 ± 17.2			
Alcohol during pregnancy		0.900	1, 515	p=0.343
Yes (116)	30.6 ± 17.3			
No (401)	32.3 ± 17.3			
Stature		6.750	1, 542	**p=0.010**
< 157cm (98)	27.7 ± 17.2			
≥ 157 cm (446)	32.7 ± 17.2			
Health problems during pregnancy		0.001	1, 556	p=0.981
Yes (203)	31.6 ± 17.2			
No (355)	31.5 ± 17.2			
Received support during pregnancy		1.874	1, 554	p=0.172
Yes (481)	32.1 ± 16.9			
No (75)	29.2 ± 16.9			
Not enough money for food/daily living expenses in last 3 months		9.710	1, 547	**p=0.002**
True (172)	28.3 ± 17.1			
False (377)	33.2 ± 17.1			

[+] s= √MSE, overall s=17.1

[ǂ] p-values reported for ANOVA (separate ANOVA performed for each independent variable)

Table 9: Gestational Weight Gain (Excluding Women who Lost Weight during Pregnancy), by the Women's Characteristics

Variables (n)	Weight Gain (lbs) ± s[+]	F	d*f*	*P*[ǂ]
Pre-pregnant BMI classification		3.862	3, 532	**p=0.009**
Underweight (74)	35.7 ± 15.6			
Normal weight (310)	33.2 ± 15.6			
Overweight (98)	32.5 ± 15.6			
Obese (54)	26.5 ±15.6			
Country of Birth		30.431	1, 549	**p<0.001**
Canada (389)	34.8 ± 15.3			
Outside of Canada (162)	26.9 ± 15.3			
Education		0.710	1, 546	p=0.400
< High school (210)	33.2 ± 15.7			
≥ High school (338)	32.0 ± 15.7			
LICO status		12.971	1, 443	p=0.294
< LICO (317)	32.3 ± 15.9			
≥ LICO (128)	34.0 ± 15.9			
Marital Status		2.123	2, 544	p=0.121
Married (271)	31.4 ± 15.7			
Partner (107)	35.0 ± 15.7			
Lone/separated (169)	32.7 ± 15.7			
Nulliparous		6.230	1, 546	**p=0.013**
Yes (197)	34.7 ±15.6			
No (351)	31.3 ± 15.6			
Age		9.829	2, 548	**p<0.001**
< 20 years (82)	39.1 ± 15.4			
20-29 years (302)	32.1 ± 15.4			
≥ 30 years (167)	29.9 ± 15.4			
Prenatal Classes		10.815	1, 548	**p=0.001**
Yes (200)	35.4 ± 15.5			
No (350)	30.9 ± 15.5			
Smoking status during pregnancy		4.308	2, 521	**p=0.014**
Non smoker (312)	31.2 ± 15.6			
Current smoker (155)	33.9 ± 15.6			
Former smoker (57)	37.3 ± 15.6			
Others smoke in home during pregnancy		0.765	1, 527	p=0.382
Yes (238)	33.3 ± 15.7			
No (291)	32.1 ± 15.7			

Active during first 7 months of pregnancy		4.520	1, 544	**p=0.034**
Yes (312)	33.8 ± 15.6			
No (234)	30.9 ± 15.6			
Frequency of PA during first 7 months of pregnancy		7.239	1, 534	**p=0.007**
0-3x/week (393)	31.4 ± 15.6			
≥4x/week (143)	35.5 ± 15.6			
Alcohol during pregnancy		0.877	1, 507	p=0.349
Yes (114)	31.6 ± 15.8			
No (395)	33.2 ± 15.8			
Stature		12.971	1, 531	**p<0.001**
< 157cm (98)	27.7 ± 15.5			
≥ 157 cm (435)	33.9 ± 15.5			
Health problems during pregnancy		0.066	1, 545	p=0.798
Yes (199)	32.8 ± 15.7			
No (348)	32.4 ± 15.7			
Receive support during pregnancy		2.258	1, 544	p=0.133
Yes (472)	32.9 ± 15.7			
No (74)	30.0 ± 15.7			
Not enough money for food/daily living expenses in last 3 months		4.653	1, 536	**p=0.031**
True (165)	30.5 ± 15.7			
False (373)	33.6 ± 15.7			

[+] s= √MSE, overall s= 15.7

[ǂ] p-values reported for ANOVA (separate ANOVA performed for each independent variable)

A significant difference in average GWG between pre-pregnant BMI classifications was detected. Women who had a pre-pregnant BMI classified as obese had lower average GWG than the other three pre-pregnant BMI classifications. There were no significant differences in average GWG between the pre-pregnant BMI classifications of normal, underweight or overweight. Similar results were found when women who lost weight during pregnancy were excluded. Post-hoc Tukey's HSD found the same significant difference as above.

Women who were born outside of Canada had a significantly lower GWG by an average of eight pounds, than women born in Canada. This relationship remained significant when women who lost weight during pregnancy were excluded, with women born outside of Canada gaining on average seven pounds less than women born in Canada.

Women with one or more previous pregnancies gained on average slightly less weight than women who had been pregnant for the first time (i.e. nulliparous) by an average of 4.2 lbs. The probability was increased slightly when women with weight loss were excluded, but remained significant ($F_{1,547}$=6.230; p=0.013).

Women who were under the age of 20 years at their child's birth had a significantly higher average GWG than women who were 20 to 29 years and women 30 and older as demonstrated by a post-hoc Tukey test. Women under 20 years of age at delivery gained on average 8.3 lbs more than women 20 to 29 years old and 9.9 lbs more than women 30 years or older. There was no significant difference in the average GWG of women 20 to 29 and 30 years old. The same significant relationship was found when women who lost weight were excluded.

A significant difference was detected in the average GWG of women who attended prenatal classes and those who did not with women who attended classes having higher average GWG by 4.5 lbs. A significant relationship remained when women who lost weight were excluded.

Smoking status was also found to be significantly related to GWG. Women who had quit smoking in the three months before their pregnancy or during their pregnancy had higher average GWG by an average of 6.6 lbs than women who were non-smokers and a higher average GWG by 4.9 lbs than women who smoked throughout pregnancy. Non-smokers gained slightly less on average than women who smoked during pregnancy, but the difference was not significant. These relationships remained after exclusion of women who lost weight during pregnancy.

Women who reported being active during the first seven months of pregnancy had a slightly lower average GWG by two pounds compared to women who reported no activity and this difference was significant. The relationship remained after the exclusion of women who lost weight. Frequency of physical activity was also associated with differences in GWG, although the relationship was not significant when all women were included in the analysis. Women who were active four or more times per week gained on average 2.9 lbs more than women who were active less than four times or were not active at all. When women who lost weight were excluded, the average GWG for women active four or more times per week increased by only 0.7 lbs while average GWG for women active 0 to three times per week increased by 1.9 lbs. As a result, the difference became significant.

Women 157cm or taller gained on average five pounds more than women under 157cm and this difference was significant. The relationship remained significant after the exclusion of women who lost weight.

Women who answered true to the statement “sometimes we did not have enough money for our food and daily living expenses” gained on average 4.9 lbs less than women who answered false to this statement and this difference was significant. When women who lost weight were excluded the relationship remained significant. Of the 11 women who had lost weight, seven (63.6%), had answered true to the above statement.

Educational attainment, Low Income Cut-Off status , marital status, support from others during pregnancy, the presence of others smoking in the household, reported health problems during pregnancy and alcohol consumption were not found to be related to significant differences in average GWG.

5.1.3 Predictors of GWG

Following bivariate analysis, it was of interest to determine if GWG could be predicted from a model including all of the previously analyzed independent variables or a combination of several of them. As such, multiple linear regression was used as a method to find a model which could best predict GWG using the fewest number of variables of which all were significant contributors to the model's predictive ability. The first model constructed included all of the independent variables analyzed in the bivariate analysis, with GWG as the dependent variable. The purpose of including all variables, regardless of significance in bivariate analysis was to determine if the variables would work together to predict GWG, and if so which would give the largest and most significant contributions. Using the stepwise (backward) entry method three variables were found to be significant predictors of GWG: pre-pregnant BMI, country of birth and financial stress. Age was not significant at the 0.05 level but was retained because it added to the R-square value (table 7). These four variables had also been significantly related to GWG in the bivariate analysis. As a check, the full model was run using the "enter" entry method. The variables with the smallest contributions (standardized beta) and the least significance were dropped, one variable at a time, until a significant model with the best predictive ability and containing the fewest number of variables emerged. The final result was the same as that achieved by the using the stepwise "backward" entry method. Variables were dropped from the model in the following sequence: (1) others smoking in the home, (2) smoking status -smoking during pregnancy, (3) educational achievement, (4) income, (5) activity, (6) nulliparity, (7) marital status -single, (8) health problems during pregnancy, (9) frequency of activity, (10) attendance at prenatal classes, (11) support during pregnancy, (12) alcohol consumption, (13) marital status – partner, (14) height, (15) smoking status – former smoker. To maximize the sample size, the model made up of pre-pregnant BMI, country of birth, age and financial stress, was input using the "enter" method and emerged as significant ($F_{4,531}$=17.178; p<0.001). Although the model was significant, the R-square value was not large, suggesting that pre-pregnant BMI, country of birth, financial stress and maternal age explain only a small amount of the variability in GWG (R-square = 0.115; Adjusted R-square = 0.108). Although pre-pregnant BMI made the largest contribution to the model as evidenced by the standardized beta value, country of birth was the variable associated with the largest difference in GWG. Women born in Canada were found to gain on average 7.986 lbs more than women born outside of Canada. Not having enough money for food and living expenses was associated with an average GWG of 3.429 lbs less than those women who did not report a lack of money for food and living expenses. Each one unit increase in pre-pregnant BMI was found to decrease gestational weight gain on average by 0.738 lbs. The final variable which contributed to the model, age at the focal child's birth, was associated with a decreasing GWG as age increased. Each additional year of age was associated with a decrease of 0.215 lbs of GWG on average. A summary of the final model is presented in table 10.

Table 10: Predictors of Gestational Weight Gain Obtained through Multiple Linear Regression Model "A" (n=535)

Variable	Un-standardized Beta	Standardized Beta	t	Sig.
Pre-pregnant BMI	-0.738	-0.231	-5.445	P<0.001
Country of birth	-7.986	-0.204	-4.678	p<0.001
Maternal age	-0.215	-0.072	-1.657	p=0.098
Not enough money for food and living expenses	-3.429	-0.092	-2.211	p=0.027

5.1.3.1 BMI status as a Predictor of GWG

An additional multiple regression model was built using the variables country of birth, age and financial stress and with pre-pregnant BMI classification (categorical) in place of pre-pregnant BMI (continuous). This was done to explore whether BMI status as determined by the WHO BMI cut-offs (i.e. underweight, normal weight, overweight and obese), was associated with GWG. This model was input using the stepwise "backward" method. The classifications normal pre-pregnant BMI, underweight pre-pregnant BMI and overweight pre-pregnant BMI did not contribute significantly to prediction of GWG and as such were not included in the final model. A model including obese pre-pregnant BMI, country of birth, maternal age and not enough money for food and living expenses input using the "enter" method was significant ($F_{4,529}$=15.085; p<0.001; R-square=0.102; Adjusted R-square=0.096). As in the previous model using GWG as a continuous variable, the R-square value indicates that this model accounts for only a small portion of the variability in GWG. Having a pre-pregnant BMI classified as obese was associated with a lower GWG by 10.883 lbs than having a BMI classified at underweight, normal, or overweight. Similar to the previous model, being born outside of Canada was associated with a decreased GWG by 7.174 lbs on average. Not having enough money for food and living expenses was associated with a lower average GWG by 3.589 lbs. Being younger during pregnancy was associated with higher gestational weight gain, as each additional year of age was associated with an average decrease in GWG of 0.278 lbs. A summary of this model is presented in table 11.

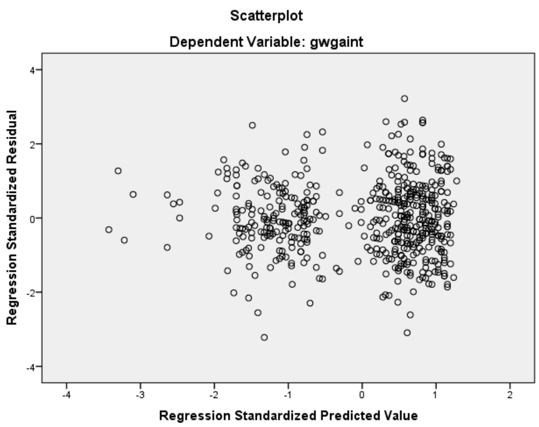
Table 11: Predictors of Gestational Weight Gain Obtained through Multiple Linear Regression Model "B" (n=533)

Variable	Un-standardized Beta	Standardized Beta	t	Sig.
Obese pre-pregnant BMI	-10.883	-0.196	-4.671	p<0.001
Country of birth	-7.174	-0.183	-4.220	p<0.001
Age	-0.278	-0.092	2.147	p=0.032
Not enough money for food and living expenses	-3.589	-0.096	-2.297	p=0.022

5.1.3.2 Checking the Assumptions and Fit of the Models

Linearity was assessed as were the assumptions of normality and homoscedasticity (equality of variance) in addition to collinearity and the presence and effect of outliers to verify the fit and appropriateness of linear regression models A and B. Examination of bivariate scatterplots and significant F-values indicated that linear regression was appropriate for both models. No serious deviations from normality were detected from a histogram of standardized residuals and a normal P-P plot of regression standardized residuals created for model A and for model B. Homoscedasticity was checked by creating a plot of standardized predicted values versus standardized residuals for each model. The plots created for both models A and B showed even spread of the residuals along a horizontal line at 0. Variance inflation factors (VIFs) for all four variables included in linear regression model A (pre-pregnant BMI, country of birth, maternal age, financial stress) were low (all less than 1.15) indicating that collinearity between variables was not a concern. Additional Collinearity diagnostics confirmed this finding with a maximum condition index value of 13.899. The same was true of model B where the highest VIF value was 1.11 and the maximum condition index value was 11.592. Model A contained seven outliers (beyond 3 standard deviations). After removal of these cases the significance of the variables was not substantially changed. Model B contained 8 outliers. After removal of the outlier cases, the variable age was no longer significant (p=0.074) and the plot of standardized predicted values versus residuals showed a clustering effect (figure 3).

Figure 3: Scatterplot of Standardized Predicted Residuals by Regression Standardized Residuals for Model B with Outliers Removed



5.1.4 Bivariate Relationships between GWG Classification and Maternal/Prenatal Factors

Following the analysis of gestational weight gain as a continuous variable, the women's GWG was classified as either below recommendations (i.e. low), within recommendations, or above recommendations (i.e. high) This classification was based on their pre-pregnant BMI and the number of pounds that they had gained and where that weight gain was located on the IOM range for recommended weight gain. Of the 547 women with pre-pregnancy BMI and GWG data available, 239 (43.7%) gained above the IOM recommendations.

Chi-square tests were used to determine if any of the women's characteristic variables were associated with different proportions of high GWG (table 12).

