MATERNAL OBESITY, EXCESSIVE GESTATIONAL WEIGHT GAIN AND PREGNANCY OUTCOMES

FINAL REPORT

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Executive Summary

This review, conducted by the Saskatchewan Prevention Institute (Prevention Institute), aimed to: (a) examine the relationship between maternal obesity and pregnancy outcomes (i.e., maternal outcomes and neonatal, infant and child outcomes); and (b) assess the association between excessive gestational weight gain (GWG) and pregnancy outcomes (i.e., maternal outcomes and neonatal, infant and child outcomes). The document reports on findings from a review of the literature on maternal obesity, excessive gestational weight gain and pregnancy outcomes, conducted between December 1, 2009 and March 31, 2010.

A search was performed in two computerized databases: MEDLINE and PubMed. Primary search terms included maternal obesity and excessive gestational weight gain, cross-referenced with pregnancy outcomes, pregnancy-induced hypertension, preeclampsia, gestational diabetes mellitus, miscarriage, caesarean section, type 2 diabetes, breastfeeding outcomes, large-for-gestational-age infants, macrosomia and postpartum weight retention. Studies were also located by reviewing reference lists and bibliographies in selected articles.

According to the available evidence, the most common health effects of maternal obesity on the mother include hypertension (pre-existing and pregnancy-induced), preeclampsia, diabetes mellitus (pregestational and gestational), and the need for caesarean section. The most common health outcome of maternal obesity on the newborn is macrosomia or a large-for-gestational-age neonate (LGA). Furthermore, macrosomia has been associated with the following pregnancy outcomes, including: caesarean birth, prolonged labour, birth trauma, cephalopelvic disproportion, birth asphyxia, and increased risk of perinatal mortality. There is also evidence to suggest that maternal obesity is linked to obesity in the child, adolescent and adult offspring, although the causal nature of this relationship is unclear at present. The most identified health risk of excessive GWG in the literature is the delivery of a LGA infant/macrosomia.

As is the case with other health problems, the obesity epidemic disproportionately affects lower-socioeconomic groups, including ethnic minorities and individuals residing in rural communities. Socio-demographic and maternal characteristics of excessive gestational weight gain in Canada include having a body mass index (BMI) > 27, giving birth for the first time, having a lower level of education, being a young mother, and being Aboriginal.

Because recent research suggests the in utero environment may program the fetus for elevated risk of later obesity, attempts should be made to prevent or reduce obesity prior to pregnancy. Practitioners and educators may wish to begin counselling adolescent and young women prior to pregnancy regarding maternal obesity and the associated costs for the mother and her fetus/neonate/child. Limited data exists regarding effective interventions for pregnant, obese women and even less information on promising or best practices. Due to insufficient evidence, specific recommendations (e.g., health care policy recommendations) cannot be made at this time; however, some broad suggestions for future interventions are offered by several researchers.

1. Introduction

1.1 Defining Obesity

According to the World Health Organization (WHO), overweight and obesity are defined as "abnormal or excessive fat accumulation that presents a risk to health." A basic population measure of obesity is the body mass index (BMI), which is calculated by dividing a person's weight (in kilograms) by his or her height (in meters). An individual with a BMI of 30 or more is generally considered obese. A person with a BMI equal to or more than 25 is considered overweight (WHO).

1.2 Prevalence of Obesity

According to the WHO's latest projections, globally in 2005, approximately 1.6 billion adults (age 15+) were overweight; and at least 400 million adults were obese. WHO further projects that by 2015, approximately 2.3 billion adults will be overweight and more than 700 million will be obese. In addition, at least 20 million children under the age of 5 years were overweight globally in 2005. At a national level, in 2004, approximately one-quarter (5.5 million) of adult Canadians (age 18+) were obese. An additional 8.6 million were overweight (Tjepkema, 2005).

The obesity epidemic is reported to be particularly pronounced among young people, including women of reproductive age (Guelinckx, Devlieger, Beckers & Vansant, 2008). Canadian women of childbearing age are substantially heavier today than in the past (Tjepkema, 2005). According to the 2006-2007 Canadian Maternity Experiences Survey (MES), approximately one-third of Canadian women aged 15 and older began their pregnancy either overweight or obese (Health Canada, 2009).

1.3 Maternal Obesity

According to Morin and Reilly (2007), prevalence rates of obesity in the general population have increased substantially in the past 20 years. These authors state, "while these figures include the population as a whole and are of great concern, what is even more alarming is the number of women of childbearing age who are overweight or obese" (p.482). This increase in the prevalence of maternal obesity is of great concern as it has been found to be associated with adverse health outcomes affecting the mother and her fetus, neonate and child. Unfortunately, the association between obesity and adverse pregnancy outcomes is not universally acknowledged, which only serves to perpetuate the problem (Yogev & Catalano, 2009). Because recent research has suggested that the in utero environment may program the fetus for elevated risk of later obesity, attempts to prevent obesity prior to becoming pregnant are crucial. At the very least, interventions must aim to limit excessive weight gain during pregnancy.

1.4 Excessive Gestational Weight Gain (GWG)

Not only is pre-existing maternal obesity associated with adverse pregnancy outcomes, but also gaining too much weight during pregnancy has been linked with poor pregnancy outcomes. Specifically, gaining excessive weight during pregnancy can result in the delivery of a large-for-gestational-age (LGA) baby or macrosomia. Macrosomia has been associated with adverse maternal and neonatal outcomes, including caesarean birth, prolonged labour, birth trauma, cephalopelvic disproportion, birth asphyxia, and increased risk of perinatal mortality (Zhang, Decker, Platt, & Kramer 2008). Because research has linked excessive GWG to labour complications, greater weight retention postpartum, and childhood, adolescent and adult obesity, the topic of gestational weight gain is indeed worthy of further attention and investigation.

