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Does the Amount of Gestational Weight Gain Modify the Risk of Adverse Maternal and Neonatal Outcomes for Obese Women?

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Does the Amount of Gestational Weight Gain Modify the Risk of Adverse Maternal and Neonatal Outcomes for Obese Women?

by

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Abstract

Background: Obesity during pregnancy is growing in prevalence. There has been a significant linear increase in the prevalence of obesity in American women from 35% (95% CI: 32 – 38) in 2005 to 40.5% (95% CI: 37.6 – 43.4) in 2014 (1). The increase in prevalence of obesity (body mass index (BMI) ≥ 30 kg/m^2) is also seen in women of reproductive age (2). Previous studies suggested that the Institute of Medicine (IOM) gestational weight gain (GWG) guidelines needed modification by obesity severity.

Objectives: The present study investigated whether the IOM guidelines for obese women needed modification for obesity severity by determining the risk of maternal, obstetric, and neonatal outcomes for class I, II and III obese pregnant women who either: lost weight during pregnancy, gained below the IOM guidelines, or gained above the IOM guidelines, compared to women who gained within the IOM guidelines (11-20 lbs).

Methods: A cross-sectional study using 2014 U.S. birth certificate data (N=646,642). Chi-square tests examined associations between GWG categories and adverse outcomes. Log-binomial regression models were built to examine relative risks of adverse maternal, obstetric, and neonatal outcomes following adjustment for maternal age, education, marital status, race, insurance status, and parity.

Results: The observed pattern of association was the same between all 3 obese classes indicating evidence for a single GWG recommendation for all 3 classes of obesity. Obese women who lost weight during pregnancy or gained below the IOM recommendations were at a significantly decreased risk for caesarean delivery (RR, 95% CI class I: 0.92, 0.90-0.94; II: 0.91, 0.89-0.93; III: 0.92, 0.90-0.93) and large-for-gestational age (LGA) births (class I: 0.80, 0.77-0.83; II: 0.76, 0.73-0.78; III: 0.73, 0.70-0.75) but had a significantly increased risk of small-for-gestational age (SGA) births (class I: 1.34, 1.26-1.43; II: 1.381.28-1.49; III: 1.35, 1.24-1.46) compared to women who had GWG within IOM guidelines. Obese women who gained above IOM guidelines were at an increased risk for caesarean delivery and LGA births but are at a decreased risk for SGA births.

Conclusion: A single GWG recommendation for all obese women is possible, but 2009 IOM guidelines may need to be updated as current recommendations may be too high.

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List of Symbols, Abbreviations and Nomenclature

Symbol	Definition
BMI	Body Mass Index
IOM	Institute of Medicine
GWG	Gestational Weight Gain
GWL	Gestational Weight Loss
WHO	World Health Organization
CDC	Center for Disease Control and Prevention
NCHS	National Center for Health Statistics
NBER	National Bureau for Economic Research
CHREB	Conjoint Health Research Ethics Board
OR	Odds Ratio
RR	Risk Ratio
PPV	Positive Predictive Value
NPV	Negative Predictive Value
NNT	Number Needed to Treat
NNH	Number Needed to Harm
ARR	Absolute Risk Reduction
ICU	Intensive Care Unit
SGA	Small-for-gestational Age, 10^{th} percentile
LGA	Large-for-gestational Age, 90^{th} percentile

Chapter One: **INTRODUCTION**

The prevalence of women who are entering pregnancy obese is increasing (1, 2). There has been a significant linear increase in the prevalence of obesity (body mass index (BMI) $\geq$ 30 kg/m^2) in American women from 35.7% (95% CI: 33.0 – 38.5) in 2005 to 40.5% (95% CI: 37.6 – 43.4) in 2014 (1). The increased prevalence of obesity is correspondingly seen in women of reproductive age (1, 2). In 2014, 37% (95% CI: 33.9 – 40.3) of women 20-49 years old were estimated to be obese in the United States compared to 25% of 20-49 year olds in 2005 (1, 3).

Obesity during pregnancy is associated with a myriad of adverse outcomes such as pre-eclampsia, labour induction, postpartum haemorrhage, caesarean delivery, and preterm birth (4, 5). Women who are morbidly obese (BMI $\geq$ 40 kg/m^2), based upon their prepregnancy BMI have 7.2 times the odds (95% CI: 4.7 – 11.2) of developing pre-eclampsia, 2.0 times the odds (95% CI: 1.7 – 2.5) of having a preterm birth, and 2.8 times the odds (95% CI: 2.0 – 3.9) of having a caesarean delivery than women whose BMI falls in the normal range (4). It has been suggested that restricting the amount of additional weight gained during pregnancy may help decrease the risk of adverse pregnancy outcomes in obese women (6). The Institute of Medicine (IOM) has developed guidelines for optimal gestational weight gain based on pre-pregnancy BMI categories that are widely used internationally (7, 8). However, the IOM guidelines only provide one recommendation for all obese women, even though there are 3 classes of obesity: (I (BMI 30-34.9 kg/m^2), II (BMI 35-39.9 kg/m^2), and III (BMI $\geq$ 40 kg/m^2)). Some studies have suggested that the IOM recommendation of 11-20 lbs of gestational weight gain should not apply to all obese women (9) and that weight gain less than the amount recommended in these guidelines (and in some cases weight loss) were associated with lower rates of adverse neonatal and maternal outcomes for obese women (10-14). However, these previous studies have either been small, did not account for multiple hypothesis testing, lacked information on women in the highest class of obesity (BMI $\geq$ 40 kg/m^2), used a non-representative population (e.g. only included low-income women), or used old data that may not be applicable to the current population of reproductive women given demographic shifts in population norms (e.g. a pregnancy dataset of births from 1959-1960). Currently it is unclear whether weight loss or gestational weight gain less than the IOM guidelines for obese pregnant women will be associated with less adverse maternal and neonatal outcomes. Further, more research is needed in the use of a single IOM guideline for gestational weight gain (GWG) for all 3 obese classes.