Table 12: Gestational Weight Gain Classification and Characteristics of all Women with Pre-pregnant BMI and GWG Data

Variable	Below or Within Recommendations n (%)*	Above Recommendations (High GWG) n (%)*	Chi-square *df* (p value)
Pre-pregnant BMI classification (n=547)			**33.049** **3** **(p<0.001)**
Under weight	50 (67.6%)	24 (32.4%)	
Normal weight	198 (63.3%)	115 (36.7%)	
Overweight	37 (36.6%)	64 (63.4%)	
Obese	23 (39.0%)	36 (61.0%)	
Country of birth (n=547)			**33.411** **1** **(p<0.001)**
Canada	193 (48.7%)	203 (51.3%)	
Outside of Canada	115 (76.2%)	36 (23.8%)	
Educational attainment (n=544)			2.248 1 (p=0.134)
< high school	126 (60.3%)	83 (39.7%)	
≥ high school	180 (53.7%)	155 (46.3)	
LICO status (n=444)			1.056 1 (p=0.304)
< LICO	178 (56.5%)	137 (43.5%)	
≥ LICO	66 (51.2%)	63 (48.8%)	
Marital status (n=543)			1.379 2 (p=0.502)
Married	150 (56.6%)	115 (43.4%)	
Partner	55 (51.4%)	52 (48.6%)	
Lone/separated	100 (58.5%)	71 (41.5%)	
Nulliparous (n=544)			0.194 1 (p=0.660)
Yes	108 (54.8%)	89 (45.2%)	
No	197 (56.8%)	150 (43.2%)	
Age (n=547)			1.965 2 (p=0.374)
< 20 years	41 (50%)	41 (50%)	
20-29 years	56.3%)	131 (47.3%)	
≥ 30 years	98 (59.4%)	67 (40.6%)	
Prenatal classes (n=546)			**6.698** **1** **(p=0.010)**
Yes	98 (49.0%)	102 (51.0%)	
No	209 (60.4%)	137 (39.6%)	
Smoking status during pregnancy (n=519)			**7.032** **2** **(p=0.030)**
Non smoker	182 (60.1%)	121 (39.9%)	
Current smoker	83 (51.9%)	77 (48.1%)	
Former smoker	24 (42.9%)	32 (57.1%)	

Others smoking in home during pregnancy (n=527)			0.029 1 (p=0.864)
Yes	137 (56.4%)	106 (43.6%)	
No	158 (55.6)	126 (44.4%)	
Active during first 7 months of pregnancy (n=542)			**4.96** **1** **(p=0.026)**
Yes	164 (52.2%)	150 (47.8%)	
No	141 (61.8%)	87 (38.2%)	
Frequency of PA during first 7 months of pregnancy (n=533)			0.095 1 (p=0.758)
0-3x/week	219 (56.9%)	166 (43.1%)	
≥4x/week	82 (55.4%)	66(44.6%)	
Alcohol during pregnancy (n=508)			0.213 1 (p=0.645)
Yes	66 (57.4%)	49 (42.6%)	
No	216 (55.0%)	177 (45.0%)	
Stature (n=544)			**11.453** **1** **(p=0.001)**
<157 cm	70 (71.4%)	28 (28.6%)	
≥ 157 cm	235 (52.7%)	211 (47.3%)	
Health problems during pregnancy (n=543)			3.742 1 (p=0.053)
Yes	101 (50.8%)	98 (49.2%)	
No	204 (59.3%)	140 (40.7%)	
Received support during pregnancy (n=541)			1.531 1 (p=0.216)
Yes	259 (55.0%0	212 (45.0%)	
No	44 (62.9%)	26 (37.1%)	
Not enough money for food/daily living expenses in last 3 months			**4.945** **1** **(p=0.026)**
True	105 (62.9%)	62 (37.1%)	
False	194 (52.6%)	175 (47.4%)	

* Row percentage

Women who had a pre-pregnancy BMI categorized as overweight or obese had higher proportions of high GWG (63.4% and 61.0%) than the women with pre-pregnancy BMIs categorized as normal or underweight (36.7% and 32.4%) ($p<0.001$). Just over half of the women born in Canada had high GWG (51.3%), while 23.8% of women born outside of Canada had high GWG. Attendance at pre-natal classes was also significantly associated with high GWG. Fifty-one percent of women who attended prenatal classes gained above recommendations, while 39.6% of women who did not attend classes gained above. When examining smoking status, women who were former smokers had the largest proportion of high GWG at 57.1% compared to 39.9% for non-smokers and 48.1% for current smokers. Women who reported being active during pregnancy had a larger proportion of high GWG than those who did not report being active (47.8% and 38.2% respectively), however being active four or more times per week versus being active zero to three times per week was not associated with a significant difference in the proportion of women with high GWG (44.6% and 43.1% respectively). Women who were more than 157 cm tall had a significantly greater proportion of high GWG than women less than 157cm tall (47.3% and 28.6% respectively).

Women who reported experiencing health problems during their pregnancy had a greater proportion of high GWG (49.2%) than those who did not report health problems (40.7%) and this relationship was close to reaching significance.

Differences in the proportion of women with high GWG according to a measure of financial stress (not having enough money for food and living expenses) also reached statistical significance. Forty-seven point four per cent of women who answered “false” to the statement “sometimes we did not have enough money for our food and living expenses” gained above recommendations compared to 37.1% of women who answered “true”. There were no statistically significant relationships found between the proportions of women with high GWG and: educational attainment; LICO status; marital status; nulliparity; age, the presence of others in the household smoking and; alcohol consumption.

5.1.5 Predictors of High GWG

Following bivariate analysis of maternal characteristics and GWG classification, it was of interest to determine if some combination of these maternal characteristic variables could be used to predict the odds of a woman having high GWG and if so, which factors would be associated with the greatest odds. A full model using all variables examined in the bivariate Chi-square analysis was input using the stepwise “backward” entry method. The resulting model included pre-pregnant BMI, country of birth, educational attainment, monthly household income, height and financial stress; however income was not significant and was removed from the model. With the removal of income, education was no longer a significant predictor of high GWG and it was also removed so that the final, significant model contained the variables pre-pregnant BMI, country of birth, height and financial stress. These four variables were then input using the enter method to maximize the sample size. This model as previously described was statistically significant (Chi-square=51.208 with df=4, $p<0.001$) (table 10). Nagelkerke’s R-square of 0.122 indicated a weak relationship between the predictor variables and GWG. A Hosmer and Lemeshow Test gave a Chi-square value of 4.193 and a significance of $p=0.839$ with df=8, indicating that the model estimates fit the data across the entire range of the explanatory variables at an acceptable level. Prediction success overall was 64.2% (72.6% for gaining within or below recommendations and 53.6% for gaining above). Being born in Canada was associated with the highest increase in odds for having high GWG. Canadian born women were 2.451 times more likely to have high GWG compared to those born outside of Canada. Women who reported not having enough money for food or daily living expenses had slightly lower odds (OR: 0.675) of high GWG than women who did not report this problem. Each one unit increase in pre-pregnant BMI was associated with a 1.054 times increase in the odds of high GWG. Each additional centimeter in height was associated with a 1.032 times increase in the odds of having a high GWG. A summary of the model is presented in table 13.

Table 13: Predictors of High Gestational Weight Gain Obtained from Binary Logistic Regression (n=542). Model "C"

Variable	Wald	Sig.	EXP (B)	95 % CI Lower	95 % CI Upper
Pre-pregnant BMI	9.038	p=0.003	1.054	1.019	1.091
Country of birth	15.006	p<0.001	0.408	0.259	0.642
Height in cm	7.142	p=0.008	1.032	1.008	1.056
Not enough money for food and living expenses	3.754	p=0.053	0.675	0.454	1.005

5.1.5.1 Theoretical Predictors of High GWG

An additional logistic regression model was built using variables that have been found to be related to GWG in previous studies (overweight and obese pre-pregnant BMI; smoking status -former smoker and current smoker; parity; maternal age – younger than 20 years or older than 30 years; stature). The purpose of this model was to see if variables that have been found to increase or decrease the odds of high GWG in other populations would also function as predictors in the current study's population of low income women from disadvantaged communities. The addition of country of birth and financial stress (the two most significant predictors in the previous model) to this model improved the Nagelkerke's R-square value and predictive ability. Using the "enter" method the following significant model was obtained (Chi-square=70.461 with df=7; p<0.001) (table 12). The Nagelkerke's R-square of 0.173 was slightly higher than the previous model. The Hosmer and Lemeshow Test Chi-square value was 1.438 (with df=7, p=0.984) indicating that this model also fit the data at an acceptable level.

Having an obese pre-pregnant BMI was associated with the highest odds of having a high GWG. Women with a pre-pregnant BMI of 30 or greater (obese) were 3.403 times more likely to gain above recommendations compared to women with a BMI below 30. Similarly, women with a BMI between 25 and 29.9 (overweight) prior to pregnancy were 3.151 times more likely to have high GWG than women with a non-overweight pre-pregnancy BMI. The predictor with the third highest odds ratio for high GWG was country of birth. Canadian-born women were 2.439 times more likely to have high GWG compared to women born outside of Canada. Being taller than 157 cm was associated with a 1.686 times greater odds of having high GWG. Not having enough money for food and living expenses was associated with reduced odds of high GWG by 0.641 times. Being under the age of 20 years increased the odds of high GWG by 1.526 times, and being a former smoker increased the odds of high GWG by 1.480 times. Although being under 20 years of age and being a former smoker were variables that did not reach the level of significance, when they were removed from the model the predictive ability was reduced and as such they were retained in the final model. The overall success of this model was slightly higher than the previous logistic regression model (64.6% versus 64.2%) although the correct prediction of women gaining above recommendations was slightly reduced from the previous model (53.1% versus 53.6%). A summary of the model is presented in table 14.

Table 14: Predictors of High Gestational Weight Gain Obtained from Binary Logistic Regression (n=542). Model "D"- Theoretical Model

Variable	Wald	Sig.	EXP (B)	95% CI	
				Upper	Lower
Overweight pre-pregnant BMI	20.203	p<0.001	3.151	1.910	5.198
Obese pre-pregnant BMI	14.244	p<0.001	3.403	1.802	6.429
Former smoker	1.694	p=0.193	1.480	0.820	2.673
< 20 years of age	2.437	p=0.116	1.526	0.901	2.584
Not enough money for food and living expenses	4.311	p=0.038	0.641	0.421	0.975
Stature	3.735	p=0.053	0.593	0.349	1.007
Country of birth	12.260	p<0.001	0.410	0.249	0.676

Despite the small Nagelkerke's R-square values and predictive success around 55-64%, the models show consistency in terms of the significant or near significant predictive variables and those variables contributions to predictive success. While other variables not examined here must contribute to the variance in GWG, the variables examined here do appear to account for a small amount of the variation in GWG among this population.

5.1.5.2 Checking the Assumptions and Fit of the Models

Examination of bivariate scatterplots in addition to non-significant Hosmer and Lemeshow Chi-square statistics indicated that logistic regression was appropriate for both models C and D. A correlation matrix for model C indicated that there were no strong correlations between any pair of predictor variables (the highest correlation was r=0.250 between height and country of birth). Similarly, a correlation matrix for model D showed no high correlations between any pairs of predictor variables (the highest correlation was r=0.206 between overweight pre-pregnant BMI and obese pre-pregnant BMI). Neither Model C nor model D contained any outliers (beyond 3 standard deviations).

5.2 Objective 2

5.2.1 Birth Weight

Birth weight data were available for all infants of the 562 women with GWG data. Of these infants, 312 (55.5%) were male and 250 (44.5%) were female. The average birth weight was 7.48 lbs ± 1.29 lbs. Of the 562 infants, 435 (77.4%) had a normal birth weight, 39 (6.9%) had a low birth weight, and 88 (15.7%) had a high birth weight. Women whose GWG was above recommendations had the highest proportion of infants with a high birth weight and the lowest proportion of infants with a normal birth weight compared to women who gained within recommendations and women who gained below recommendations. Women who gained below recommendations had the highest proportion of infants born with a low birth weight (table 15).

Table 15: Birth Weight Classification of all Infants by Women's Gestational Weight Gain Classification

Gestational weight gain classification	Low birth weight n (%)*	Normal birth weight n (%)*	High birth weight n (%)*
Below recommendations	17 (11.3%)	129 (85.4%)	5 (3.3%)
Within recommendations	4 (2.5%)	133 (84.7%)	20 (12.7%)
Above recommendations	17 (7.1%)	163 (68.2%)	59 (24.7%)

* Row percentage

While table 15 describes the proportions of low, normal and high birth weight for each GWG classification, there were also some notable differences in the proportion of GWG classifications by birth weight classification. Of the 435 infants with a normal birth weight, 38.4% were born to a mother with GWG above recommendations, 31.3% to a mother with GWG within recommendations and 30.4% to a mother with GWG below recommendations. Of the 39 infants with a low birth weight, 44.7% were born to a mother with GWG below recommendations, 44.7% were born to a mother with GWG above recommendations and 10.5% were born to a mother with GWG within recommendations. Of the 88 infants born with a high birth weight, 70.2% were born to a mother with GWG above recommendations, 23.8% were born to a mother with GWG within recommendations and 6.0% were born to a mother with GWG below recommendations.

5.2.2 Bivariate Relationships between Birth Weight and Maternal/Infant Characteristics

The first part of the second objective of this study was to determine if GWG is associated with birth weight after controlling for other variables that are associated with birth weight. ANOVA was therefore used to examine the relationship between GWG, demographic, maternal and infant characteristics with birth weight as the dependent variable. Using ANOVA, a significant difference was detected between the average birth weight of the infants born to women with GWG below, within or above recommendations. The average birth weight of infants born to women who gained above recommendations was highest at 7.80 lbs. This was 0.3 lbs higher than the average birth weight of infants born to women who gained within recommendations (7.50 lbs) and 0.85 lbs higher than the average birth weight of infants born to women who gained below recommendations (6.95 lbs). A post-hoc Tukey test showed a significant difference in the average birth weight of infants born to mothers who gained below recommendations compared to the infants born to women gaining within or above recommendations.

Table 16 shows mean infant birth weight by other infant and maternal characteristics. Significant differences were detected in the mean birth weights of infants born to mothers with normal, underweight, overweight and obese pre-pregnant BMIs. A post-hoc Tukey test found the average birth weight of infants born to a mother with an underweight pre-pregnant BMI (6.9 lbs) to be significantly less than the average birth weights of infants born to women with normal, overweight or obese pre-pregnant BMIs. This test also found that women with obese pre-pregnant BMIs gave birth to infants with significantly higher birth weights on average (8.2 lbs) than women with underweight, normal or overweight BMIs. No significant difference was detected between the average birth weights of infants born to women with normal or overweight pre-pregnant BMIs (7.4 lbs and 7.8 lbs respectively). Women who smoked during their pregnancy gave birth to infants who weighed on average 0.52 lbs less than women who did not smoke and this difference was significant. Also, infants born to into a household where there was at least one smoker (not including the mother) weighed on average 0.35 lbs less than infants born into a household with no smokers. This difference was significant. Maternal educational attainment was also associated with significant differences in average birth weight. Mothers with less than a high school education gave birth to infants who weighed on average 0.33 lbs less than mothers with at least a high school diploma. No significant difference was detected between the average birth weight of male and female infants.

Table 16: Birth Weight of all Infants by Maternal and Infant Characteristics

Variables (n)	**Average Birth Weight (lbs) ± s[+]**	**F**	**d*f***	***p*[ǂ]**
Gestational weight gain classification		21.481	2, 544	**p<0.001**
Below recommendations (151)	6.95 ± 1.2			
Within recommendations (157)	7.50 ± 1.2			
Above recommendations (239)	7.80 ± 1.2			
Pre-pregnant BMI classification		15.692	3, 543	**p<0.001**
Underweight (74)	6.86 ± 1.2			
Normal (313)	7.40 ± 1.2			
Overweight (101)	7.75 ± 1.2			
Obese (59)	8.23 ± 1.2			
Smoked during pregnancy		18.428	1, 530	**p<0.001**
Yes (160)	7.10 ± 1.3			
No (372)	7.62 ± 1.3			
Others in home smoked during pregnancy		10.161	1, 536	**p=0.002**
Yes (244)	7.29 ± 1.3			
No (294)	7.64 ± 1.3			
Maternal educational achievement		8.831	1, 557	**p=0.003**
< High school (213)	7.27 ± 1.3			
≥ High school (346)	7.60 ± 1.3			
Sex of infant		2.361	1, 560	p=0.125
Female (250)	7.39 ± 1.3			
Male (312)	7.56 ± 1.3			

[+] s= √MSE, overall s= 1.3

[ǂ] p-values reported for ANOVA (separate ANOVA performed for each independent variable)

5.2.3 Bivariate Relationships between Birth Weight Classification and Maternal/Infant Characteristics

While the previous analysis examined the relationship between GWG and birth weight as a continuous variable, previous studies have also examined the relationship between GWG classification and categorical birth weight (using the classifications, low, normal and high birth weight). Therefore, to examine the relationship between GWG classification and birth weight classification a Chi-square test was used. Chi-square tests were also used to examine the relationships between other maternal/infant categorical variables and birth weight classification.

A Chi-square test of birth weight classification by GWG classification showed that the observed proportions were significantly different from those expected if there was no relationship between the two variables (Pearson Chi-square=41.868 with d*f* = 4; $p<0.001$). As previously described, women who gained below recommendations had the lowest proportion of HBW infants, and the highest proportion of LBW infants out of all GWG classifications, but a similar proportion of normal birth weight infants to women who gained within recommendations. Women who gained above recommendations had the largest proportion of HBW infants and the smallest proportion of normal birth weight infants. Women who gained within recommendations had the smallest proportion of LBW infants of all GWG classifications and nearly half the proportion of HBW infants as women who gained above recommendations.