2. Effects of Obesity Pre-Pregnancy

The following health risks have been associated with obesity (not pregnancy-specific):

- *chronic hypertension* (Dietl, 2005)
- *type 2 diabetes mellitus* (Dietl, 2005)
- *respiratory complications (e.g., sleep apnea, asthma*; Dietl, 2005)
- *hormone sensitive cancers* (Dietl, 2005; Sarwer et al., 2006; Smith et al., 2008)
- *heart disease/cardiovascular disease* (Dietl, 2005; Smith et al., 2008)
- *thromboembolic disease* (Dietl, 2005)
- *gallstones, pancreatitis* (Dietl, 2005)
- *venous insufficiency* (Dietl, 2005)
- *depression* (Dietl, 2005)
- *osteoarthritis* (Smith et al., 2008)
- *irregular menstrual cycles* (Sarwer et al., 2006)
- *infertility/difficulty conceiving* (Morin & Reilly, 2007; Siega-Riz et al., 2006)
- *periodontal disease* (Genco et al., 2005)

It is vital for women of childbearing age to acknowledge the above health risks as they can lead to poor pregnancy outcomes (during conception, during pregnancy and in the post-partum period). For example, researchers have suggested that pre-pregnancy weight is likely to impact a woman while trying to get pregnant. Specifically, some researchers have suggested obese women experience more difficulty conceiving, as compared to normal-weight women (Morin & Reilly, 2007; Sarwer, Allison, Gibbons, Markowitz, & Nelson, 2006; Yogev & Catalano, 2009). Reasons for why obese women may find it difficult to conceive (compared to normal-weight women) include experiencing irregular menstrual cycles and high levels of male hormones (e.g., testosterone; Sarwer et al., 2006). For these reasons, clinicians should counsel both women who are considering pregnancy and those who are not, but are of childbearing age, about the adverse effects obesity has on a woman's fertility.

Pre-pregnancy weight can also impact a woman's weight during her pregnancy; specifically, if a woman is obese prior to becoming pregnant, she is likely to remain obese during pregnancy (Dietl, 2005). Because maternal obesity during pregnancy is linked to poor pregnancy outcomes (e.g., hypertension, gestational diabetes, oversized infant), it is important for a woman to consider her weight prior to becoming pregnant.

Finally, pre-pregnancy BMI has been linked to childhood and adult BMI. Specifically, a mother who is overweight or obese prior to becoming pregnant has a greater likelihood of having an obese child, whose obesity will persist into adulthood (*note:* causal nature of this relationship is unclear at present; Durand, Logan, & Carruth, 2007). Indeed, the positive association between pre-pregnancy weight and the likelihood of childhood and adult obesity has implications for perpetuating the *cycle* of obesity, as well as its adverse health outcomes for the mother and her fetus, neonate and child.

3. Pregnancy Outcomes of Maternal Obesity

Preface: Although researchers have suggested that maternal obesity affects pregnancy outcomes, such as preeclampsia, gestational diabetes, and LGA infants among others, the causal nature of this relationship is not well-established. The relationship between maternal obesity and pregnancy outcomes may be based on confounding effects of other variables known to affect pregnancy, such as genetics and smoking.

3.1 Maternal Consequences of Maternal Obesity

The adverse effects of maternal obesity during pregnancy can be divided into two groups: those that affect the mother; and those that affect the fetus, neonate and child. This section will begin by exploring potential health effects of maternal obesity on the mother.

3.1.1 Maternal Outcomes During Pregnancy

According to the literature, the most common health effects of maternal obesity during pregnancy on the mother are hypertension (pregestational and gestational), preeclampsia and diabetes mellitus (pregestational and gestational; Castro & Avina, 2002; Catalano & Ehrenberg, 2006; Diet, 2005; Morin, 1998; etc.).

- **Hypertension** is defined as high blood pressure (i.e., repeatedly elevated blood pressure exceeding 140 over 90 mmHg – a systolic pressure above 140 with a diastolic pressure above 90). Investigators have suggested a three- to ten-fold increased risk of pre-existing chronic hypertension in pregnant, obese women compared to normal-weight or lean pregnant women. Pregnancy-induced hypertension (PIH) or gestational hypertension refers to high blood pressure that develops during pregnancy in a woman who previously did not have high blood pressure and may subside after delivery. Researchers have suggested the risk of PIH or gestational hypertension is significantly greater if the pregnant woman is overweight or obese (Yogev & Catalano, 2009).

- **Preeclampsia** is a condition that typically starts after the 20th week of pregnancy and is related to increased blood pressure and protein in the mother's urine (as a result of kidney problems). Preeclampsia affects the placenta, and it can affect the mother's kidney, liver, and brain. When preeclampsia causes seizures, a condition known as eclampsia occurs, which is the second leading cause of maternal death in the United States. Preeclampsia is also a leading cause of fetal complications, including low birth weight, premature birth, and stillbirth. Studies have suggested a two- to three-fold increased risk of preeclampsia in obese women, compared with normal-weight women (Yogev & Catalano, 2009).
- **Diabetes mellitus** is a group of metabolic diseases characterized by high blood sugar (glucose) levels that result from defects in insulin secretion, or insulin action, or both. Researchers have suggested a three- to ten-fold increased risk of pregestational diabetes in pregnant, obese women compared to normal-weight or lean pregnant women (Castro & Avina, 2002; Dietl, 2005). Furthermore, women who are overweight or obese pre-pregnancy are more likely to develop gestational diabetes mellitus (GDM) during pregnancy (Morin & Reilly, 2007; Reece, 2008). GDM is a form of diabetes mellitus that appears during pregnancy (gestation) in a woman who previously did not have diabetes and usually goes away after the baby is born.