Chapter Two: **LITERATURE REVIEW**

2.1 Literature Search

A literature search was conducted between May to August 2016. The search strategy included terms such as “gestational weight gain/weight gain”, “pregnancy”, “obesity”, “body mass index”, and “pregnancy outcomes”. Search terms within categories were combined using the Boolean search term ‘or’ to explode and map the keywords to MeSH headings. Search terms between categories were combined using the Boolean term ‘and’ to give the full set of articles for the search terms. Two online databases were searched for relevant articles: PubMed and MEDLINE (OVID). The search of online databases was not restricted by language or date. Relevant articles were used to conduct backward and forward citation searching to access any additional articles.

2.2 Obesity

Obesity is defined as having an excessive accumulation of body fat/adipose tissue (15). Obesity is one of the most common, pervasive chronic diseases. It is a leading cause of mortality, morbidity, disability, healthcare utilization and healthcare costs (15). Furthermore, the prevalence of obesity is increasing worldwide, doubling between 1980 and 2014 (3). The increasing rate of maternal obesity provides a major challenge to obstetric practice as maternal obesity can result in negative outcomes for both the woman and the growing fetus (16). The most common method of measurement of obesity is the Body Mass Index (BMI).

2.3 Body Mass Index (BMI) as a Measure of Obesity

BMI is a simple calculation using a person’s height and weight – whereby the weight in kilograms (kg) is divided by the square of the height in metres (m) (BMI= kg/m^2)(17, 18). Per the World Health Organization (WHO), a BMI of <18.5 kg/m^2 is considered underweight, 18.5 – 24.9 kg/m^2 is healthy weight, 25.0 – 29.9 kg/m^2 is overweight, 30.0 to 34.9 kg/m^2 is obese class I, 35.0 – 39.9 kg/m^2 is obese class II, and 40.0 or more is kg/m^2 is obese class III (**Figure 1**).

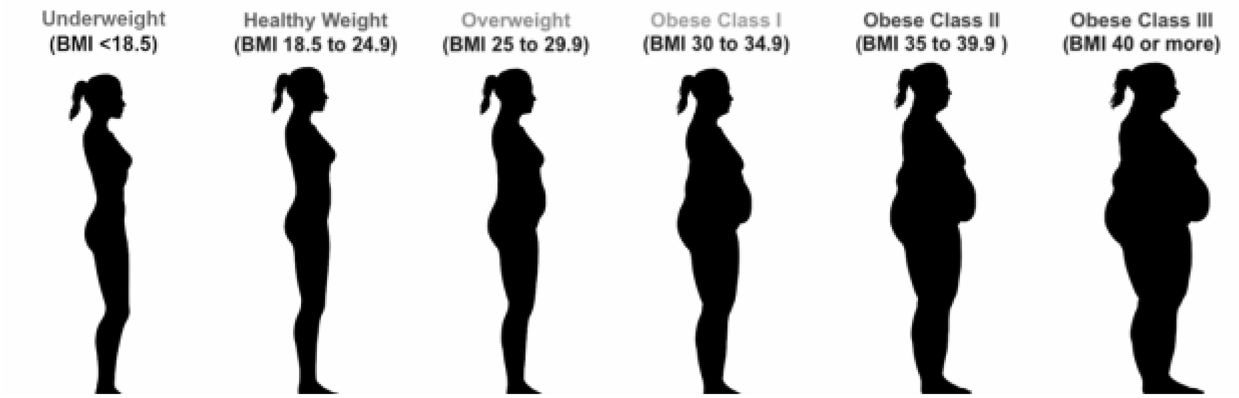

Figure 1. Body Mass Index (BMI) classification measured in kg/m^2 represented visually in Adobe Photoshop CC 2017

2.3.1 Strengths of the use of BMI

BMI is generally considered by some groups such as the WHO and the Centers for Disease Control (CDC) as the best way to determine if an individual is at a healthy weight (18, 19). Its use is popular because it is quick, effective, and applies to men, women, and children. Though it does not measure body fat, BMI calculations are fast approximations of the degree of body fatness (20).