Table 17 shows the proportions of infants with low, normal and high birth weight by other maternal and infant characteristics. Significant differences were detected in the proportion of infants born with low, normal or high birth weight to women with underweight, normal, overweight or obese pre-pregnant BMIs. Women with an obese pre-pregnant BMI had the lowest proportion of normal weight or low birth weight infants (57.6% and 1.7% respectively) and the highest proportion of HBW infants (40.7%). By comparison, only 18.8% of infants born to women with an overweight pre-pregnant BMI were HBW, as were 11.5% of the infants born to women with a normal pre-pregnant BMI and 6.8% of infants born to a woman with an underweight pre-pregnant BMI. Because the expected cell count for one cell was less than five (expected = 4.10) a second Chi-square test was run combining the categories of overweight and obese pre-pregnant BMI to meet the assumption of all expected cell counts equal to at least five. This test was also significant, demonstrating a higher proportion of HBW infants and a lower proportion of normal weight infants among women with overweight or obese pre-pregnant BMIs (Pearson Chi-Square=28.840 with d*f* = 4; p<0.001). Women who smoked during their pregnancy had a higher proportion of infants born with a LBW (13.1%) compared to women who did not smoke (4.6%) and this was significant. The presence of other smokers in the home was also related to differences in the proportion of low and high birth weight infants compared to homes without smokers. A higher proportion of infants born into a household with at least one smoker (excluding the mother) had a LBW (8.2%) compared to the infants born into homes without smokers (5.8%), and the proportion of HBW infants was greater in the non-smoking homes (19.7%) compared to infants born into households with at least one smoker (10.7%). There were no statistically significant differences in the proportions of low, normal and high birth weight babies by maternal educational achievement level.

Table 17: Chi-Square Analysis of Birth Weight Classification of All Infants by Maternal and Infant Characteristics

Variables	**Total, percentage (n)**	**Infant birth weight %* (n)**			**Chi-square d*f* p-value**
		Low	Normal	High	
Gestational weight gain classification (n=547)					**41.868** **4** **p<0.001**
Below recommendations	27.6 (151)	11.3 (17)	85.4 (129)	3.3 (5)	
Within recommendations	28.7 (157)	2.5 (4)	84.7 (133)	12.7 (20)	
Above recommendations	43.7 (239)	7.1 (17)	68.2 (163)	24.7 (59)	

Pre-Pregnant BMI classification (n=547)					**28.840** **6**
Underweight	13.5 (74)	13.5 (10)	79.7 (59)	6.8 (5)	**p<0.001**
Normal	57.2 (313)	6.1 (19)	82.4 (258)	11.5 (36)	
Overweight	18.5 (101)	7.9 (8)	73.3 (74)	18.8 (19)	
Obese	10.8 (59)	1.7 (1)	57.6 (34)	40.7 (24)	
Maternal smoking status during pregnancy (n=532)					**14.320** **2**
Non smoker/former smoker	69.9 (372)	4.6 (17)	78.0 (290)	17.5 (65)	**p=0.001**
Smoker	30.1 (160)	13.1 (21)	75.6 (121)	11.3 (18)	
Maternal educational achievement					5.258 2
< High school	38.1 (213)	8.9 (19)	79.3 (169)	11.7 (25)	p=0.072
≥ High school	61.9 (346)	5.8 (20)	76.3 (264)	17.9 (62)	
Others smoking in home during pregnancy					**8.921** **2**
Yes	45.4 (244)	8.2 (20)	81.1 (198)	10.7 (26)	**p=0.012**
No	54.6 (294)	5.8 (17)	74.5 (219)	19.7 (58)	

* Row percentage

5.2.4 Correlations between Birth Weight and Maternal Characteristics

A weak but statistically significant correlation was found between GWG and birth weight (r=0.129; p=0.010). Weak correlations were also found between maternal pre-pregnant weight and infants birth weight (r=0.320; p<0.001) and maternal BMI and infant birth weight (r=0.280; p<0.001). No correlation was found between maternal age and infant birth weight (r=0.037; p=0.378) or monthly household income and infant birth weight (r=0.046; p=0.333).

5.2.5 Predictors of Birth Weight

Bivariate analysis showed that GWG classification was associated with significant differences in average birth weight and birth weight classification and revealed a weak correlation between continuous GWG and birth weight; however, the main interest of this objective was to determine if the relationship would remain after accounting for other associates of birth weight. As such, multiple linear regression was used to determine if GWG would contribute to a model predictive of birth weight and if so, the size and significance of its contribution. An initial model was constructed which included all of the variables examined in the bivariate analysis. For characteristics that could be expressed as both continuous and categorical variables (e.g. pre pregnant BMI and pre-pregnant BMI classification) the continuous version was used. The variables GWG; pre-pregnant BMI; smoking status – smoker and quitter; smoking in household; maternal educational attainment and; sex of child were input using the backward method. The resulting model included GWG, pre-pregnant BMI, smoking status – smoker, smoking in household and sex of child, however smoking in the household was not a significant contributor from the model and so it was removed. The final model contained GWG, pre-pregnant BMI, smoking status –smoker and sex of child (table 18).

Table 18: Predictors of Birth Weight Obtained Through Multiple Linear Regression - Model "E" (n=518)

Variable	Un-standardized B	Standardized B	t	Sig.
Gestational weight gain	0.170	0.217	5.382	p<0.001
Pre-pregnant BMI	0.084	0.349	8.541	p<0.001
Smoker during pregnancy	-0.612	-0.219	-5.470	p<0.001
Male sex	0.260	-0.100	-2.509	p=0.012

A check was performed by inputting all of the same predictor variables from the bivariate analysis and using the enter method; variables that were not significant and did not contribute appreciably to the model were dropped from the model one at a time. Variables were dropped in the following order: (1) smoking status – former smoker, (2) others smoking in the home, (3) educational achievement. The final model achieved in this method produced the same results as were found using the backward entry method. To maximize the sample size the four significant variables were input using the enter method ($F_{4,518}$=28.528; p<0.001; R-square=0.182; Adjusted R-square=0.175).

Maternal smoking exerted the greatest change in birth weight of the four variables; the infants of women who smoked during pregnancy weighed on average 0.612 lbs less than the infants of women who did not smoke during pregnancy. Being a male infant was associated with weighing on average 0.260 lbs more at birth than being a female infant. Increasing maternal pre-pregnant BMI and GWG were both associated with small increases in birth weight. Each additional pound of GWG was related to an increase in 0.170 lbs in infant birth weight, while each one unit increase in pre-pregnant BMI was related to a 0.084 lb increase in birth weight.

5.2.5.1 Checking the Assumptions and Fit of the Model

Examination of bivariate scatterplots and the significant F-value indicated that linear regression was appropriate for model E, predicting birth weight. No serious deviations from normality were detected from a histogram of standardized residuals and a normal P-P plot of regression standardized residuals created for model E. Homoscedasticity was checked by creating a plot of standardized predicted values versus standardized residuals. This plot showed even spread of the residuals along a horizontal line at zero. Variance inflation factors (VIFs) for all four variables included in linear regression model E (GWG, pre-pregnant BMI, smoking status and infant sex) were low (the largest was 1.047) indicating that collinearity between variables was not a concern. Additional Collinearity diagnostics confirmed this finding with a maximum Condition Index value of 13.609. Model E contained six outliers (beyond three standard deviations). After removal of these outliers the significance of only one variable (infant sex) was changed and this was minor; the p-value reducing to $p=0.001$ from $p=0.012$. Further, the plots discussed above were not seriously altered and hence the use of linear regression remained appropriate and there was nothing to suggest any serious deviations from normality, nor violation of the assumption of homogeneity of variance.

5.2.6 Predictors of High and Low Birth Weight

The variables examined in the bivariate analysis, i.e. GWG, pre-pregnant BMI, maternal smoking status, household smoking status, educational attainment and sex of the infant could not be used to predict either high or low infant birth weight.

5.2.7 Weight-for-Height Z-scores

Weight-for-height z-scores at 48 months of age were available for 413 children of the women with GWG data. The mean z-score was 0.522 (normal range). The majority of the children had weight-for-height z-scores in the normal range (291, 70.5%). Five children (1.2%) had weight-for-height z-scores categorizing them as either wasted or severely wasted. Nineteen children (4.6%) were categorized as overweight and 17 (4.1%) were categorized as obese. More than half of the children were male (56.4%). Breastfeeding data were available for all 413 of the children and the majority had been breastfed at least once as infants (80.4%). Further data on duration of breastfeeding were available for 398 of the children. The average number of months that the children had been breastfed as infants was 4.68 months, but the median was only two months and the mode was zero months.

5.2.8 Bivariate Relationships between Weight-for-Height Z-Scores and Maternal/Child Characteristics

The purpose of the second part of objective two, was to determine if GWG was associated with child weight status (indicated by weight-for-height z-score) at four years of age, after accounting for other covariates of child weight status. Bivariate analysis was first undertaken to determine if GWG was related to child weight status and if so how significant the relationship was. Additional variables that could influence child weight status were also examined using bivariate analysis. Table 19 shows mean weight-for-height z-scores by child and maternal characteristics, obtained through ANOVA.

Table 19: Weight-for-Height Z-scores of all Children by Maternal and Child Characteristics

Variables (n)	weight-for-height z-score ± s⁺	F	d*f*	*p*ǂ
Gestational weight gain classification		6.228	2, 399	**p=0.002**
Below recommendations (103)	0.17 ± 1.2			
Within recommendations (116)	0.52 ± 1.2			
Above recommendations (183)	0.68 ± 1.2			
Birth weight		7.723	2, 410	**p=0.001**
Low (269)	0.05 ± 1.2			
Normal (314)	0.46 ± 1.2			
High (70)	0.97 ± 1.2			
Pre-Pregnant BMI classification		8.707	3, 398	**p<0.001**
Underweight (46)	-0.10 ± 1.2			
Normal (227)	0.48 ± 1.2			
Overweight (84)	0.55 ± 1.2			
Obese (45)	1.15 ± 1.2			
Smoked during pregnancy		1.384	1, 392	p=0.240
Yes (117)	0.61 ± 1.2			
No (277)	0.46 ± 1.2			
Sex of child		1.681	1, 411	p=0.195
Female (180)	0.61 ± 1.2			
Male (233)	0.45 ± 1.2			
Maternal educational achievement		0.091	1, 408	p=0.763
< High school (143)	0.49 ± 1.2			
≥ High school (267)	0.53 ± 1.2			
Others smoking in home during pregnancy		0.735	1, 398	p=0.392
Yes (180)	0.55 ± 1.2			
No (220)	0.45 ± 1.2			
Ever breastfed		0.131	1, 411	p=0.717
Yes (332)	0.51 ± 1.2			
No (81)	0.57 ± 1.4			

⁺ s= √MSE, overall s= 1.2

ǂ p-values reported for ANOVA (separate ANOVA performed for each independent variable)

Three variables were related to statistically significant differences in average weight-for-height z-score; gestational weight gain classification, birth weight classification and pre-pregnant BMI classification. Post-hoc Tukey's test identified a significant difference between the average weight-for-height z-score of children whose mother had low GWG during the child's gestation and children whose mother had high GWG. Children whose mother had low GWG had a lower average weight-for-height z-score. No significant difference in average z-score between children whose mother gained within recommendations and those whose mother had low GWG, or children whose mother gained within recommendations and those whose mother had high GWG were detected. A post Hoc Tukey test also detected a significant difference in mean weight-for-height z-scores of children born low birth weight and children born high birth weight. No significant differences were detected between mean weight-for-height z-scores of children born with low or normal birth weight, or between children born with normal or high birth weight. While the mean weight-for-height z-score of children whose mothers had underweight, normal or overweight pre-pregnant BMIs were all within the normal range, children born to a mother with an obese pre-pregnant BMI had a mean weight-for-height z-score categorized as at-risk for overweight. A post-hoc Tukey's test found a significantly lower mean weight-for-height z-score of children born to a mother with an underweight pre-pregnant BMI (-0.0987) compared to children whose mother had a pre-pregnant BMI of normal or higher. Children born to a mother with an obese pre-pregnant BMI also had a significantly higher mean weight-for-height z-score (1.15) than children born to a mother with an overweight pre-pregnant BMI or less. There were no statistically significant differences in average weight-for-height z-score based on maternal or household smoking status during the child's gestational period, maternal educational achievement, whether the child was ever versus never breastfed or sex of the child.

5.2.9 Bivariate Relationships between Weight-for-Height Z-Score Classification and Maternal/Child Characteristics

Using WHO cut-points for weight-for-height z-scores, each child's z-score was classified as wasted/normal, at possible risk for overweight, or overweight/obese and then Chi-square tests were used to determine if differences in the proportion of children in the three weight status classifications were related to differences in GWG classification or other maternal and child variables (pre-pregnant BMI, maternal and household smoking status during pregnancy, maternal educational attainment, birth weight classification, breastfed status and sex of the child). Table 20 shows the proportions of children with weight-for-height z-scores classifying their weight as normal or wasted, at risk for overweight and overweight/obese by the above mentioned characteristics.

Table 20: Child Weight for Height Z-score by Maternal and Child Characteristics

Variables	**Total, percentage (n)**	**Weight-for-Height Categorization (48 Months of Age) %* (n)**			**Chi-Square d*f* p**
		Normal/ wasted	**Possible risk of overweight**	**Overweight/ Obese**	
Gestational weight gain classification (n=402)					**10.739**
					4
Below recommendations	25.6 (103)	83.5 (86)	10.7 (11)	5.8 (6)	**p=0.030**
Within recommendations	28.9 (116)	71.6 (83)	20.7 (24)	7.8 (9)	
Above recommendations	45.5 (183)	65.6 (120)	24 (44)	10.4 (19)	
Birth weight classification (n=413)					6.317
Low	7.0 (29)	72.4 (21)	20.7 (6)	6.9 (2)	4
Normal	76.0 (314)	74.2 (233)	18.2 (57)	7.6 (24)	p=0.177
High	17 (70)	60.0 (42)	25.7 (18)	14.3 (10)	
Maternal pre-pregnant BMI Classification (n=402)					**13.129**
					6
Underweight	11.4 (46)	84.8 (39)	10.9 (5)	4.3 (2)	**p=0.041**
Normal	56.5 (227)	72.7 (165)	19.8 (45)	7.5 (17)	
Overweight	20.9 (84)	70.2 (59)	22.6 (19)	7.1 (6)	
Obese	11.2 (45)	57.8 (26)	22.2 (10)	20.0 (9)	

Maternal smoking status during pregnancy (n=394)					4.430
Non smoker/former smoker	70.3 (227)	74.7 (207)	18.8 (52)	6.5 (18)	2
Smoker	29.7 (117)	65.8 (77)	22.2 (26)	12.0 (14)	p=0.109
Sex of Child (n=413)					3.706
Female	43.6 (180)	68.3 (123)	20.0 (36)	11.7 (21)	2
Male	56.4 (233)	74.2 (173)	19.3 (45)	6.4 (15)	p=0.157
Maternal educational achievement (n=410)					1.555
< High school	34.9 (143)	74.1 (106)	16.1 (23)	9.8 (14)	2
≥ High school	64.5 (267)	70.8 (189)	21.0 (56)	8.2 (22)	p=0.460
Others smoking in home during pregnancy (n=400)					5.414
Yes	45.0 (180)	66.7 (120)	23.9 (43)	9.4 (17)	2
No	55.0 (220)	76.8 (169)	15.5 (34)	7.7 (17)	p=0.067
Ever breastfed as infant (n=413)					0.217
Yes	80.4 (332)	71.7 (238)	19.9 (66)	8.4 (28)	2
No	19.6 (81)	71.6 (58)	18.5 (15)	9.9 (8)	p=0.897

* Row percentage

A significant difference in the proportion of children whose weight was categorized as normal/wasted, at possible risk for overweight or overweight/obese was detected for two variables; GWG classification and maternal pre-pregnant BMI classification. Women with high GWG had the highest proportion of children who were at risk for overweight (24%), and overweight or obese (10.4%) and the lowest proportion of children who had a normal or wasted height-for-weight (65.6%). Women who were obese prior to their pregnancy had the lowest proportion of children with a normal or wasted weight-for-height categorization at 57.8% (a 12.4% difference from the next lowest proportion which was among children whose mother had been overweight prior to pregnancy). Children whose mother had an obese pre-pregnant BMI also had the highest proportion of overweight or obese weights-for-height at 20%. No significant differences were detected between the proportions of children's weight-for-height z-score classifications by birth weight, maternal or household smoking status, maternal educational achievement, breastfed status, or sex of the child. While not statistically significant, children whose mother smoked during their pregnancy had a greater proportion of overweight/obese weight-for-height z-scores compared to children whose mother did not smoke during pregnancy (12.0% and 6.5% respectively).