Although the evidence is not conclusive, other potential outcomes of maternal obesity for the mother during pregnancy include:

- **Thromboembolic complications (including thrombosis):** Thrombosis is the formation or presence of a blood clot in a blood vessel, which can lead to maternal morbidity and mortality (Castro & Avina, 2002). Pregnancy is a risk factor for thromboembolic complications; obesity during pregnancy further increases this risk. On average, women who are obese during pregnancy are two- to four-times more likely to experience thromboembolic complications, as compared to normal-weight pregnant women (Yogev & Catalano, 2009).
- **Excessive Gestational Weight Gain:** According to Siega-Riz and colleagues (2006), overweight and obese women are more likely to gain excessive gestational weight and retain it after delivery. Excessive GWG in this case is defined as weight gained in excess of the 1990 Institute of Medicine recommendations for gestational weight gain. Excessive GWG has in turn been associated with preeclampsia, failed induction, caesarean delivery and LGA infants (DeVader, Neeley, Myles & Leet, 2007). The consequences of excessive GWG will be outlined in more detail in a subsequent section of this document.
- **Miscarriage:** Several researchers have found that obese women are at increased risk for experiencing a miscarriage (both after natural conception and infertility treatment), as compared to normal-weight women (Catalano &Ehrenberg, 2006; Guelinckx et al., 2008). Specifically, obese women are 25-37% more likely to experience a miscarriage compared with lean women (Guelinckx et al., 2008).

- **Breathing or respiratory complications:** Little research has examined the association between maternal obesity and breathing or respiratory complications. Of the available studies, some have found a positive association between maternal obesity, asthma and sleep apnea; however, the sample sizes in these studies were not large enough to assess whether these respiratory complications had an adverse impact on pregnancy outcomes (Castro & Avina, 2002; Dietl, 2005). Because of the health complications associated with obesity (e.g., decrease in chest wall compliance, increase in airway resistance and work of breathing), additional research is needed to examine the type and incidence of respiratory complications associated with maternal obesity (Castro & Avina, 2002).

3.1.2 Maternal Outcomes During Labour

The most common effect of maternal obesity on the mother during labour is an increased risk for a **caesarean section** (Castro & Avina, 2002; Guelinckx et al., 2008; Morin, 1998; Seligman et al., 2006). A caesarean section may be performed for multiple reasons, including failed induction and cephalopelvic disproportion due to fetal macrosomia (Castro & Avina, 2002). Cephalopelvic disproportion is a condition in which a maternal pelvis is small in relation to the size of the fetal head. Fetal macrosomia is defined as babies weighing more than 4000g (i.e., an overly large body). Dietl (2005) asserts that caesarean section rates are 30% more common among obese compared to normal-weight women. Other studies have reported a nearly two-fold increased risk of caesarean delivery in obese women after controlling for other factors (Yogev & Catalano, 2009).

Other potential consequences of maternal obesity on the mother during labour include:

- *labour induction* (Guelinckx et al., 2008; Morin, 1998)
- *complications with the anaesthetic (e.g., epidural failure, anaesthesia-related maternal death*; Catalano & Ehrenberg, 2006; Dietl, 2005)
- *prolonged delivery* (Morin & Reilly, 2007; Siega-Riz et al., 2006)
- *blood loss/excessive bleeding* (e.g., as a result of operative complications; Guelinckx et al., 2008; Morin, 1998)
- *higher rate of failed vaginal birth after caesarean* (Morin & Reilly, 2007)
- *preterm delivery (induced, not necessarily spontaneous*; Castro & Avina, 2002; Catalano & Ehrenberg, 2006)
- *maternal morbidity and mortality* (Guelinckx et al., 2008)[1]

[1] Consequences are considered *potential* outcomes of maternal obesity as few studies have examined these associations. Consequently, the evidence is not conclusive and warrants further investigation.

3.1.3 Maternal Outcomes for the Mother in the Postpartum Period

Consequences of maternal obesity for the mother in the postpartum can be divided into short-term and medium- to long-term outcomes. Potential short-term outcomes include:

- *infection (e.g., genital/urinary tract infections, infections due to operative complications*; Morin, 1998; Sarwer et al., 2006; Yogev & Catalano, 2009)
- *haemorrhage* (Guelinckx et al., 2008; Smith et al., 2008)
- *anemia* (Guelinckx et al., 2008; Siega-Riz et al., 2006)
- *endometritis* (Guelinckx et al., 2008)
- *prolonged hospitalization* (Smith et al., 2008; Sarwer et al., 2006)

Potential medium- to long-term outcomes of maternal obesity for the mother in the postpartum include:

- *stress incontinence* (Guelinckx et al., 2008)
- *depression or depressive symptoms* (Guelinckx et al., 2008; Morin & Reilly, 2007)
- *increased risk of postpartum weight retention* (Yogev & Catalano, 2009)[1]

An additional medium- to long-term postpartum outcome of maternal obesity for the mother is the **development of type 2 diabetes**. According to Dietl (2005) and Sarwer et al. (2006), obese women are more likely to develop GDM, which in turn places them at higher risk for the development of type 2 diabetes later in life. Guelinckx and colleagues (2008) report up to 70% of obese women with GDM developing type 2 diabetes within 15 years of delivery, compared with 30% of normal-weight women.

In addition to the development of type 2 diabetes, some researchers have suggested that obese mothers are more likely to experience **poor breastfeeding outcomes** (e.g., decreased likelihood of initiating breastfeeding or breastfeeding for a shorter period of time). Morin and Reilly (2007) have offered several possible explanations for why overweight or obese mothers are less likely to initiate breastfeeding or discontinue breastfeeding early. First, it has been reported that obesity may influence the delayed onset of lactogenesis (i.e., milk coming in more than 72 hours after giving birth). Overweight or obese mothers may also experience less satisfaction with their appearance and as a result, decide not to breastfeed or discontinue breastfeeding early. Finally, Morin and Reilly suggest that overweight or obese mothers may experience more indifference to breastfeeding compared to normal-weight women.

3.2 Fetal, Neonatal and Child Outcomes of Maternal Obesity

Not only is maternal obesity associated with adverse pregnancy outcomes for the mother, but also short- and long-term health risks for the fetus.

3.2.1 Fetal Outcomes

Researchers have suggested that maternal obesity increases the risk of **fetal birth defects** (Castro & Avina, 2002; Catalano & Ehrenberg, 2006; Yogev & Catalano, 2009; etc.). The literature has identified several birth defects associated with maternal obesity including: neural tube defects (NTDs); abdominal wall defects; heart defects; and spina bifida.

Several possible explanations have been offered in the literature for why the risk of birth defects is higher among obese, pregnant women compared to normal-weight, pregnant women. To begin, Morin and Reilly (2008) have described complications with visualizing the fetus of pregnant, obese women (even with advanced ultrasound equipment). Guelinckx and colleagues (2008) also outline the challenge of visualizing a pregnant, obese woman's fetus: "The risk of missing these congenital malformations is higher among obese pregnant women: because of the interposing fat layer, visualization of the foetus during the ultrasound examination is more complicated" (p. 144). In addition to difficulties with visualizing the fetus, several researchers have suggested that the link between maternal obesity and birth defects may be the result of a deficient diet (Morin, 1998; Morin & Reilly, 2007). Other researchers still have suggested that diabetes (a common consequence of obesity) combines forces with obesity to cause birth defects. Indeed, Sarwer and colleagues (2006) assert that birth defects occur in 6-12% of infants born to diabetic mothers. According to Reece (2008), women may not even need to have diabetes to increase their risk of delivering an infant with birth defects: "Obese women need not have fully developed the clinical symptoms of diabetes to be at significantly increased risk of having a child with a birth defect. Chronically high levels of blood glucose, or hyperglycemia, may be sufficient to help trigger the development of birth defects" (p. 175).

Although much of the literature has suggested a positive association between maternal obesity and birth defects (particularly NTDs), some studies have not found an association. Dietl (2005) highlights several studies finding no relationship between maternal obesity and birth defects, even with a sample size of greater than 10,000 pregnancies. Because the link between maternal obesity and birth defects is unresolved at present, more research is needed to examine this possible association.

In addition to the development of birth defects, several researchers have suggested a link between maternal obesity and **fetal death**; however, the evidence is not conclusive (Guelinckx et al., 2008; Smith et al., 2008). Additionally, some researchers have proposed that maternal obesity results in **insulin resistance** in the offspring; however, there has been little evidence to support this theory (e.g., Freeman, 2009).

3.2.2 Consequences for the Neonate During Labour

Several outcomes of maternal obesity for the neonate during labour have been identified in the literature, some of which are a direct result of macrosomia. For example, obese women are more likely to have babies who experience **shoulder dystocia** or **injuries to the brachial plexus** during labour (Castro & Avina, 2002; Guelinckx et al., 2008; Smith, Husley, & Goodnight, 2008). Shoulder dystocia occurs when the baby's shoulder is wedged behind the mother's pubis bone (usually due to the baby being too big to fit through the birth canal). Shoulder dystocia, in turn, can result in injuries to the neonate's brachial plexus (e.g., the baby's shoulders become impacted during the birth process, causing the brachial plexus nerves to stretch or tear). The brachial plexus is a network of spinal nerves that originates in the back of the neck, extends through the armpit, and gives rise to nerves in the upper limb. Injuries to the brachial plexus can cause numbness, a tingling sensation, weakness, limited movement, and paralysis of the upper limb. Treatment (e.g., occupational, physical therapy) and prognosis (e.g., permanent or temporary injury) of a brachial plexus injury depends on the site and type of injury.

Other research has shown a link between maternal obesity and **still birth** (i.e., the birth of a dead fetus), as well as **early neonatal death** (i.e., death of a live-born baby within the first seven days of life; Castro & Avina, 2002; Morin & Reilly, 2007; Smith et al., 2008; Yogev & Catalano, 2009). Guelinckx and colleagues (2008) suggest that maternal obesity is associated with a more than doubled risk of stillbirth and perinatal death.

Although the evidence is not conclusive, an additional labour complication of maternal obesity for the neonate includes meconium stained amniotic fluid, which can lead to *meconium aspiration* (MAS; Seligman et al., 2006). Meconium is the baby's first feces, which is sticky, thick, and dark green and is typically passed in the womb during early pregnancy and again in the first few days after birth. MAS occurs when a newborn inhales (or aspirates) a mixture of meconium and amniotic fluid.

3.2.3 Postnatal Outcomes for the Infant

Many studies have been able to show a positive association between maternal obesity and **macrosomia** or **LGA babies** (i.e., a baby weighing more than 4,000 grams; Morin, 1998; Smith et al., 2008; Yogev & Catalano, 2009). As highlighted above, potential adverse health outcomes of macrosomia include shoulder dystocia and injuries to the brachial plexus.

Other potential outcomes of maternal obesity for the neonate include: *reduced energy expenditure* (Oken, 2009); *very-low-birth-weight babies* (a possible consequence of preeclampsia; Smith et al., 2008); *and early neonatal death* (Smith et al., 2008). In addition, Guelinckx and colleagues (2008) suggest that because of various infant

complications, the percentage of babies admitted at the intensive care department is 3.5 times higher in the case of maternal obesity.[2]

3.2.4 Consequences for the Child, Adolescent and Adult

Although the causal nature of the relationship is unclear, studies have linked both maternal obesity and macrosomia/LGA babies (a consequence of maternal obesity) to **childhood**, **adolescent** and **adult obesity in the offspring** (Catalano & Ehrenberg, 2006; Guelinckx et al., 2008; Yogev & Catalano, 2009). For example, Durand and colleagues (2007) report that the risk of childhood obesity is more than double for 2-year-olds and 4-year-olds if the mother was obese in early pregnancy. Researchers who have sought to examine the influence of paternal obesity on the child's BMI (e.g., Heude et al., 2005) have reported a stronger relationship between maternal and childhood obesity than with father-child obesity. Furthermore, childhood obesity has been found to be a strong predictor of adolescent and adult obesity (Durand et al., 2007). Indeed, Yogev and Catalano (2009) state, "The implications of maternal obesity [during pregnancy] far surpass intrauterine life, extending into infancy and even adulthood with severe health repercussions" (p. 292).