5.2.10 Correlations between Weight-for-Height Z-Scores and Maternal/Child Characteristics

No correlation was found between GWG and 48 month weight-for-height z-score ($r=0.077$; $p=0.120$). Weak but significant correlations were found between 48 month weight-for-height z-score and: maternal pre-pregnant BMI ($r=0.232$; $p<0.001$); maternal BMI 4 years postpartum, ($r=0.220$; $p<0.001$); maternal weight in pounds ($r=0.238$; $p<0.001$) and; birth weight ($r=0.226$; $p<0.001$). There was no correlation between the number of months breastfed and weight-for-height z-score at 48 months ($r=-0.012$; $p=0.811$).

5.2.11 Predictors of Weight-for-Height Z-Score at 48 Months

No strong linear regression models to predict weight-for-height z-score at 48 months were found using the predictor variables examined in the bivariate analysis (The largest R-squared value was 0.097). Despite a lack of correlation between GWG and weight-for-height z-score and low R-squared values, GWG consistently appeared as weakly predictive indicator for weight-for-height z-score at 48 months.

5.2.12 Predictors of Weight-for-Height Z-Score Indicative of Overweight or Obesity at 48 Months

No significant logistic regression models for predicting overweight/obese weight-for-height z-scores were found using the variables examined in the bivariate analysis.

5.3 Objective 3

5.3.1 BMI and Characteristics of the Women over Time

As described in previous sections, data on pre-pregnant BMI were available for 547 women. The average pre-pregnant BMI was 23.29 kg/m^2 ± 5.4 (classified as a "normal" BMI). Data on GWG were available for all of these women and the average gain was 31.71 lbs ± 17.2, indicating a great deal of variability. Data were again collected from the women at 48 months (i.e. four years) and eight years postpartum. At four years postpartum, BMI data were available for 380 of the original 547 women (69.5%). The average BMI had increased to 25.21 kg/m^2, which is classified as overweight. By 8 years postpartum BMI data were available for 313 of the women (57.2% of the original sample). Mean BMI had not increased much from four years postpartum and was 25.34 kg/m^2. There was an average increase of 1.94 kg/m^2 in BMI from pre-pregnancy to four years postpartum and an additional average increase of 0.94 kg/m^2 of BMI from four years to eight years postpartum. On average, women had gained 11.94 lbs by four years postpartum and an additional 4.88 lbs by eight years postpartum for a total average gain of 16.88 lbs over an eight year period.

The average age of the women at four years postpartum was 31.3 years and the average age of the women at eight years postpartum was 35.3 years. Data on average monthly household income were obtained for both time periods and the mean values were $2,674.97 ± 1,828.24 (n=346) at four years postpartum and $3,513.48 ± 2,377.15 9n=287) at eight years postpartum. At four years postpartum 35% of the women were smokers and at eight years postpartum 31.7% were smokers.

5.3.2 Bivariate Relationships between BMI and the Women's Characteristics

While the main interest of this objective was to determine if GWG is associated with

BMI longitudinally, it was first necessary to determine if other characteristics of the women (for which there were available data) were associated with BMI and the strength of these associations. There was no significant difference in average BMI of women who had a high school education or greater and those who had less than a high school education at four years postpartum. However, a significant difference was detected at eight years postpartum (F_{282}=8.503; p=0.004). There were no significant differences in average BMI of women who were non-smokers and those who were smokers at four or at eight years postpartum (table 21).

Table 21: BMI by Maternal Characteristics

Variables (n)	**Average BMI ±s**[+]	**F**	**d*f***	***p***[ǂ]
	4 Years Postpartum			
Educational achievement		2.672	1, 375	p=0.103
< High school (136)	24.60 ± 5.5			
≥ High school (241)	25.56 ± 5.5			
Smoking status		1.184	1, 378	p=0.277
Smoker (133)	25.62 ± 5.5			
Non-smoker (247)	24.98 ± 5.5			
	8 Years Postpartum			
Educational achievement		8.503	1, 280	**p=0.004**
< High school (108)	24.59 ± 6.0			
≥ High school (174)	26.75 ± 6.0			
Smoking status		1.753	1, 311	p=0.186
Smoker (100)	25.27 ± 6.0			
Non-smoker (213)	26.25 ± 6.0			

[+] s= √MSE

[ǂ] p-values reported for ANOVA (separate ANOVA performed for each independent variable)

5.3.3 Correlations between BMI and Characteristics of the Women

As expected, there were significant correlations between pre-pregnant BMI and BMI at four years postpartum (r=0.769; p<0.001) and pre-pregnant BMI and BMI at eight years postpartum (r=0.674; p<0.001). There was also a significant correlation between BMI at four and eight years postpartum (r=0.813; p<0.001). No correlations were found between GWG and BMI at either four years postpartum (r=-0.026; p=0.613) or eight years postpartum (r=-0.029; p=0.632). No correlations were found between age and BMI at either four years postpartum (r=0.047; p=0.364) or eight years postpartum (r=-0.006; p=0.920) nor between BMI and monthly household income at four years postpartum (r=0.017; p=0.756). A weak yet significant correlation was detected between BMI and monthly household income at eight years postpartum (r=-0.126; p=0.034), however a scatter plot demonstrates that outliers may be driving the association as most points were clustered around the lower to mid range of BMI and lower end of monthly household income.

5.3.4 Predictors of BMI at Four Years Postpartum

Linear Regression was used to determine if GWG was a predictor of the women's BMI at four years postpartum when other covariates of BMI were included as predictors. An initial multiple regression model was built with BMI at four years postpartum as the dependent variable and including pre-pregnant BMI, GWG, average monthly household income, age, smoking status and educational achievement as predictors, input using the backward entry method. Two variables, pre-pregnant BMI and GWG were included in the model. As a check, all of the variables were input using the enter method and then removed if not significant, one variable at a time. Educational achievement was the first variable dropped from the model. Next, monthly household income was dropped from the model followed by smoking status. The final model contained pre-pregnant BMI, GWG, and age (table 22). Because age was a significant predictor it was included in the final model. These three variables were then re-input using the enter method to maximize sample size. This model was significant ($F_{3,379}$=194.778; p<0.001; R-square =0.608; Adjusted R-square=0.605), although none of the predictors was associated with large changes in BMI at four years postpartum and GWG had the smallest influence. Pre-pregnant

BMI was the strongest predictor of BMI at four years postpartum such that each one unit increase in pre-pregnant BMI was associated with an increase of 0.832 kg/m^2 in BMI four years postpartum. Age was also found to be weakly predictive of BMI at four years postpartum such that each additional year of age was related to an increase in BMI of 0.060 kg/m^2. A one pound increase in GWG was associated with a 0.035 kg/m^2 increase in BMI at four years postpartum.

Table 22: Predictors of BMI at Four years Postpartum Obtained Through Multiple Linear Regression – Model "F"

Variable	Un-standardized B	Standardized B	t	Sig.
Pre-pregnant BMI	0.832	0.799	24.122	p<0.001
Gestational weight gain	0.035	0.107	3.233	p=0.001
Age	-0.060	-0.065	-1.990	p=0.047

Previous research suggests that an association of GWG with longitudinal weight status may be modified by pre-pregnant BMI classification. To test this theory, four separate linear regressions to predict BMI at four years post partum were created; one for each pre-pregnant BMI classification (i.e. underweight, normal weight, overweight and obese).

5.3.4.1 Underweight pre-pregnant BMI

Only 47 women with data on BMI at four years postpartum had an underweight pre-pregnant BMI and it was not possible to obtain a linear regression model to predict four-year postpartum BMI.

5.3.4.2 Normal pre-pregnant BMI

The same method as described above for predicting BMI at four years postpartum for all women was used to predict the same outcome among women with normal pre-pregnant BMIs only. The only variable which was a significant predictor of BMI at four years postpartum among women with normal pre-pregnant BMIs was GWG ($F_{1,219}$=38.889; p<0.001; R-square=

0.151; adjusted R-square=0.147) (table 23). Each one pound increase in GWG was associated with an average in increase in four-year postpartum BMI of 0.079 kg/m^2.

Table 23: Predictors of BMI at Four Years Postpartum for Women with a Normal Pre-pregnant BMI, Obtained through Multiple Linear Regression – Model "G"

Variable	Un-standardized B	Standardized B	t	Sig.
Gestational weight gain	0.079	0.389	6.236	p<0.001

5.3.4.3 Overweight pre-pregnant BMI

The same method as described above for predicting BMI at four years postpartum for all women was used to predict the same outcome among women with overweight pre-pregnant BMIs only. Two variables remained in the final model for predicting four-year postpartum BMI of women with overweight pre-pregnant BMIs; age and smoking status. ($F_{2,74}$=7.974; p=0.001; R- square=0.181; adjusted R-square=0.159) (table 24). Each additional year of age was associated with a decreased four-year postpartum BMI of 0.260 kg/m^2 and being a smoker was associated with a lower four-year postpartum BMI by 1.997 kg/m^2.

Table 24: Predictors of BMI at Four Years Postpartum for Women with an Overweight Pre-pregnant BMI, Obtained Through Multiple Linear Regression – Model "H"

Variable	Un-standardized B	Standardized B	t	Sig.
Age	-0.260	0.072	-3.614	p=0.001
Smoking status	-1.997	0.781	-2.557	p=0.013

5.3.4.4 Obese pre-pregnant BMI

Only 38 women with data on BMI at four years postpartum had an obese pre-pregnant BMI and a significant linear model to predict their four-year postpartum BMI was not found using the variables pre-pregnant BMI, GWG, educational attainment, monthly household income, age, and smoking status.

5.3.4.5 Checking the Assumptions and Fit of the Models

Examination of bivariate scatterplots of each predictor variable and BMI at four years postpartum in addition to significant F-values indicated that linear regression was appropriate for models F, G and H. No serious deviations from normality were detected from a histogram of standardized residuals and a normal P-P plot of regression standardized residuals created for models F, G and H. For model F, these plots were improved following the removal of seven outliers. Homoscedasticity was checked by creating a plot of standardized predicted values versus standardized residuals for each model. The plots created for model F, G and H showed random spread of the residuals along a horizontal line at zero. Variance inflation factors (VIFs) for models F and H were low (the largest were 1.053 and 1.031 respectively) indicating that collinearity between variables was not a concern. Additional Collinearity diagnostics confirmed this for both models with a maximum Condition Index value of 16.981 for model F and 14.423 for model H. Because there was only one predictor in model G collinearity was not a concern. Model F contained seven outliers (beyond 3 standard deviations). After removal of these outliers the significance of the variables was not changed. Model G contained two outliers and removal of these outliers did not change the significance of GWG as a predictor of BMI at four years postpartum. Model H did not contain outliers beyond 3 standard deviations.

5.3.5 Predictors of BMI at 8 Years Postpartum

To determine if GWG retained any predictive effect on BMI at eight years postpartum a linear regression model was built with the same variables used to predict BMI at four years postpartum in addition to BMI at four years postpartum. Because the total number of women with data available had decreased between four-years and eight years postpartum the women were examined as a group rather than divided up by pre-pregnant BMI category to keep the sample size as large as possible and to compare the results of the linear regression with that created for BMI at four years postpartum. The same method and check used previously to predict BMI at four years postpartum was utilized to build a model to predict BMI at eight years postpartum. The final model included pre-pregnant BMI, GWG, smoking status and BMI at four years postpartum. ($F_{4,254}$=121.469; p<0.001; R-square=0.657; Adjusted R-square=0.651) (table 25).

Table 25: Predictors of BMI at Eight Years Postpartum Obtained Through Multiple Linear Regression – Model "I"

Variable	Un-standardized B	Standardized B	t	Sig.
Pre-pregnant BMI	0.166	0.135	2.369	p=0.019
Gestational weight gain	0.042	0.111	2.892	p=0.004
Smoking status	-0.816	-0.061	-1.642	p=0.012
4 year postpartum BMI	0.805	0.710	12.794	p<0.001

Although the model contained four significant predictors of BMI at eight years postpartum, all of the predictors were associated with very small changes in BMI. The largest change was a lower eight year postpartum BMI by 0.816 kg/m^2 for women who smoked compared to those who were not smokers. A one kg/m^2 increase in four year postpartum BMI was associated with an average increase of 0.805 kg/m^2 of BMI at eight years postpartum. Higher pre-pregnant BMI was associated with higher BMI at eight years postpartum as well, but only by 0.166 kg/m^2 for each additional one kg/m^2 of pre-pregnant BMI. GWG was related to the smallest increase in eight year postpartum BMI such that each one pound increase in GWG was associated with a 0.042 kg/m^2 increase in BMI.

5.3.5.1 Checking the Assumptions and Fit of the Model

Examination of bivariate scatterplots of each predictor variable with BMI at eight years postpartum in addition to a significant F-value indicated that linear regression was appropriate for model I. No serious deviations from normality were detected from a histogram of standardized residuals and a normal P-P plot of regression standardized residuals created for model I. Homoscedasticity was checked by creating a plot of standardized predicted values versus standardized residuals for each model. The plot created for model I showed random spread of the residuals along a horizontal line at zero. Variance inflation factors (VIFs) were low (the largest was 2.441) indicating that collinearity between variables was not a concern. Additional Collinearity diagnostics confirmed this with a maximum Condition Index value of 19.695. There were three outliers (beyond 3 standard deviations). After removal of these outliers GWG and maternal smoking during pregnancy were no longer significant predictors of BMI at eight years postpartum.

Chapter 6

DISCUSSION

6.0 Discussion

This study is unique in that the sample was drawn from a Canadian population that was selected to represent low-income women living in disadvantaged communities; a population that is not well represented in studies of GWG and the perinatal period. At their initial interview, 71.3% of the participants were living below the LICO and 31.3% reported not having enough money for food or living expenses in the previous three months. Additionally, this study was longitudinal, and few of such studies are representative of low income populations. A strength of this study is that it allows for the comparison of GWG relationships in a low income population to relationships found in previous studies of women from different demographics. An additional strength is that GWG is explored both as a continuous variable and categorically as GWG classification (above, within, or below the 2009 IOM recommendations). Oza-Frank and Keim (2013) note that, "few studies have examined [GWG] as a continuous variable, and this lapse may obscure subtle differences across the range of weight gain values" (p. 108) (55). The findings of this study shed light on factors associated with high GWG as well as the relationship between GWG and longitudinal weight status of both the mother and child. The results of this study can help to determine where future research is needed as well as helping to identify demographic and lifestyle factors which may make women and their children more vulnerable to future weight problems via differences in GWG.

6.1 Maternal and Demographic Factors Related to GWG

Most of the literature examining predictors of GWG is specific to women who are white, married, and of middle or higher income and education levels. A number of modifiable factors associated with GWG have been identified through these studies including clinician advice and number of care-visits, physical activity level, dietary intake, and smoking status. For example, in a 2009 study where the participants were primarily white, married and had higher levels of education; activity levels and food intake were the most significant predictors of GWG, while ethnicity, educational level, health status, parity and smoking status were not significant predictors (86) The present study among disadvantaged women found both similarities and differences to these and other studies that have included women of more varied demographics.

Average GWG has been shown to range from 26.4 lbs to 34.8 lbs (86, 114-117). Lower income women appear to be on the lower end of this range and have a higher proportion of GWG below recommendations compared to higher income women. In the present study, 27.6% of women had low GWG, consistent with the 28% of women with low GWG found among low income African American women (114). A similar rate was found among a sample of Asian women primarily of middle or higher income and education levels, where 27.7% gained below recommendations. It should be noted however that the recommendations used to assess the women's GWG were specific to Asian women and hence different from the IOM guidelines used in the present study (117). In studies where the participants are primarily white and of a higher income/education levels or are from diverse economic backgrounds, the rate of low GWG tends to be lower (18.7%-21%) (86, 115, 116). The proportion of high GWG in the present study (43.7%) is within the range consistent with the literature. A study of Canadian women from diverse demographic backgrounds found 48.7% gained above recommendations, while two American studies, one of low income women and one with women from diverse income levels found rates of 41% and 40% respectively (114-116). Overall, this suggests that high GWG is a concern for women of all income or SES groups, but women from low income or low SES groups have a greater proportion of low GWG as well.