3.3 Potential Mechanisms Linking Maternal Obesity to Child Obesity

As highlighted above, the causal nature of the relationship between maternal obesity and child obesity is unclear at present. Oken (2009) asserts that both shared genes and the external environment account for some of the mother-child obesity relationship; however, new research is beginning to suggest that exposure in utero may directly program the fetus for obesity later in life. One proposed mechanism through which child obesity may develop involves the concept of over-nutrition. Specifically, maternal over-nutrition may result in fetal over-nutrition, which affects fetal adipose tissue deposition. Oken (2009) states, "Since adipocyte number appears to be set in the first years of life, excess fat formed in early life may result in lifelong excess adiposity" (p. 369-370). Similarly, Gillman, Rifas-Shiman, Berkey, Field and Colditz (2003) discuss altered maternal-fetal glucose metabolism in the context of maternal obesity: "Maternal hyperglycemia leads to excess fetal insulin, itself a growth hormone for the fetus. Thus, offspring of mothers with gestational diabetes mellitus (GDM) have higher birth weights" (p. 221). Although the programming hypothesis has been proposed by several researchers (e.g., Freeman, 2009; Gillman et al., 2003; Oken, 2009), there is little evidence to support the theory; further investigation regarding the possible mechanisms linking maternal obesity to child obesity is needed.

[2] Consequences are considered *potential* outcomes of maternal obesity as few studies have examined these associations. Consequently, the evidence is not conclusive and warrants further investigation.

4. Pregnancy Outcomes of Excessive Gestational Weight Gain

4.1 Appropriate Weight Gain During Pregnancy

According to Smith and colleagues (2008), the two key periods in a woman's life where she is more likely to gain weight are pregnancy and menopause. In an effort to encourage appropriate weight gain during pregnancy and to reduce the risk of small-for-gestational-age (SGA) babies, the Institute of Medicine (IOM), in 1990, developed prenatal weight gain recommendations. The IOM recommended that the amount of weight a woman gains during pregnancy be guided by her pre-pregnancy BMI; those with a higher BMI prior to pregnancy were advised to gain less weight during pregnancy than those with a lower BMI. Since the guidelines were developed in 1990, definitions of overweight and obesity during pregnancy have been more consistent among researchers and practitioners (Morin, 1998). However, because of the increasing prevalence of obesity among women of reproductive age, increases in GWG and the associated health complications of both, the IOM has recently re-examined and modified their pregnancy weight guidelines. Health Canada uses the new US IOM 2009 guidelines to counsel women with respect to appropriate weight gain during pregnancy (see Table 1). According to Ramussen, Chu, Kim, Schmid and Lau (2009), the new guidelines differ from those issued in 1990 in two important ways:

1) the guidelines are based on WHO cut-off points for the BMI categories, as opposed to the previous ones (i.e., categories derived from Metropolitan Life Insurance tables); and
2) the guidelines include a specific, relatively narrow range, of recommended gain for obese women.

Table 1. New Guidelines for Gestational Weight Gain

Pre-Pregnancy BMI Category	Recommended Range of Total Weight Gain		Mean Rate of Weight Gain in the 2nd and 3rd Trimester	
	kg	lbs	kg/week	lb/week
Underweight BMI < 18.5	12.5-18	28-40	0.5	1.0
Normal Weight BMI 18.5 – 24.9	11.5-16	25-35	0.4	1.0
Overweight BMI 25.0 – 29.9	7-11.5	15-25	0.3	0.6
Obese BMI ≥ 30	5-9	11-20	0.2	0.5

Note: A narrower range of weight gain may be advised for women with pre-pregnancy BMI of 35 or greater. Individualized advice is recommended for these women.

4.2 Why Follow the Weight Recommendations During Pregnancy?

Researchers and clinicians agree that the best birth outcomes are found in women whose weight gains are within the IOM's recommended ranges (Olson, 2008). For example, DeVader, Neeley, Myles and Leet (2007) assessed the association between GWG and adverse pregnancy outcomes among women with normal pre-pregnancy BMI. DeVader and colleagues found those women who gained less than the recommended amount were at decreased odds for experiencing preeclampsia, cephalopelvic disproportion, failed induction, caesarean delivery, and LGA infants; however, these women were at increased odds for delivering an SGA infant. Likewise, those women who gained more than the recommended amount were at decreased odds for having SGA infants, but were at increased risk for experiencing preeclampsia, failed induction, caesarean delivery and an LGA infant.

Fewer studies have examined the outcomes of excessive GWG among women who are overweight or obese prior to pregnancy (particularly studies using a large sample size). Kiel, Dodson, Artal, Boehmer and Leet (2007) assessed the effects of gestational weight gain on pregnancy outcomes in obese women and found that limited or no weight gain was linked to favourable pregnancy outcomes (i.e., lower risk of preeclampsia, caesarean delivery, LGA birth).

Olson states, "In summary, the range of maternal weight gain in pregnancy recommended by the IOM continues to be associated with the optimal birth size of 3000 to 4000 g, as originally defined by the IOM, as well as with decreased risk of bearing an infant with low birth weight (<2500 g), macrosomia (>4000 g), SGA, or LGA" (p. 413).

4.3 Adverse Health Outcomes of Excessive Gestational Weight Gain (GWG)

Excessive GWG has been found to be independently and strongly associated with **LGA neonates** or **macrosomia**, particularly among overweight and obese women (Olson, 2008; Ramussen et al., 2009; Siega-Riz et al., 2009). Macrosomia, in turn, is associated with adverse maternal and neonatal outcomes, including caesarean birth, prolonged labour, birth trauma, cephalopelvic disproportion, birth asphyxia, and increased risk of perinatal mortality (Zhang, Decker, Platt, & Kramer 2008).