Pre-pregnant BMI appears to be consistently related to GWG across the spectrum of income and education levels. In accordance with previous research, the present study found that total GWG decreases as pre-pregnant BMI increases, yet women with higher BMIs, i.e. those who are overweight or obese prior to pregnancy, have an increased odds of gaining above IOM recommendations (86, 114, 115).

Linear and logistic regression analysis to determine predictors of GWG and high GWG respectively produced similar results and are in some ways consistent with previous research. Pre-pregnant BMI, country of birth, and answering “true” to the statement, “we did not have enough money for food or daily living expenses” were consistently predictors of both continuous GWG and high GWG. Age was also a predictor of both continuous GWG and high GWG but appeared only as a predictor of high GWG when expressed categorically as “less than 20 years old”. Height expressed continuously as centimeters or categorically as shorter or taller stature was a significant predictor of high GWG only, as was being a former smoker. These relationships and how they compare to the literature are explored in the following sections.

Women who are pregnant for the first time have been found to gain more weight on average than women who have given birth at least once before, and being multiparous has been associated with an increased odds of gaining below recommendations, while being pregnant for the first time has been associated with increased odds of GWG above recommendations (114, 115). In the present study nulliparous women did gain more on average than women with one or more children, but they did not have a significantly higher proportion of GWG above recommendations, nor was nulliparity a predictor of either continuous GWG or high GWG.

Educational achievement, marital status and household income/LICO status were not related to either GWG or GWG classification as has been found previously among Canadian women (115). Given that all of the participants of this study lived in neighbourhoods considered to be disadvantaged with most living below the LICO it is likely that the participants were too homogenous to detect an association between income or LICO status and GWG. Additionally, educational achievement was dichotomized as “less than high school” versus “high school or greater” and therefore differences between women with higher levels of education would have been missed. Nonetheless, Kowal (2012) did find that women with less than a high school education had higher odds of GWG above recommendations compared to women with at least a high school education. That study however included women from various SES backgrounds, thus homogeneity may also be the reason that an association was not found in the present study. The presence of other smokers in the household, the frequency of physical activity, alcohol consumption during pregnancy, health problems during pregnancy, physical activity and support during pregnancy were not significant predictors of either GWG or GWG classification. While the relationship between maternal exposure to second hand tobacco smoke or alcohol consumption with GWG has not been well explored previously to the this author’s knowledge, associations have previously been demonstrated between physical activity levels, health problems and social support (not necessarily together) with GWG. Women who are less active or who consider themselves to be less active during pregnancy compared to before pregnancy tend to have higher GWG than women with higher levels of activity or those who report being at least as active during pregnancy as they had been before (86, 114, 116). Health problems that developed during pregnancy have also been associated with increased odds of low GWG (115). In the present study pre-existing health problems and health problems developed during pregnancy were not differentiated which may be why the same relationship was not found here. Low social support was previously associated with higher GWG among women of lower, normal or obese BMIs, but because the same measure was not used in the present study and because the relationship between social support and GWG was not examined by differing pre-pregnant BMI status it is difficult to speculate why the results of the present study differ from those of the former (116).

6.1.1 The Relationship between Pre-pregnant BMI and GWG

Consistent with the literature, the present study found that both pre-pregnant BMI and pre-pregnant BMI classification were associated with GWG and GWG classification in bivariate analysis, where higher BMI was associated with lower total GWG, yet women with obese or overweight pre-pregnant BMIs were more likely to have GWG classified as high (118, 119). Women with an obese BMI prior to pregnancy gained on average 13.5 lbs less than women with underweight pre-pregnant BMIs and 10.5 lbs less than women with normal pre-pregnant BMIs. There was less of a difference in the average weight gain of women with overweight and normal pre-pregnant BMIs, with overweight women gaining on average only 1.4 lbs less. Olson (2003) also found that obese women gained the least amount of weight, but contrary to the present study, normal weight, rather than underweight women gained the most amount of weight (116). Kowal and colleagues (2012) however also found that it was underweight women who gained the most (115).

When GWG was examined categorically the difference between the proportion of underweight or normal weight and overweight or obese women gaining above recommendations was also striking. While only 32.4% of underweight women and 36.7% of normal weight women gained above recommendations, overweight and obese women had almost twice this rate at 63.4% and 61.0% respectively. Kowal and colleagues (2012) similarly found that 60% of women who were obese prior to pregnancy gained above recommendations and Althuizien found that

62% of overweight women gained above recommendations (86, 115).The reason behind this seemingly paradoxical relationship may be due to the fact that women who are considered overweight or obese prior to pregnancy have a lower range of recommended weight gain than women with underweight or normal BMIs and hence even if they gain less quantitatively than women with lower BMIs there is still a greater propensity to gain above this lower recommended range. Such differences may be related to eating behaviours and body weight regulation mechanisms (115).

Pre-pregnant BMI was also a predictor of both GWG and high GWG in multivariate analysis. In linear regression model A, which was modeled to predict pre-pregnant BMI as a continuous variable, each one kg/m^2 increase in pre-pregnant BMI was associated with a decrease of 0.738 lbs of GWG. This accounts for a difference of about 5.9 lbs between a woman with a normal pre-pregnant BMI of 22 and a woman with an obese pre-pregnant BMI of 30. In logistic regression, increasing pre-pregnant BMI was associated with only a very small increase in the odds for high GWG, such that each one kg/m^2 increase in pre-pregnant BMI increased the odds to only 1.054. When examined categorically, pre-pregnant BMI appeared to have a more significant role on the odds of increasing or high GWG. Having either an overweight or obese pre-pregnant BMI was associated with increased odds of high GWG. The odds were 3.403 times greater for women obese prior to pregnancy and 3.151 times greater for women overweight prior to pregnancy. These are very similar results to those obtained by Kowal and colleagues (2012) where overweight and obese Canadian women from diverse SES backgrounds were three times more likely to have GWG above recommendations when compared to normal weight women (115). In an American study of primarily white, rural women of diverse SES, those with high BMIs were approximately five times more likely than women of normal weight to have high

GWG (116). In a study of Dutch, primarily white, married women with higher education, the odds were even higher, whereby overweight women were six times more likely to gain excessively during pregnancy (86). These comparisons suggest that while pre-pregnant BMI is associated with GWG across SES categories, being of a low SES moderates the association somewhat.

In linear regression, only the classification of obese pre-pregnant BMI was a significant predictor of GWG. According to model B, being obese prior to pregnancy was related to GWG of 10.883 lbs less compared to women with underweight, normal and overweight pre-pregnant BMIs. Similarly, Althuizien and colleagues' 2012 study of Dutch women showed that in a significant multiple linear regression model obese women gained on average 8.8 lbs less than normal weight women (86).

Some studies have examined differences in trimester-specific weight gain and the relationship to pre-pregnant BMI (120). In one study, where the majority of participants were white, with at least a high school education and most had a normal pre-pregnant BMI, having a low pre-pregnant BMI was associated with higher GWG in the second and third trimesters, but lower gains in the first trimester, while a high pre-pregnant BMI was associated with lower GWG throughout pregnancy (66). Inverse associations between BMI and GWG during the second trimester, and positive associations between BMI and GWG in the third trimester have also been demonstrated. Because data on trimester-specific weight gain were not available for analysis in the present study, comparisons cannot be made. What is apparent however is that regardless of income/education background, being overweight or obese prior to pregnancy is a strong predictor of gaining above IOM recommendations during pregnancy, although the difference in odds of high GWG may not be as profound in lower income women. Nonetheless, overweight and obese low income women and their infants are vulnerable to the numerous health consequences associated with high GWG.

6.1.2 The Relationship between Country of Birth and GWG

Country of birth, dichotomized in this study to "Canada" and "outside of Canada" consistently showed a relationship with both GWG and GWG classification. In bivariate analysis being born in Canada was associated with an average GWG of 7.9 lbs more than being born outside of Canada and was also associated with a larger proportion of high GWG. Only 23.8% of women born outside of Canada had high GWG while more than half (51.3%) of women born in Canada had high GWG. Country of birth also appeared as a predictor of both GWG in linear regression and high GWG in logistic regression. Being born in Canada was associated with higher average GWG by 7.986 lbs and a more than doubling in the odds of high GWG (2.5 times in model C and 2.4 times in model D). These results are similar to those found previously, where Canadian-born women had higher GWG than women born outside of Canada, and women born outside of Canada were more likely to gain below Health Canada's recommended range for GWG (115). The authors of that study suggest this relationship could be the result of acculturation, whereby as women spend more time in Canada they adopt more unhealthy eating and physical activity behaviours (115). Kramer (2000) has also described the tendency of recent immigrants to retain more favourable nutrition and health characteristics and to therefore avoid some of the negative health risks (in this case, high GWG) of non-immigrant individuals living in similar disadvantaged socioeconomic conditions (121). Another possible explanation for this variation could be different recommendations or expectations for GWG that exist in other countries. A review of GWG recommendations of 22 countries found a variety of different guidelines for both GWG and energy intake during pregnancy (122). Furthermore, immigrants motivated to leave their country of origin because of poverty are likely to live in more economically disadvantaged circumstances in the country that they have emigrated to, and are likely to encounter greater barriers to accessing healthcare (123). Ostrach and colleagues (2013) have identified numerous factors that make accessing reproductive health care more difficult for immigrants including language barriers and cultural factors such as reluctance to seek care and fear of jeopardizing their legal immigrant status (123). If these women are more isolated from Canadian health care systems and hence GWG recommendations then they are also more likely to retain discordant beliefs and practices and cultural norms of their native country, such as the need to minimize weight gain in pregnancy. Other characteristics of women born outside of Canada may also be influencing this association. For instance, Asian women tend to be smaller and have lower BMIs and gain less weight during pregnancy than Caucasian women from Europe or the U.S. (124).

6.1.3 The Relationship between Financial Stress and GWG

In this study the term "financial stress" was used to indicate a state where participants had answered "true" to the statement, "sometimes we didn't have enough money for our food and living expenses". This question was asked at the Three Month Parent Interview and was in references to the experience of the participants in the previous three months. As such the response of the participants may not have been indicative of financial stress during pregnancy. However, previous research has shown that among households with children and female-headed households (which were a large proportion of the households in this study) there is less movement out of a state of food insecurity (125). Because it was the best measure available, this variable was used to predict which women would have experienced financial stress during their pregnancy.

Answering “true” to the financial stress statement was consistently associated with differences in GWG or the proportions of high GWG in both bivariate and multivariate analyses. Women who experienced this form of financial stress gained on average 4.9 lbs less than women who did not. There was approximately a 10 % difference in the proportion of women with high GWG with those indicating financial stress having a proportion of 37.1% high GWG compared to 47.4% for women without financial stress and this difference was statistically significant. This form of financial stress was also associated with a GWG of 3.4-3.6 lbs less on average than not having this form of financial stress in linear regression. Women who answered “false” to the financial stress statement had 2.38 times greater odds of high GWG compared to those who answered “true”. It is also interesting to note that of the 11 women who lost weight during their pregnancy, 63.6% indicated financial stress, while the rate among the entire sample was only 31.3%. This suggests that some of the women who lost weight may not have been trying to do so, but rather had to sacrifice the quantity or quality of their diet which in turn affected GWG.

These findings, though not directly comparable, are consistent with a 2013 study that found women who experienced marginal food insecurity in the absence of high dietary restraint (defined as thinking about diet and weight and restricting intake) had significantly lower GWG (126). It is also well established in the literature that mothers will often sacrifice their own food intake to feed their children (127, 128). In the present study 73.8% of the women who answered “true” to the financial stress statement had at least one child at the time of their pregnancy and therefore may have lessened their food intake, perhaps contributing to a lower GWG than that of the women who had enough money for food and living expenses. Food insecurity is also associated with a poorer quality diet, including reduced energy and nutrient intakes, and reduced consumption of fruits and vegetables among women in disadvantaged circumstances which may affect GWG (129, 130).

In 2007-2008, approximately 7.7% of Canadian households were food insecure, while in this study, nearly one third of the participants reported not having enough money for food or living expenses (131). While the two measures are not identical, this does serve to demonstrate the higher level of disadvantage in this population compared to the general population. This may also help explain why lower income and education have been associated with higher GWG in the general population, but are associated with lower GWG among the most economically disadvantaged women (115, 116). At moderate levels of food insecurity there may be consumption of less healthy, more energy dense foods and hence a propensity for adequate or even high GWG, but in the most severe circumstances, when intake is reduced, it may be a cause of inadequate gains.

6.1.4 The Relationship between Age and GWG

In this study, women under the age of 20 years gained on average 8.4 lbs more than women aged 20-29 years and 9.9 lbs more than women 30 or older. Women under 20 years also had a higher proportion of high GWG at 50%, compared to 47.3% for women 20-29 years and 40.6% for women 30 years and over, although this difference was not statistically significant. This finding is contrary to other studies where women at both the highest and lowest ends of the age spectrum tend to have lower gains and are less likely to have high GWG than women in the middle. For instance, women under 20 year of age have previously been shown to gain less total GWG than women over 20 years and women 19 years or younger have been identified as having significantly greater odds for low GWG (87, 117). While women over 30 years in this study did have the lowest proportion of high GWG and the lowest average GWG consistent with these studies, this study's relationship between GWG and younger age (i.e. under 20 years) is novel.

In multiple linear regression analysis, each additional year of age was associated with a decrease of 0.215 lbs of GWG. This translates to an average difference of 2.15 lbs between a woman of 20 years and a woman of 30 years. Age as a continuous variable was not a predictor of high GWG; however, being less than 20 years was associated with a 1.526 times higher odds of high GWG. These results suggest that age is not a major risk factor for extreme GWG. Nonetheless, the finding that among a low income, disadvantage population women less than 20 years have greater odds for high GWG is interesting. Younger women and those who are economically disadvantaged have been shown to be less likely to receive advice on GWG in a previous study (132). This may be part of the reason why younger women in this study had higher odds of GWG above recommendations. Similarly, the younger women are likely to be nulliparous, which is also associated with higher gains.

6.1.5 The Relationship between Height and GWG

In this study women 157 cm or taller gained on average five pounds more than women shorter than 157 cm and this group of women also had a higher proportion of high GWG (47.3% versus 28.6% for women less than 157 cm). This particular height was selected in order to be consistent with a previous study that found that shorter women (those less than 157 cm) gain less weight on average than taller women (87). Another study found women 170 cm or taller had a 2.70 times greater odds for high GWG compared to women 150-159 cm tall (117). Among a racially diverse sample, increasing height was associated with excessive weight gain (133). In this study's multivariate regression, height was not predictive of continuous GWG, but was a predictor of high GWG when expressed both continuously in centimeters and categorically as a stature of 157cm or taller and less than 157 cm. The reason for this relationship has not been described in previous studies of GWG but is perhaps related to metabolic differences in taller women or because taller women have greater fat stores and or fluid volume in pregnancy as a result of their larger frame. Another, more plausible reason for this association is the relationship between malnutrition and height, given that being born outside of Canada and shorter stature were both related to decreased odds of high GWG. Women emigrating from disadvantaged countries may have experienced malnutrition, which may cause stunted growth. If these women also live in severely disadvantaged economic circumstances and experience food insecurity within Canada, it makes sense that they could have lower GWG; hence the relationship between shorter stature and lower GWG.

The main finding here was that height expressed as centimeters or stature was not associated with much of an increase in the odds of high GWG. Each additional centimeter of height was associated only with a 1.032 times increased odds of high GWG and being taller than 157cm was associated with a greater odds for high GWG of only 1.686. As a result it seems safe to assume that interventions to improve GWG among low income women need not include specific recommendations for women of different heights.

6.1.6 The Relationship between Smoking Status and GWG

Thirty point two percent of the participants in this study smoked throughout pregnancy. This is a fairly high proportion compared to the literature where the rate ranges from 2%-18% (116, 117, 120). Only 10.7% of the participants in this study were former smokers, having quit either during pregnancy or in the month prior to pregnancy. As a comparison, in a randomized control trial of a smoking cessation and relapse prevention during pregnancy which took place in clinics serving low income women, more than a quarter of participants (26%) reported having quit smoking during their pregnancy.

In bivariate analysis smoking status was significantly associated with differences in average GWG and proportions of high GWG. Women who were classified as former smokers, (i.e. those who had quit smoking during pregnancy or sometime in the three months prior to pregnancy), gained on average 6.6 lbs more than non-smokers and 4.9 lbs more than women who smoked throughout pregnancy. Former smokers also had the largest proportion of high GWG when compared to women who smoked during pregnancy or non-smokers. Non-smokers actually had the lowest proportion of high GWG out of the three smoking status categories, at 39.9% compared to 48.1% for smokers and 57.1% for former smokers. Previous studies examining the relationship between smoking and GWG have typically found that women who are smokers during pregnancy gain less weight than women who are non-smokers, although some studies have found no relationship (86, 87, 116, 117, 134). In two studies that looked at the amount of cigarettes smoked per day, it was only women who smoked at the higher end of the range who had lower GWG; at least 1.5 packs per day in one study, and more than 20 cigarettes per day in the other (116, 134). While it is unusual for this study to find that non-smokers gained less on average than smokers and had a lower proportion of high GWG, this study did not discriminate between the numbers of cigarettes smoked. Women smoking only one cigarette per day were classified as smokers, yet they may have had significantly different GWG than women smoking a greater number of cigarettes daily. This may account at least in part for the difference between this study's findings and those reported in the literature.

Smoking status was not a predictor of GWG as a continuous variable in this study, but being a former smoker did increase the odds of high GWG in multivariate logistic regression. The increase in odds however was not high, at only 1.48 times greater than for women who smoked during pregnancy or were non-smokers. Few studies have looked at the relationship between quitting smoking and GWG and in particular the odds of high GWG with which to make comparisons. However, other studies have found significantly increased odds of low GWG related to smoking during pregnancy. Secker-Walker and colleagues (2003) were able to detect a larger impact of smoking on GWG by examining the number of cigarettes smoked per day (134). They determined that smoking 20 cigarettes per day was associated with an average GWG of 6.0 kg (approximately 13.2 lbs) less than women who did not smoke. Olson and Strawderman found that women smoking more than one and a half packs per day gained on average 11.59 lbs less than non-smokers. Given that smoking cessation is favourable for the health outcomes of the mother and fetus, further investigation into the association of smoking cessation and GWG is warranted.

6.1.7 Other factors related to GWG

Despite finding significant models to predict both GWG and high GWG, it is clear from the low odds ratios and the low amount of variability that is accounted for by the models (9.6% - 10.8% of the variability in GWG) that the predictor variables explored here explain only a small amount of the variation in GWG among this population of women. Löf and colleagues (2008) had similar findings, determining that BMI, smoking, parity, education, age and pre-pregnancy physical activity levels explained only 4% of the variation in GWG in their study population (120). Herring and colleagues (2012) found that parity; clinical advice regarding appropriate GWG, television viewing and BMI explained 21% of the variation in GWG among a population of urban, low income women. Other, unmeasured characteristics, some of which may not have been identified, must account for the remaining variability in GWG. Diet very likely plays an important role, however there were no data about the participant's diet available for this study. The authors of a 2012 study exploring modifiable and non-modifiable factors that may be related to excessive GWG found that none of the dietary factors included in their analysis were predictive of gaining above IOM recommendations in multivariate analysis, although in bivariate analysis women who consuming fried or fast foods at least once per week were more likely to have excessive GWG (114). Althuizen and colleagues (2009) found that women who reported elevated food intake during pregnancy were more than three times as likely to have high GWG when compared to women who reported stable food intake during pregnancy (86). Similarly, Olson and Strawderman (2003) found that women who reported eating much less, or much more food during pregnancy (compared to their intake pre-pregnancy) gained less or more weight respectively than women who maintained similar levels of food intake (116). They also determined that women who consumed three or more servings of fruit and vegetables per day gained less than those who consumed fewer servings during pregnancy (116).

Physical activity expressed as any versus none, or as a frequency was not a significant predictor of GWG or high GWG in the present study. This is an interesting finding given that higher levels of activity have been associated with lower total GWG and reduced odds of high GWG among women of various income levels (86, 114, 116). Also interesting is the fact that women in this study who reported some activity gained less weight on average than those who reported no activity, yet women with the highest frequency of physical activity (four or more times per week) gained more weight in bivariate analysis. Active women also had a higher proportion of high GWG. It is plausible that the women who were most active were those who were younger or pregnant for the first time (and hence did not have other children to care for which may reduce time for physical activity) both factors associated with higher GWG. It is also possible that the women in the most disadvantaged circumstances, who had the lowest rates of high GWG were also less likely to be physically active. Regardless of the reason, it is unlikely that physical activity itself was responsible for the higher weight gain, but rather that among low income women other factors associated with GWG are also related to rates and frequencies of physical activity. Furthermore, 73% of the participants reported that they were physically active less than three times per week or not at all, indicating that physical activity interventions are needed among low income women.

A factor that was not explored in this study but which has been associated with GWG in the past is clinician advice. Receiving advice in line with IOM guidelines for BMI-specific weight gain and having a weight gain goal may assist in adequate GWG (114). A lack of clinician advice or advice discordant with guidelines has been associated with high GWG (114). In addition it has been suggested that women of lower income and educational attainment may be less likely to receive clinician advice on weight gain, possibly due to less contact with a clinician and/or to literacy barriers which reduce the quality of communication between the patient and health care professional (114, 132). A study of primarily white, married women with high educational achievement found only 12% reported relieving no advice on GWG from their health care provider (86). In contrast, among a group of women who were also primarily white, but of diverse SES, the proportion reporting no clinician advice increased to 60%, and a third study of primarily African American low income women documented that 81% reported receiving no advice about GWG (114, 116). While no measure of health care provider advice regarding GWG was obtained in the present study, only 36.3% of participants reported attending prenatal classes, which are a source for pregnancy education and advice. It seems plausible that low income women are more difficult to reach with prenatal advice and that even when presenting to a health care professional they are less likely to discuss and set GWG goals, which in turn may increase the odds of gains above or below recommendations. Furthermore, the fact that attendance at prenatal classes was associated with higher average GWG and a greater proportion of GWG above recommendations in bivariate analysis suggests not that attendance is a risk factor for high weight gain but that women who attend classes are different in some way from women who do not attend. Perhaps, those who are most disadvantaged, including recent immigrants and/or those who do not speak English fluently are less likely to attend.

It is also worth noting that in some of the communities the immigrant population was high. It is possible that some of the previously established relationships between maternal characteristics and GWG among North American-born and higher SES women are not true or not the same for other populations of women, hence these previously established relationships were not found in the present study or were not as strong.

6.2 The Relationship between GWG and Birth Weight

The majority of the participants gave birth to an infant with a normal birth weight (77.4%). More than two times as many infants were born HBW (15.7%) than LBW (6.9%). Women with low GWG had a higher proportion of LBW infants compared to women with adequate or high GWG and women with high GWG had a higher proportion of HBW infants than women with low or adequate GWG. These differences were statistically significant. The average birth weight of women with low GWG was also significantly lower than the average birth weight of women with adequate or high GWG by 0.55 lbs and 0.85 lbs respectively.

In multiple linear regression to predict birth weight, GWG remained a significant predictor of increasing birth weight after accounting for maternal pre-pregnant BMI, smoking status and educational achievement and household smoking status and infant sex, however pre-pregnant BMI was the largest contributor to the model. Each one pound increase in GWG was associated with an increase of 0.170 lbs in birth weight. These findings are similar to those of

Koepp and colleagues who found that each one kilogram increase in GWG was related to a 22.4g increase in birth weight (53). (The equivalent of an approximately 0.2 lb increase in birth weight per one pound increase in GWG). Margerison-Zilco and colleagues (2012) also found that each one kilogram increase in GWG was significantly associated with an increase in birth weight percentile (66). A significant logistic regression to predict either high or low birth weight was not found using GWG, maternal pre-pregnant BMI, smoking status, educational achievement and, household smoking status and infant sex as predictors. This may have been due, in part to the fact that there were few infants classified as either LBW (38) or HBW (84). However, the study by Margerison-Zilco and colleagues (2012) found that each one kilogram increase in GWG significantly increased the odds of large-for-gestational-age infant and significantly decreased the odds of small-for-gestational-age infant (66). They also found that second trimester weight gain specifically was most strongly associated with birth weight for gestational-age percentile, small-for-gestational age and large-for-gestational age (66). Oza-Frank and Keim (2013) found that each one kilogram of GWG below the recommended range increased the odds of small-for-gestational age by approximately six percent and decreased the odds of large-for-gestational age by about six percent (55). It is possible that the results of the present study may have been different had gestational age been accounted for, though it seems likely that among this group of women other, unmeasured factors are more important in determining the odds of high or low birth weight.

6.3 Covariates of Birth Weight

6.3.1 The Relationship between Pre-pregnant BMI and Birth Weight

Studies have consistently found a relationship between maternal pre-pregnant BMI and infant birth weight. Consistent with previous studies, women with underweight pre-pregnant

BMIs had the highest proportion of LBW infants (66, 118, 135). There were also significant differences in birth weight by maternal pre-pregnant BMI with the infants of underweight women weighing on average 1.37 lbs less than the infants of obese women. Previous studies have found that women with obese pre-pregnant BMI have increased odds of giving birth to either or both LBW or HBW infants (66, 118, 135). In this study, women with obese pre-pregnant BMIs did have an increased prevalence of high birth weight, but also had the lowest prevalence of low birth weight at only 1.7%, compared to 13.5% for underweight women, 7.9% for overweight women and 6.1% for normal weight women.

Pre-pregnant BMI was the largest contributor to the linear regression model fitted to predict infant birth weight. However, a one unit increase in pre-pregnant BMI accounted for only a 0.170 lb increase in infant birth weight. Nonetheless, this does account for a difference of 1.36 lbs of birth weight for an infant born to a mother with a BMI of 30 versus and infant born to a mother with a BMI of 22. Koepp and colleagues (2011) also found pre-pregnant BMI to be an important predictor of birth weight and determined that each one unit increase in pre-pregnant BMI was associated with a 25.9 g (approximately 0.06 lb) increase in birth weight (53).

6.3.2 The Relationship between Tobacco Exposure and Birth Weight

Consistent with previous studies, women who smoked during their pregnancy gave birth to infants who weighed less on average compared to women who did not smoke. The proportion of women delivering low birth weight infants was almost three times greater for smokers (13.1%) compared to non-smokers (4.6%). After controlling for other factors, maternal smoking during pregnancy remained a significant predictor of birth weight by a decrease on average of 0.61 lbs. Being exposed to tobacco smoke from other members of the household during gestation was also associated with lower birth weight and lower proportion of high birth weight compared to infants born to a mother residing in a home with no smokers, although this was no longer a significant predictor of birth weight after controlling for other factors.

6.3.3 The Relationship between Sex and Birth Weight

In this study, male infants weighed on average 0.17 lbs more than female infants. This difference was not statistically significant. When included in multiple regression, sex of the infant was a significant predictor of birth weight and was associated with an average of 0.260 lbs greater birth weight than for female infants.

6.4 The Relationship between GWG and Child Weight Status at Four Years

At four years of age the average weight-for-height z-score of the participant's children was indicative of a normal weight status. BMI data are interpreted differently for children than adults and are both sex- and age-specific. Weight-for-height z-scores were used in this study and may underestimate the prevalence of overweight and obesity in this population as a z-score of 2 (the indicator for overweight) corresponds to the 97.7th percentile, higher than the 85th and 95th percentile cut-points used to indicate overweight and obese BMI, respectively. In this study, only 4.6% of the children had a weight-for-height z-score indicative of overweight and 4.1% had a weight-for-height z-score indicative of obesity. An additional 19.6% of children had weight-for-height z-scores indicating they were at risk for overweight. As a comparison, a study published in 2010 examining overweight and obesity among two to five year old Canadian children found a prevalence between 21.5-34.5% depending on whether the WHO, CDC or International Obesity Task Force cut-points for sex-specific, BMI –for-age were used.

Initial bivariate analysis found only GWG, maternal pre-pregnant BMI and birth weight were related to differences in average weight-for-height z-score and only GWG and maternal pre-pregnant BMI were related to differences in the proportion of children classified as wasted/normal weight, at risk for overweight or overweight/obese. There were also weak correlations between weight-for-height z-score and maternal weight status, but not with GWG. Perhaps because of the low numbers of children categorized as overweight or obese, no significant logistic regression to predict these weight statuses could be found using GWG, maternal pre-pregnant BMI, birth weight, exposure to cigarette smoke in utero (through maternal smoking or other household members smoking), maternal educational achievement, breastfeeding status, or sex of the child. No significant linear regression to predict weight-for-height z-score was obtained using these predictor variables either, although GWG did appear to be a weak, though non-significant predictor.

That no significant linear model could be found to predict child weight-for-height z-score at four years using the predictors described above is surprising given the results of previous research which have frequently found associations between childhood weight status and: maternal BMI; birth weight, and/or GWG (60, 81, 135, 136). These differences may be due to the indicator used here (weight-for-height z-score) or may be due to different relationships between these variables and child weight status in the population surveyed in this research.

Hinkle and colleagues (2012) found an association between excess GWG and child adiposity at five years of age, but only among the children of women who were had normal or overweight pre-pregnancy status (137). Another study found that only first trimester weight gain was associated with BMI z-score at age five and only among the children whose mother had a low or normal BMI (66). This study did not examine the relationship between GWG and child weight status by differing maternal pre-pregnancy weight status, nor was it possible to examine trimester-specific GWG and these may also be reasons why a predictive association between GWG and child weight status was not found. Maternal BMI has also been consistently linked to child adiposity with overweight or obese maternal BMIs predicting an increased likelihood of overweight or obesity in the child. While GWG was associated with birth weight in this study, it was no longer a significant predictor of child weight status at four years of age using weight-for-height z-scores. The fact that no significant models were found to predict either weight-for-height z-score at four years or to predict overweight/obesity at four years is not necessarily indicative that the variables examined here are not associated with childhood weight status, but rather the small number of children in this study classified as overweight or obese may have prevented differences from becoming apparent. Other measures of adiposity such as age and sex-specific BMI may allow for more accurate representation of children's weight status and the relationship to GWG. Bivariate analysis did indicate that high and low GWG were associated with statistically significant differences in average weight-for-height z-score before accounting for other characteristics of the children which indicates that this relationship should be further investigated using other measures of child adiposity.

6.5 The Relationship between Pre-pregnant BMI, GWG and Longitudinal Weight Status

Data on the women's weight status at eight years postpartum were available for only 57.2% of the original sample of participants. Among these women, the average BMI had increased by 2.88 kg/m^2 and average weight had increased by 16.88 pounds over this eight year period. While few studies have examined weight retention beyond 12 to 18 months after delivery, a 2007 meta-analysis did find that while weight decreased steeply for the first 3 months postpartum and then continued to decrease up to 12 months postpartum, between 12 and 18 months there was an increase in weight observed (138). Another study found that lower SES women retained more weight at one year postpartum than women of higher SES (139).

As expected, pre-pregnant BMI was a predictor of BMI at both four and eight years postpartum and BMI at four years postpartum predicted BMI at eight years postpartum, with a gradual increase.

There was no bivariate correlation between GWG and BMI at four years or eight years postpartum. However, when entered into a linear regression model to predict BMI, GWG was found to be a significant predictor at both four and eight years postpartum. A 2013 meta-analysis determined that women who gained excess weight during their pregnancy tended to have greater postpartum weight retention over the long term and additionally were at an increased risk of becoming overweight or obese when compared to women who had adequate GWG (i.e. within recommendations) (140).