In addition, several researchers have found a positive association between GWG and **postpartum weight retention**. Olson, Strawderman, Hinton and Pearson (2003) found that women who gained more weight than the recommended amount during pregnancy were three times more likely to retain 10 pounds or more at one year postpartum (particularly low-income women). Rooney and Schauberger (2002) examined 540 women after childbirth for an average of 8.5 years. These authors found that women who gained less than the IOM-recommended weight gain during pregnancy, those who gained the recommended amount and those who gained more than the IOM recommendations were all heavier than their pre-pregnancy BMI. Furthermore, those women who gained more than the IOM recommendations retained the most weight postpartum (compared with women who gained less than the recommended amount and those who gained the recommended amount). In a systematic review of maternal

weight gain outcomes, Siega-Riz and colleagues (2009) found moderate, consistent evidence linking excessive GWG to higher weight retention in both the immediate postpartum period and in the longer term (e.g., within 2 years postpartum). Although these studies have found a positive link between GWG and postpartum weight retention, the evidence is not conclusive and as such, more research is needed to examine this association (Sarwer et al., 2006).

Researchers have also suggested a positive association between weight gain during pregnancy and the likelihood of **developing obesity postpartum**. Sarwer and colleagues (2006) assert that anecdotally, many women identify weight gain during pregnancy as a major impetus in the development of obesity postpartum.

Additional proposed health outcomes of excessive GWG for the mother include *preeclampsia*, *seizures*, *hypoglycemia*, *failed induction* and *poor breastfeeding outcomes* (Olson, 2008). Adverse health outcomes for the neonate and child include *preterm birth*, *low five-minute Apgar score*, *meconium aspiration*, *infant mortality* and *childhood obesity* (Olson, 2008; Ramussen et al., 2009). A new study by Hedderson, Gunderston and Ferrara (2010) has found a link between GWG and the risk of *gestational diabetes mellitus* (GDM*)*. After adjusting for a variety of factors (i.e., age at delivery, race/ethnicity, parity, and pre-pregnancy BMI), the risk of GDM increased as gestational weight gain increased. More research is needed to explore the possible association between gestational weight gain and GDM.[3]

Note: The only outcome that researchers have found conclusively to be independently associated with excessive GWG is LGA infants or macrosomia. Evidence linking excessive GWG with other health outcomes (e.g., postpartum weight retention, preeclampsia, infant mortality, etc.) is less conclusive and warrants further investigation. Furthermore, the causal nature of the GWG-pregnancy outcome relationship is unclear at present. According to Ramussen and colleagues (2009), it is possible that the link between GWG and outcomes does not result from GWG itself, but rather from underlying factors that influence both weight gain and outcomes (e.g., maternal diet composition, physical activity level, etc.). Ramussen et al. (2009) state, "it is important to determine whether these relationships are independent of pre-pregnancy body mass index (BMI) or if they differ by pre-pregnancy BMI. Only with large, well-designed, and carefully controlled randomized studies can causal relationships be inferred with a high degree of confidence" (p. 195).

[3] Consequences are considered *potential* outcomes as few studies have examined these associations. Consequently, the evidence is not conclusive and warrants further investigation.

5. Socio-Demographic and Maternal Characteristics of Maternal Obesity

As is the case with other health problems, the obesity epidemic disproportionately affects **lower-socioeconomic groups**, including *ethnic minorities* and individuals residing in *rural communities* (Phelan, 2009). This is indeed the case in developed countries (e.g., Canada, United States); however, in developing countries rates of obesity are higher in the wealthier classes (Castro & Avina, 2002). This document will focus on the socio-demographic and maternal characteristics of maternal obesity in developed countries, including Canada and the United States. Heslehurst, Simpson, Batterham, Wilkinson and Summerbell (2006) sought to identify those women most at risk for maternal obesity and found that participants in the obese group were significantly *older*, *had given birth to more children*, and *resided in the more deprived neighbourhoods*. Being of a younger age, being single, participating in educational programs, and not having paid employment were found to be protective factors against maternal obesity. Interestingly, ethnicity was not found to be a significant predictor of maternal obesity, although interpretation of this finding may be limited due to a small sample size representing the non-Caucasian populations. Brennand, Dannenbaum and Willows (2005) examined maternal obesity among First Nations women and concluded that there is a high prevalence of overweight and obesity, type 2 diabetes mellitus, GDM and infant macrosomia among First Nations women in Canada.

Less research has examined the socio-demographic and maternal characteristics of excessive GWG. According to the results of the 2006-2007 Maternity Experiences Survey, particular socio-demographic and maternal characteristics were linked with gaining excessive weight during pregnancy, including: *having a BMI > 27*; *giving birth for the first time*; *having a lower level of education*; *being a young mother*; and *being Aboriginal* (Health Canada, 2009).

Researchers have also linked particular socio-demographic and maternal characteristics to weight trends postpartum. Walker et al. (2004) examined weight change during the postpartum period and found that on average, *low-income*, *ethnic minority women* (i.e., African American and Hispanic women) did not lose weight (following fluid-related weight losses in the early postpartum weeks), as compared to Caucasian women. In fact, Hispanic women gained slightly more weight post-partum.

Most research in the area of maternal obesity has examined the implications of obesity during pregnancy; little research has examined the socio-demographic and maternal characteristics of maternal obesity, excessive GWG or weight retention postpartum. As such, further investigation is needed to assess the social determinants of maternal obesity.

6. Prevention and Intervention

6.1 Preventing Maternal Obesity

As highlighted in the introduction, because recent research suggests the in utero environment may program the fetus for elevated risk of later obesity, preferably attempts should be made to *prevent* obesity prior to pregnancy. Dodd and colleagues (2008) state, "Currently the guidelines recommend that, ideally, women should be counselled prior to conception about the increased pregnancy risks associated with obesity, and encouraged to make lifestyle changes to minimize their risk of developing subsequent complications..." (p. 705). Similarly, Galtier-Dereure et al. (2000) suggest that given the significant costs (e.g., economic and medical) of pregnancy in overweight and obese women, all efforts must be made to prevent obesity in women of childbearing age and to promote weight loss prior to pregnancy.

Several means to prevent maternal obesity have been identified in the literature. Dietl (2005) suggests the need for public education, whereby the general public is informed about maternal obesity (including the associated costs), as well as the benefits of good nutrition and physical activity. Similarly, Smith et al. (2008) highlight the importance of developing educational programs aimed at promoting good health among the general public (e.g., programs that encourage quality food, as opposed to quantity, importance of meal planning, need to increase physical activity, etc.). Siega-Riz and colleagues (2006) discuss the need to identify best practices (i.e., at obesity prevention, treatment and optimal weight maintenance), so that practitioners have access to multiple strategies to help combat the obesity epidemic. In order to break the cycle of obesity, increasing public knowledge of the consequences of maternal obesity is particularly important among women of childbearing age, including adolescents and young women. Practitioners and educators may wish to begin counselling adolescents and young women, prior to pregnancy, regarding maternal obesity and the associated costs for both the mother and the fetus, neonate and child.

6.2 The Importance of Interventions

Although efforts must be made to prevent obesity prior to pregnancy, interventions aimed at limiting weight gain during pregnancy should also be given serious consideration. Because both the prevalence of maternal obesity and excessive GWG has increased significantly in recent years, and because it is not safe for women to lose weight during pregnancy, interventions aimed at controlling gestational weight gain are needed. The following is a discussion of interventions developed to limit excessive weight gain during pregnancy (among both normal-weight and overweight and obese women).

Little research has sought to examine obesity interventions aimed at limiting excessive GWG. Dodd et al. (2008) state, "While there is an extensive literature defining the problems and complications associated with obesity during pregnancy and childbirth, there is limited information available related to effective interventions that can be implemented to improve maternal, fetal and infant health outcomes" (p. 703). Most intervention studies have sought to

promote sufficient weight gain during pregnancy rather than encourage women to avoid excessive GWG (Olson et al., 2003). The intervention studies that do exist to control excessive GWG vary considerably in terms of duration, gestational age at commencement and the approaches used (e.g., informational brochure, intensive counselling, group sessions, etc.). Furthermore, few intervention studies have adopted a randomized-controlled design. For these reasons, concrete recommendations for interventions aimed at controlling excessive GWG cannot be made at this time. Nonetheless, it is important to examine the interventions that do exist and draw some general conclusions based on the results of these interventions.

6.2.1 Major Goals and Activities of the Intervention Studies

Most interventions have sought to limit excessive GWG through provisions in both diet and lifestyle (e.g., improving dietary habits and increasing physical activity); however, as highlighted above, the approaches and activities adopted to influence dietary and lifestyle changes have varied considerably. For example, interventions have involved individualized counselling, the offering of written information (e.g., brochures, newsletters, by-mail education programs) and group sessions/counselling. Although intervention activities have varied considerably, Dodd et al. (2008) conclude from their systematic review that significant improvements in health outcomes are most likely to occur when a multi-faceted intervention is adopted (compared with stand-alone dietary advice, exercise modifications and behavioural strategies).

6.2.2 Randomized-Controlled Intervention Studies

Only a few intervention studies have adopted a randomized-controlled design. According to Ramussen et al. (2009), “Only with large, well-designed, and carefully controlled randomized studies can causal relationships be inferred with a high degree of confidence” (p. 195). Findings from these randomized studies have ranged from ineffective to effective within certain subgroups (i.e., low-income, normal-weight women).

- Guelinckx and colleagues (2009) sought to examine whether a lifestyle intervention (based on a brochure or active education) could improve dietary habits, increase physical activity, and reduce GWG in obese pregnant women. Both intervention groups showed improvements in dietary habits compared to the control group; however, the lifestyle intervention did not impact participants’ physical activity or the amount of weight gained during pregnancy.
- Asbee et al. (2009) sought to examine whether an intervention (based on dietary and lifestyle counselling) could prevent excessive GWG among underweight, normal-weight, overweight and obese women. Asbee and colleagues found that women in the intervention group gained significantly less weight than those in the control group; however, adherence to the IOM guidelines did not significantly differ between the intervention and control group. In fact, the most important predictor of adhering to the IOM guidelines was having a normal weight pre-pregnancy.

- Olson and colleagues (2004) evaluated the efficacy of an intervention aimed at preventing excessive weight gain during pregnancy among normal and overweight women. The intervention involved both a clinical component, as well as a by-mail education program. Olson et al. found that those in the intervention group were less at risk for gaining excessive weight during pregnancy; however, this was only true for the low-income women (52% of control group exceeded IOM recommendations, as compared to 33% of intervention group). Overall, gestational weight gain did not differ between the intervention and control group, nor did the proportion of women exceeding the IOM guidelines during pregnancy.
- Polley et al. (2002) examined whether a stepped care, behavioural intervention would decrease the likelihood of exceeding the IOM weight gain recommendations. Among normal-weight women, those in the intervention group were significantly less likely to exceed IOM recommendations compared to those in the control group; however, a non-significant difference was found among overweight women (with the trend in the opposite direction).
- Gray-Donald et al. (2000) examined whether a community-based intervention would improve dietary intake, limit excessive GWG, and optimize glycemic levels and birth weight among women in four Cree communities. The intervention was based on social learning theory and included both dietary and physical activity components. Gray-Donald and colleagues found that the intervention did not significantly influence any of the outcome measures.