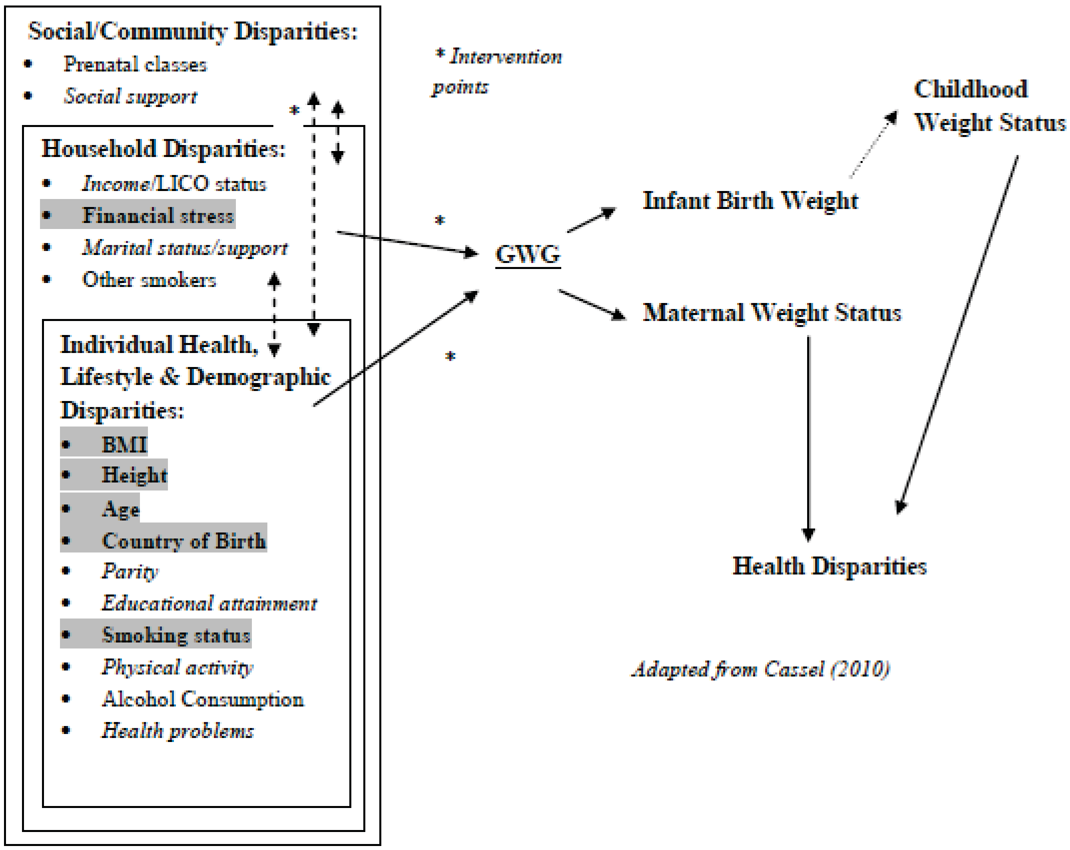
Previous studies have suggested that pre-pregnant BMI may moderate the effects of GWG. For example a 2011 study showed that GWG beyond IOM recommendations significantly increased the odds of retaining weight at one year postpartum in normal, overweight and obese women (141). Retention of more than 10 kg (approximately 22 lbs) was prevalent among 5.5% of overweight women, 2.4% of normal weight women and 2.2% of obese women (141). In the present study, when examined separately, GWG was predictive of four year postpartum BMI only for normal weight women. However, predictive models were not found for women in the underweight and obese pre-pregnant BMI categories which may in part be due to drop-out over time and the small number of women in these categories. Perhaps among normal weight low income women, GWG has a similar effect on future weight status as it does among higher income women, yet among underweight, overweight, and obese low income women other factors such as food security, health status, and metabolic issues etc. which have led to the development of a BMI outside of the ideal range are more important in determining future weight status.

Schmitt and colleagues also argue that because environmental and lifestyle factors are more likely to explain weight gains or retention than the events of pregnancy over time, the term "postpartum weight retention" should be reserved for the period only up to 12 or 18 months after delivery (138). It is also important to note that in this study, subsequent pregnancies (and accompanying GWG) over the eight year period were not accounted for. Nonetheless, the results of this study indicate that for normal weight women in particular, a higher GWG is associated with an increased BMI at four years after delivery independent of pre-pregnant BMI.

6.6 Findings in the Context of the Social Ecological Model

Reflecting back on the Social Ecological Model presented earlier in the theoretical framework section it becomes clear that the factors most strongly associated with GWG among the participants of the present study are different from those determined in previous research. Figure 4 presents a revised diagram of the relationships between individual, household and community level characteristics and GWG, child weight outcomes and maternal weight outcomes. The highlighted variables are those which were found to be the most significant predictors of GWG in the present study. The italicized variables are those which have previously been associated with GWG among samples of women with varying demographics, but especially among white women, and frequently those with higher incomes and educational attainment than in the present study.

Figure 4: Modified Social Ecological Model



While modifiable lifestyle characteristics such as physical activity have previously been demonstrated as more significant factors in influencing GWG, this was not the case in the present study. With the exception of smoking, the factors found to be predictors of GWG were primarily non-modifiable (height, age, country of birth) or difficult to modify during pregnancy (financial stress, BMI). Furthermore, GWG as a modifiable characteristic was only associated with small changes in infant birth weight and longitudinal maternal weight status, and was not found to be predictive of child weight status by four years of age. These results suggest that among low income women, interventions at higher levels of influence than the "individual" or even "household" levels are required to improve health and weight outcomes. As described earlier, the theory behind the SEM is that the various levels of influence interact with and therefore affect each other. Among women from less disadvantaged neighbourhoods, about whom much of the previous research on influences of GWG is based, interventions at the individual level (for example to improve physical activity levels) may be beneficial. Among the women of the present study however, it would seem that interventions to improve the women's environments, are needed first. This would include institutions or policies to improve income or further subsidizing living expenses and improving food security. By improving factors at higher levels of influence, individual characteristics may be improved, as research suggests for example, that smoking and obesity rates are higher among low income women (10, 11, 142). At that point modifiable individual characteristics such as physical activity may become more important predictors of GWG. Furthermore, attempts to include women in interventions may be more successful. This seems plausible given the fact that attendance at prenatal class, while low, was in bivariate analysis associated with higher GWG, suggesting that those who were most disadvantaged and hence had increased odds for low GWG may have been less likely to attend.

It is also important to note that while maternal BMI was associated with GWG, and both child and maternal weight outcomes in similar ways to those described previously in the literature, the factors influencing BMI outside of recommended ranges are almost certainly different among women who are economically disadvantaged and those who are not. Low income is associated with a higher prevalence of overweight or obesity, perhaps due in part to consumption of poor quality, energy dense diets made up of inexpensive foods and limited physical activity resulting from neighbourhood environments that discourage walking and playing outside (143, 144). Yet, in this study it is clear that the most disadvantaged women may be experiencing more severe food insecurity (i.e. inability to purchase enough food) and may be more likely to be underweight as well. Underweight BMIs may also be the result of malnutrition among women who had immigrated to Canada from economically disadvantaged countries. Hence the aforementioned efforts to improve food security could help to improve women's BMIs, which the results of this study would suggest could also help improve rates of GWG within recommendations and ultimately maternal and child weight outcomes in the future.

The most important point to be drawn from the use of the SEM in the present study is that the relationships between various inter- and intrapersonal characteristics and GWG are not the same for low income women as they are for higher income women. As a result these women require special consideration and unique interventions to help them achieve healthy weight gain during pregnancy and a healthy weight status for themselves and their children in the future.

6.7 Generalizability

The participants of this study resided in small, economically disadvantaged neighbourhoods in Ontario. Ontario is different from other Canadian provinces in several ways; for example, the prevalence of overweight and obesity is lower, and along with Quebec and British Columbia, Ontario has the highest prevalence of foreign-born residents. The five communities included in this study however, were diverse in terms of their demographics in several respects. For example, 94.9% of the participants from Peterborough were born in Canada, compared to only 23.3% in Toronto. Similarly, 48.5% of participants in Peterborough had household incomes at or above the LICO, compared to just 6.1% of the Toronto residents. While the relationships found in this study may therefore reflect similar relationships to be found among the residents of other low income Canadian women, any generalizing to the other Canadian provinces should be done with caution. As has been discussed above regarding the SEM, factors at the community and societal levels of influence may affect the relationships between intra- and interpersonal characteristics and health outcomes. Sibley (2011) has demonstrated that inequalities in access to health care exist between the rural and urban residents of Canada such that the residents of the most rural and the most urban areas of the country are less likely to have a regular medical doctor and rural and urban residents have different rates of health care seeking behaviours (145). Furthermore, White and colleagues have discussed that while living in disadvantaged neighbourhoods and having low socioeconomic status have been linked to poorer health outcomes, regional differences within Canada may moderate these associations, particularly in the Pacific and Atlantic regions (146). "Living in neighbourhoods marked by high levels of deprivation may be more influential on the pathways leading to disease for populations residing in the coastal regions of Canada" (p.361) (146). As a result, the relationships found in this study may not accurately reflect relationships with GWG in Nova Scotia.

6.8 Limitations

One of the primary limitations of conducting secondary data analysis is that additional information or clarification cannot be collected from the participants. Although the BBBF surveys included a wide range of questions and there are data available on a number of prenatal and demographic variables that may be associated with GWG, some information that would most likely be associated with GWG was not included and hence is not available. Maternal diet and eating patterns would almost certainly have a relationship with GWG yet there were no such data collected. Another limitation is that height and weight of the participants (i.e. the mothers) was self-reported. Pre-pregnancy weight and weight at delivery were also reported retrospectively and may not be as accurate as they would, had they been reported at those times. However, Hinkle and colleagues (2013) conducted a study to assess reliability of self reported GWG at ten months postpartum by comparing the estimated (i.e. reported) weight gain to birth certificate data and found that for most women the estimates were within five pounds of what was recorded on the birth certificate (147).

Although participants were asked specifically if they had diabetes during their pregnancy, too few responded “yes” to examine the variable individually and hence the variable “any health problems during pregnancy” was used instead, limiting the ability to draw any inferences from potential associations with GWG. Finally, dichotomizing variables into high/low and yes/no categories can result in the loss of information, so whenever variables that could be examined either continuously or dichotomously were analyzed the continuous version was used if possible.

Another limitation of this study was missing data. While there were 720 participants interviewed in the first two survey periods, data required to calculate GWG were available for 562 women (78.1% of the sample). Some of this missing data was due to non-response and some due to the fact that the participant responding was not the biological mother of the focal child. Furthermore, data required to classify GWG as below, within or above recommendations (i.e. height and pre-pregnancy weight) were available for 547 women (76% of the sample). By the 48 month interview data required to calculate BMI were available for 380 women (52.8% of the total sample; 69.5% of the participants analysed in the first objective of the present study). By the eight year postpartum interview, data required to calculate BMI were available for only 313 participants (43.5% of the total sample; 57.2% of the participants analysed in the first objective of the present study). This missing data limits the ability to generalize the results of this study.

Finally, it should be noted that the Better Beginnings, Better Futures sample was clustered due to the nature of the data being collected from five distinct communities. Despite this clustering, statistical analysis of the data was undertaken as though the sample were not clustered. Because alternative analyses such as the use of interaction terms to deal with the clustering were not undertaken, generalizability of the results of this study is limited.

CHAPTER 7

RECOMMENDATIONS AND CONCLUSIONS

7.0 Recommendations and Conclusion

7.1 Recommendations

This study has shown that while low income women share some of the same predictive factors for GWG outside of recommendations as women of higher incomes, they are a unique population with unique needs. The SEM framework was used in this study to explore how inequalities in modifiable and non-modifiable personal characteristics, interpersonal variables and environmental factors influence each other and interact to influence GWG, and ultimately maternal and child weight status. Given the disadvantaged environment in which the participants of this study resided, it makes sense that the interrelationships between the participants' characteristics and GWG would be different than has been found among women living in more favourable environments. While individual level interventions to promote increased physical activity and healthy eating habits may be beneficial among women from non-disadvantaged communities, policy to improve the income and educational achievement of women and to address issues of food insecurity are necessary to improve the disadvantaged neighbourhood circumstances that influence inter- and intra-personal characteristics that increase the odds of high GWG and obesity among low income women and children.

The persistent association between pre-pregnant BMI and GWG suggests that pre-pregnancy counselling to assist in achieving an ideal BMI prior to conception is also needed. Previous research suggests that disadvantaged women may be less likely to receive advice on appropriate GWG. Most women in this study did not attend prenatal classes which suggests that future research could investigate if and why participation in such classes is lower among disadvantaged women and how participation could be increased. Such programming should include advice on realistic and appropriate GWG goals, and how to incorporate regular physical activity and health eating habits into the one's lifestyle during pregnancy. Programming should also be available to women who smoke, not only to help them to quit but to address the potential for excess weight gain that may be related to smoking cessation. Given the relationship between country of birth and GWG it would also appear that consideration in planning prenatal classes should be given to culturally appropriate information. Perhaps unique prenatal programs could be developed to operate out of cultural centres or other facilities accessible to minority populations. These programs could be presented in languages other than English or French and include culturally relevant diet and lifestyle counselling. This would require collaboration from health professionals such as dietitians as well as the community, specifically individuals from the target audience.

Further research is needed to examine the relationship between active and passive smoking during pregnancy, in particular the association between smoking cessation shortly before or during pregnancy and the odds of high GWG. Future research should also address food insecurity among pregnant women. The present study suggests that lacking money for food increases the odds of inadequate GWG. When possible, future analyses of predictors or consequences of GWG should be analysed by pre-pregnant BMI category as the results of this study and previous works suggest that BMI moderates the relationships between these factors. It has been established that both high and low GWG can have negative consequences on pregnancy and birth outcomes, but these relationships may be more pronounced for some pre-pregnant BMI categories than others.

7.2 Conclusion

High rates of GWG above recommendations are prevalent among low income women, with proportions similar to those found in the general population. However, GWG below recommendations also continues to be an issue for low income women, with those who are most disadvantaged having the highest odds. Living in a disadvantaged community may be associated with overweight and obesity, younger age, smoking, being born outside of Canada and lacking money for food, all factors which this study found to be related to GWG outside of the recommended ranges. Women born outside of Canada may be particular likely to live in disadvantaged circumstances and experience low GWG, yet may be among the most difficult group to reach out to given language or cultural barriers. Young women under 20 years of age and those pregnant for the first time have higher odds of experiencing GWG above recommendations, as are those women who quit smoking shortly before or during pregnancy.

As described, among the low income women of this study the most significant predictors of GWG outside of IOM recommendations were pre-pregnant BMI, country of birth, financial stress, age and smoking status, however these factors accounted for only a small amount of the variation in GWG. Unlike populations of women with higher incomes and more varied demographics, factors such as education and income were not significant predictors of GWG in the present study, likely due to the homogeneity of the population. This study was also unique in that women under 20 years of age had higher average GWG than women 20 or older and were more likely to experience high GWG. Modifiable intra- and interpersonal factors such as support or physical activity were not significant predictors after accounting for the factors previously described. It stands to reason that in this study's unique population, where characteristics that typify one as being disadvantaged, such as low income, low educational achievement, financial stress and higher rates of smoking are prevalent these factors are also the most important determinants (whether directly or indirectly) of GWG outside of recommendations. Among higher income women where the prevalence of such characteristics are lower there may be a greater diversity in physical activity and eating habits and with factors such as financial stress not influencing weight gain, modifiable factors may become more influential. Using the SEM it can be postulated that improving the circumstances of low income women at the federal or provincial level may work towards improving characteristics at the inter- and intrapersonal level that are associated with elevated GWG (such as BMI, financial stress, having children at a young age, smoking, etc). Improving these conditions and factors would create more favourable environments such as those experienced by higher income women at which point community level interventions to address issues such as physical activity may have more of an impact on GWG.

It is important to note that pre-pregnant BMI is consistently associated with GWG across all income levels. The findings of this study do not suggest that GWG within 2009 IOM recommendations can make up for the health risks and negative associations of a high BMI. Achieving a healthy BMI before pregnancy is therefore ideal, as it influences pregnancy outcomes, birth weight and perhaps child weight outcomes even when GWG is adequate. The results of this study do not allow us to draw strong conclusions about the relationship between GWG and either child weight status or maternal weight status long term. Among low income women it would seem that addressing BMI prior to pregnancy may be the more pressing concern.