6.2.3 General Conclusions Regarding Interventions

Although specific recommendations cannot be made at this time with respect to effective interventions, researchers have made some broad conclusions and/or suggestions for future interventions, based on the available evidence.

- The success of any intervention increases significantly when a multi-faceted approach is adopted (as opposed to, for example, stand-alone dietary advice, exercise modification, and behavioural strategies; Dodd et al., 2008).
- Historical, cultural and local considerations must be given when developing any intervention to control excessive weight gain during pregnancy. For example, Gray-Donald and colleagues (2000) examined whether a community-based intervention would limit excessive GWG among women in four Cree communities (as well as improve dietary intake and optimize glycemic levels and birth weight). The intervention had only a minor impact on diet and did not limit excessive weight gain during pregnancy. One explanation for this non-significant finding involves historical events and current community perceptions of weight gain during pregnancy. Cree elders discussed experiences in the 1930s and 1940s where family members experienced starvation; in this case, past events (i.e., experiences with starvation) may have shaped current perceptions of weight gain during pregnancy (e.g., equating plumpness with prosperity). Indeed, women in the four Cree communities expressed how it is desirable to be plump during pregnancy, while physical activity during

pregnancy is unfavourable. Gray-Donald et al. assert that because of both historical influences and current perceptions of weight during pregnancy, the interventions may not have been sufficiently intense to promote dietary and lifestyle change among participants.

7. Conclusion

Rates of obesity in Canada have significantly increased in recent years; these rates are particularly alarming among women of childbearing age, as maternal obesity is associated with multiple and adverse pregnancy outcomes. Potential consequences of maternal obesity for the mother include: hypertension (pregestational and gestational), preeclampsia, and diabetes mellitus (pregestational and gestational). Potential consequences of maternal obesity for the fetus, neonate and child include: fetal birth defects, shoulder dystocia/injuries to the brachial plexus, macrosomia, and the development of future obesity (i.e., in childhood, adolescence and adulthood). Gaining excessive weight during pregnancy is also associated with adverse health outcomes (mainly macrosomia, which has further health implications for the infant). Resultantly, it is important for pregnant women to follow the IOM recommendations for weight gain during pregnancy, in order deliver an infant of optimal birth size and decrease the risk of poor pregnancy outcomes.

As recent research suggests the in utero environment may program the fetus for elevated risk of later obesity, attempts should be made to *prevent* obesity prior to pregnancy. Potential means to prevent maternal obesity identified in the literature include:

- increasing public awareness and education regarding maternal obesity and the associated costs
- the development of educational programs aimed at increasing awareness and education concerning proper nutrition and the benefits of physical activity
- the development of best practices (i.e., at obesity prevention, treatment and optimal weight maintenance) so that practitioners have access to multiple strategies to help combat the obesity epidemic

Efforts to prevent obesity during pregnancy should be particularly directed towards adolescents and young women, so that, if necessary, lifestyle changes may be made prior to conception; this in turn will result in better pregnancy outcomes for these women if and when they do become pregnant.

Intervention studies aimed at controlling weight gain during pregnancy must also be given serious consideration, as it is not always possible for obese women of childbearing age to lose weight and achieve a normal BMI prior to conception. Most intervention studies have sought to limit excessive GWG through provisions in both diet and lifestyle; indeed, Dodd and colleagues (2008) conclude that significant improvements in health outcomes are most likely to occur when a multi-faceted intervention is adopted.

7.1 Recommendations for the Saskatchewan Prevention Institute

Based on the literature reviewed in this document, the following recommendations have been made for the Prevention Institute regarding future direction in the area of maternal obesity:

- As recent research suggests the in utero environment may program the fetus for elevated risk of later obesity, attempts should be made to prevent obesity prior to pregnancy. It is recommended that the Prevention Institute encourage the development of health promoting dietary and exercise habits that will keep weight normal throughout a woman's life.
- Because the association between maternal obesity and poor pregnancy outcomes is not universally acknowledged, it is recommended that the Prevention Institute make efforts to increase public awareness and education regarding the association between maternal obesity during pregnancy and adverse pregnancy outcomes.
- It is recommended that the Prevention Institute makes efforts to increase public awareness and education regarding the IOM's pregnancy weight guidelines and the associated benefits of following these recommendations.
- It is recommended that the Prevention Institute promote a multi-disciplinary approach to promoting a healthy weight among women of childbearing age (e.g., encourage collaboration between health educators, practitioners, front-line service providers, etc.).
- It is recommended that the Prevention Institute support future research endeavours regarding maternal obesity (e.g., association between maternal obesity and poor pregnancy outcomes, maternal obesity intervention studies, etc.).
- It is recommended that the Prevention Institute focus particular attention on raising awareness and education about maternal obesity among populations at greater risk for maternal obesity and excessive GWG (e.g., ethnic minority groups, individuals residing in rural communities, individuals residing in deprived neighbourhoods, etc.).

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Glossary

Anemia: A condition in which the blood is deficient in red blood cells, in hemoglobin, or in total volume.

Cesarean section: Surgical incision of the walls of the abdomen and uterus for delivery of offspring.

Endometritis: Inflammation of the endometrium. The endometrium is the inner layer of the womb (uterus).

Haemorrhage: A copious discharge of blood from the blood vessels.

Parous: Having given birth one or more times.

Spina bifida: A congenital defect in which the spinal column is imperfectly closed so that part of the meninges or spinal cord protrudes, often resulting in hydrocephalus and other neurological disorders.

Stress incontinence: Involuntary leakage of urine from the bladder accompanying physical activity (as in laughing, coughing, sneezing, or physical exercise) which places increased pressure on the abdomen.

Type 2 diabetes: Diabetes mellitus of a common form that develops especially in adults and most often in obese individuals and that is characterized by hyperglycemia resulting from impaired insulin utilization coupled with the body's inability to compensate with increased insulin production.