Chapter 8

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Appendix 1

SURVEY QUESTIONS

Perinatal Parent Interview

childid	Unique child ID
site	Site
cohort	Cohort
sexchild	Sex of child
bdy	Child's date of birth (year)
bdm	Child's date of birth (month)
bdd	Child's date of birth (day)

SECTION A

relchlda A.3 What is your relationship to (name of baby)? Are you
The biological mother/father = 1
In some other relationship to the baby = 2

sexra A.4 What is the sex of the respondent?
Male = 1
Female = 2

sexchlda A.5 What is the sex of the baby?
Male = 1
Female = 2

evermara A.14 Are you now or have you ever been married?
No = 0
Yes = 1

whuswifa A.17 Are you currently living with your husband?
No = 0
Yes = 1

livparta A.18 Are you living with a partner or in a common-law relationship?
No = 0
Yes = 1

bdrya A.20 When were you born (Record year, month, day)
bdrma
bdrda

bpra A.23 Where were you born?

In Canada...

- Ontario = 01
- Outside Ontario = 02

Outside Canada...

- China = 03
- Germany = 04
- Hong Kong = 05
- India = 06
- Iran = 07
- Italy = 08
- Jamaica = 09
- Pakistan = 10
- Poland = 11
- Portugal = 12
- Somalia =13
- Sri Lanka = 14
- Trinidad = 15
- United Kingdom = 16
- U.S.A.= 17
- Vietnam = 18
- Lebanon = 19
- Haiti = 20
- Other (SPECIFY ON LONG FORM) = 21

wghtclba A.27 How much did the baby weight? (RECORD IN POUNDS)
wghtcoza

edlevlra A.34 What is the highest level of schooling that you have completed? (INCLUDE ANY PROGRAMS TO PREPARE A PERSON FOR WORK)

- No formal schooling = 01
- Some primary school = 02
- Primary school = 03
- Some secondary or high school = 04
- Completed secondary or high school) = 05
- Some community college, technical college, CEGEP,or RN program without a university degree = 06
- Completed community college, technical college, CEGEP, or RN program without a university degree = 07
- Some university (not completed) = 08
- University degree (completed) B.A./B.Sc = 09
- University degree (completed) Professional (e.g., law, nursing, dentistry, Medicine, commerce, engineering) degree = 10
- University degree (completed) M.A./Ph.D. = 11

SECTION F

babyfeda F.1 How did you feed your baby at birth?

Breast-fed = 1
Bottle-fed = 2
Other (Record on Long Form). Ask "When baby was brought home, was he/she breast-fed or bottle-fed? CONTINUE WITH F.1 (CHOICE #1 OR #2) AS IF THIS HAPPENED AT BIRTH = 3

brstnowa F.3 Are you breast-feeding your baby now?

No = 0
Yes = 1

brslng1a F.4 How long did you breast-feed? (RECORD IN WEEKS)

SECTION L

IMPORTANT NOTE: FOR SECTION L, ONLY ASK QUESTIONS L.1-L.57 IF THE R IS THE BIOLOGICAL MOTHER OF THE FOCAL COHORT CHILD. IF THE R IS NOT THE BIOLOGICAL MOTHER, PLEASE ASK L.18B, L.30, L.31 AND THEN GO TO L.58.

I would like to ask you some questions about your pregnancy.

prghltha L.2 Did you have any health problems during this pregnancy?

No = 0
Yes = 1

prghlt1a L.3 What kinds of problems? (RECORD ALL THAT APPLY)
prghlt2a
prghlt3a
prghlt4a

Operation on your abdomen = 1
Kidney Infection = 2
Vaginal bleeding after 12 weeks (3 months) of pregnancy = 3
Diabetes = 4
High blood pressure = 5
Toxemia (high blood pressure with protein in urine) = 6
Fibroids (non-cancerous tumours in uterus) = 7
Sexually transmitted diseases = 8
Other (SPECIFY ON LONG FORM = 9

Some women go to groups or classes with other pregnant women to learn about their pregnancy and their baby. So I would like to ask you some questions about your use of prenatal classes and other supports during their pregnancy.

classesa L.5 Did you attend prenatal or pregnancy classes during this pregnancy?
No = 0
Yes = 1

prgsuppa L.11 Did you receive support (help) from other people or groups during your pregnancy? (such as friends, relatives, parent group.)
No = 0
Yes = 1

activ7a L.15 During the first seven months of your pregnancy, did you do any type of activity that got your heart beating a bit faster for 15 or 20 minutes (for example, brisk walk on average once a week?
No = 0
Yes = 1

exerc7a L.16 On average, how often?
1-3 times per week = 1
4-6 times per week = 2
Once a day or more = 3

Now I would like to ask you some general questions about your pregnancy.

wghtprea L. 17 How much did you weigh before you became pregnant? (RECORD IN POUNDS)

wghterma L.18a How much did you weigh at the end of your pregnancy before giving birth? (RECORD IN POUNDS)

weighlba L.18b How much do you currently weigh? (RECORD IN POUNDS)

heighfta
heighina L. 19 How tall are you (HEIGHT IS TO BE MEASURED DIRECTLY IF THIS IS FEASIBLE. REORD IN FEET AND INCHES. IF USING SELF-REPORT, MAKE A NOTE OF THIS ON THE ANSWER SHEET.)

numprega L.20 How many times have you been pregnant?
Once = 1
Two or more = 2

Now I want to ask you about your drug use before and during pregnancy. By that I mean your use of tobacco, street drugs, alcohol, over-the-counter drugs. These questions are being asked of all families. I want to remind you that all of your answers are confidential.

(NOTE: IF YOU HAVE ANY REASON TO BELIEVE THAT THESE QUESTIONS ARE INAPPROPRIATE FOR R (EG. CULTURAL OR RELIGIOUS REASONS) THEN SAY “IF YOU DO

NOT FEEL COMFORTABLE ANSWERING ANY OF THE QUESTIONS, PLEASE SAY SO AND I WILL MOVE ON TO THE NEXT SET OF QUESTIONS." AND THEN SKIP TO L.71)

smokcona L.33 Did you smoke cigarettes during the month before you became pregnant?
No = 0
Yes = 1

smokprga L.35 Did you smoke cigarettes during your pregnancy?
No = 0
Yes = 1

smokchga L.37 Did you change your smoking pattern during this pregnancy?
No change, I smoked the same amount = 1
Yes, I smoked more = 2
Yes, I smoked less = 3
Yes, stopped smoking = 4

osmkprga L. 39 Did any of the other people living in your household smoke cigarettes during your pregnancy?

I would now like you to consider the number of times you drink either wine, liquor or beer.

alcprga L.47 Did you drink alcohol during your pregnancy?
No = 0
Yes = 1

SECTION N

mincoma N.1 What is your current total monthly household income from all sources before taxes or other deductions? (RECORD FULL AMOUNT, E.G., "EIGHT FIFTY" AS 00850. USE 3 MONTH AVERAGE IF R SAYS IT CHANGES. PROBE. IF R IS UNABLE TO ANSWER THEN SAY "COULD YOU GIVE ME A RANGE?")

Which of the following was true for your household in the past 3 months.

finstr1a N. 4 Sometimes we didn't have enough money for our food and daily living expenses.
True = 1
Not true = 2

finstr2a N. 5 We've had to go to a food bank.
True = 1
Not true = 2

finstr3a N.6 We have not been able to pay all of our bills.

True = 1

Not true = 2

18 Month Parent Interview

childid	Unique child ID
site	Site
cohort	Cohort
sexchild	Sex of child
bdy	Child's date of birth (year)
bdm	Child's date of birth (month)
bdd	Child's date of birth (day)

SECTION A

relchldb A.3 What is your relationship to (name of baby)? Are you
- The biological mother/father = 1
- In some other relationship to the baby = 2

sexrb A.4 What is the sex of the respondent?
- Male = 1
- Female = 2

sexchldb A.5 What is the sex of the baby?
- Male = 1
- Female = 2

evermarb A.14 Are you now or have you ever been married?
- No = 0
- Yes = 1

whuswifb A.17 Are you currently living with your husband?
- No = 0
- Yes = 1

livpartb A.18 Are you living with a partner or in a common-law relationship?
- No = 0
- Yes = 1

bdryb A.20 When were you born (Record year, month, day)
bdrmb
bdrdb

bprb A.23 Where were you born?

In Canada...

Ontario = 01

Outside Ontario = 02

Outside Canada...

China = 03

Germany = 04

Hong Kong = 05

India = 06

Iran = 07

Italy = 08

Jamaica = 09

Pakistan = 10

Poland = 11

Portugal = 12

Somalia =13

Sri Lanka = 14

Trinidad = 15

United Kingdom = 16

U.S.A.= 17

Vietnam = 18

Lebanon = 19

Haiti = 20

Other (SPECIFY ON LONG FORM) = 21

wghtclbb A.27 How much did the baby weight? (RECORD IN POUNDS)
wghtcozb

edlevlrb A.34 What is the highest level of schooling that you have completed? (INCLUDE ANY PROGRAMS TO PREPARE A PERSON FOR WORK)

No formal schooling = 01

Some primary school = 02

Primary school = 03

Some secondary or high school = 04

Completed secondary or high school) = 05

Some community college, technical college, CEGEP,or RN program without a university degree = 06

Completed community college, technical college, CEGEP, or RN program without a university degree = 07

Some university (not completed) = 08

University degree (completed) B.A./B.Sc = 09

University degree (completed) Professional (e.g., law, nursing, dentistry, medicine, commerce, engineering) degree = 10

University degree (completed) M.A./Ph.D. = 11

SECTION F

babyfedb F.1 How did you feed (name of child) at birth?
Formula = 0
Breast-feeding = 1

brstnowb F.2 Is your child breast-feeding now?
No = 0
Yes = 1

stopageb F.3 How old was your child when you stopped? (RECORD IN MONTHS)

SECTION L

IMPORTANT NOTE: FOR SECTION L, ONLY ASK QUESTIONS L.1-L.57 IF THE R IS THE BIOLOGICAL MOTHER OF THE FOCAL COHORT CHILD. IF THE R IS NOT THE BIOLOGICAL MOTHER, PLEASE ASK L.18B, L.19, L.30, L.31 (INDICATED WITH *) AND THEN GO TO L.58.

I would like to ask some questions about your pregnancy with (name of child).

prghlthb L.2 Did you have any health problems during this pregnancy?
No = 0
Yes = 1

prghlt1b L.3 What kinds of problems? (RECORD ALL THAT APPLY)
Operation on your abdomen = 1
Kidney Infection = 2
Vaginal bleeding after 12 weeks (3 months) of pregnancy = 3
Diabetes = 4
High blood pressure = 5
Toxemia (high blood pressure with protein in urine) = 6
Fibroids (non-cancerous tumours in uterus) = 7
Sexually transmitted diseases = 8
Other (SPECIFY ON LONG FORM = 9

Some women go to groups or classes with other pregnant women to learn about their pregnancy and the child. So I would like to ask you some questions about your use of prenatal classes and other supports during this pregnancy.

classesb L.5 Did you attend prenatal or pregnancy classes during this pregnancy?
No = 0
Yes = 1

pregsuppb L.11 Did you receive support (help) from other people or groups during your pregnancy? (such as from friends, relatives, parent group.)

activ7b L.15 During the first seven months of your pregnancy, did you do any regular exercise? (Regular exercise means on average once a week. "Exercise" is anything that got your heart beating a bit faster or got you breathing a bit faster for 15 or 20 minutes for example, brisk walking.)

No = 0
Yes = 1

exerc7b L.16 On average, how often?

1-3 times per week = 1
4-6 times per week = 2
Once a day or more = 3

Now I would like to ask you some general questions about your pregnancy.

wghtpreb L. 17 How much did you weigh before you became pregnant? (RECORD IN POUNDS)

wghtermb L.18a How much did you weigh at the end of your pregnancy before giving birth? (RECORD IN POUNDS)

weighlbb L.18b* How much do you currently weigh? (RECORD IN POUNDS)

heighftb
heighinb L. 19* How tall are you (HEIGHT IS TO BE MEASURED DIRECTLY IF THIS IS FEASIBLE. REORD IN FEET AND INCHES. IF USING SELF-REPORT, MAKE A NOTE OF THIS ON THE ANSWER SHEET.)

numpregb L.20 How many times have you been pregnant?

Once = 1
Two or more = 2

Now I want to ask you about your drug use before and during pregnancy. By that I mean your use of tobacco, street drugs, alcohol, over-the-counter drugs. These questions are being asked of all families. I want to remind you that all of your answers are confidential.

(NOTE: IF YOU HAVE ANY REASON TO BELIEVE THAT THESE QUESTIONS ARE INAPPROPRIATE FOR R (EG. CULTURAL OR RELIGIOUS REASONS) THEN SAY "If you do not feel comfortable answering any of the questions, please say so and I will move on to the next set of questions." AND THEN SKIP TO L.73)

smoknowb L.33 Did you smoke cigarettes during the month before you became pregnant?
No = 0
Yes = 1

smokprgb L.35 Did you smoke cigarettes during your pregnancy?
No = 0
Yes = 1

smokchgb L.37 Did you change your smoking pattern during this pregnancy?
No change, I smoked the same amount = 1
Yes, I smoked more = 2
Yes, I smoked less = 3
Yes, stopped smoking = 4

osmkprgb L. 39 Did any of the other people living in your household smoke cigarettes during your pregnancy?
No = 0
Yes = 1

I would now like you to consider the number of times you drink either wine, liquor or beer before and during your pregnancy.

alcprgb L.45 Did you drink alcohol during your pregnancy?
No = 0
Yes = 1

SECTION N

Now I would like to ask you some questions about your monthly income and household expenses.

mincomb N.1 What is your current total monthly household income from all sources before taxes or other deductions? (RECORD FULL AMOUNT, E.G., "EIGHT-FIFTY" AS 00850. USE 3 MONTH AVERAGE IF R SAYS IT CHANGES. PROBE. IF R IS UNABLE TO ANSWER THEN SAY "COULD YOU GIVE ME A RANGE?")

Which of the following was true or not true for your household in the past 3 months.

finstr1b N. 4 Sometimes we didn't have enough money for our food and daily living expenses.
True = 1
Not true = 2

finstr2b N. 5 We’ve had to go to a food bank.
True = 1
Not true = 2

finstr3b N.6 We have not been able to pay all of our bills.
True = 1
Not true = 2

48 Month Parent Interview

childid	Unique child ID
site	Site
cohort	Cohort
sexchild	Sex of child
bdy	Child's date of birth (year)
bdm	Child's date of birth (month)
bdd	Child's date of birth (day)
intdatyf	YEAR OF INTERVIEW
indatmf	MONTH OF INTERVIEW
indatdf	DAY OF INTERVIEW

mincomd — What is your current total monthly household income from all sources before taxes or other deductions? (RECORD FULL AMOUNT, E.G., "EIGHT-FIFTY" AS 00850. USE 3 MONTH AVERAGE IF R SAYS IT CHANGES. PROBE. IF R IS UNABLE TO ANSWER THEN SAY "COULD YOU GIVE ME A RANGE?")

weighlbd — How much do you currently weight? (RECORD IN POUNDS)

cigpackd — How many cigarettes do you currently smoke each day?

- None = 0
- Less than half a pack of cigarettes = 1
- More than half a pack to 1 pack of cigarettes = 2
- More than one pack of cigarettes = 3

whzd — Weight for height z-score of focal child

Grade 3 Parent Interview

childid	Unique child ID
Site	Site
cohort	Cohort
sexchild	Sex of child
bdy	Child's date of birth (year)
bdm	Child's date of birth (month)
bdd	Child's date of birth (day)
intdatyfh	YEAR OF INTERVIEW
indatmfh	MONTH OF INTERVIEW
indatdh	DAY OF INTERVIEW

SECTION A

Now I would like to ask you some questions about your monthly income and household expenses.

mincomh A.54 What is your current total monthly household income from all sources before taxes or other deductions? (RECORD FULL AMOUNT, E.G., "EIGHT-FIFTY" AS 00850. USE 3 MONTH AVERAGE IF R SAYS IT CHANGES. PROBE. IF R IS UNABLE TO ANSWER THEN SAY "COULD YOU GIVE ME A RANGE?")

SECTION L

weighlbh How much do you currently weight? (RECORD IN POUNDS)

Now we have some questions about your current use of tobacco and alcohol.

cigpackh L.7 How many cigarettes do you currently smoke each day?

None = 0
Less than half a pack of cigarettes = 1
More than half a pack to 1 pack of cigarettes = 2
More than one pack of cigarettes = 3