2.3.2 Limitations of BMI

BMI does not measure body fatness – it provides only a quick approximation. This means that it is possible for very muscular individuals to fall into overweight or obese categories even if they do not have high body fat (20). However, until a better method of measuring obesity is discovered BMI remains to be a very good indicator of obesity status. It is also important to note that BMI is not a good measure in pregnant women so studies typically assess pre-pregnancy BMI.

2.4 Effect of Obesity on Pregnancy Outcomes

There has been an increasing number of women who are entering pregnancy obese (2). Studies have shown that maternal obesity during pregnancy is associated with an increased incidence of adverse outcomes such as pre-eclampsia (OR 7.2; 95% CI: 4.7-11.2), gestational hypertension (OR 3.1; 95% CI: 2.0-4.3), macrosomia (OR 2.1; 95% CI: 1.3-3.2), induction of labour (OR 1.8; 95% CI: 1.3-2.5), and caesarean delivery (OR 2.8; 95% CI: 2.0-3.9) (4, 6, 21-26). The relationship between obesity and negative maternal and neonatal outcomes is well established. Several studies have found associations between pregnancy weight (either pre-pregnancy BMI or first trimester BMI) and adverse maternal and neonatal birth outcomes (4, 27-41).

A retrospective cohort study conducted by Abenhaim et al. (2006) examined the association between pre-pregnancy BMI with obstetrical and neonatal outcomes (28). Using the McGill Obstetrical and Neonatal Database to compare pre-pregnant BMI categories of all pregnancies between 1987 and 1997, obstetric and neonatal outcomes were investigated (28). Data were available for 38,305 births during this period, and 49.0% (18,643 patients) had available pre-pregnancy BMI data. Researchers found that overweight, obese, and morbidly obese women had an increased risk of preeclampsia, gestational hypertension, gestational diabetes, preterm birth, caesarean section, and macrosomia compared to women with normal BMI (28). Women who were obese (BMI 30.0-39.9 kg/m^2) had higher odds of pre-eclampsia (OR 4.65 (95% CI: 3.71 –

5.83)); gestational hypertension (OR 2.01 (95% CI: 1.64 – 2.45)), gestational diabetes (OR 3.22 (95% CI: 2.68 – 3.87)), preterm birth (OR 1.60 (95% CI: 1.32 – 1.94)), caesarean delivery (OR 1.85 (95% CI: 1.62 – 2.11)), and macrosomic babies (OR 2.32 (95% CI: 1.58 – 3.41)) compared to women with normal BMI (28). While those who were morbidly obese (BMI $\geq$ 40 kg/m^2) had even higher odds of pre-eclampsia (OR 6.26 (95% CI: 3.48 – 11.26)), gestational hypertension (OR 2.77 (95% CI: 1.60 – 4.78)), gestational diabetes (OR 4.71 (95% CI: 2.89 – 7.67)), preterm birth (OR 2.43 (95% CI: 1.46 – 4.05)), and caesarean delivery (OR 2.92 (95% CI: 1.97 – 4.34))(28).

A study by Bhattacharya et al. (2007) was conducted to investigate the impact of maternal obesity on pregnancy outcomes (4). Using a retrospective cohort study design, researchers used data from the Aberdeen Maternity and Neonatal Databank to enroll women delivering singleton infants between 1976 to 2005. Maternal BMI was calculated from the mothers' height and weight at their initial antenatal visit (4). Of the 24,241 women who were enrolled in the study, researchers' results showed that maternal obesity during pregnancy predisposes women to an increased incidence of complicated pregnancies or increased obstetric interventions such as preeclampsia (OR 7.2; 95% CI: 4.7 – 11.2), gestational hypertension (OR 3.1; 95% CI: 2.0-4.3), macrosomia (OR 2.1; 95% CI: 1.3 – 3.2), induction of labour (OR 1.8; 95% CI: 1.3 – 2.5), and caesarean delivery (OR 2.8; 95% CI: 2.0 – 3.9).

Other studies from many different countries consistently show the same results. Sahu et al. (2007) explored the correlation between BMI and obstetric outcomes in India. Researchers found that obese women had a significant risk for gestational diabetes (RR 6.5; 95% CI: 3.6 – 11.8), preeclampsia (RR 3.2; 95% CI: 1.6 – 6.4), caesarean delivery (RR 2.3; 95% CI:1.6 – 6.4), and macrosomia (RR 6.2; 95% CI: 4.4 – 8.8) (29). In Italy, a retrospective cohort study by Driul et al. (2008) examined pre-pregnancy BMI and its association with adverse maternal and neonatal outcomes (30). In this study of 916 singleton pregnancies, obese women had higher odds of having a caesarean delivery (OR 2.17; 95% CI: 1.21 – 3.89), preterm birth (OR 4.86; 95% CI: 2.49 – 9.44), preeclampsia (OR 5.67; 95% CI: 2.52 – 12.82), and macrosomia (OR 2.59; 95% CI: 1.08 – 6.21) compared to women with normal BMI. According to Hauger et al. (2008) (31) in Argentina, Leung et al. (2008) (32) in China, Roman et al. (2008) (33) and Salihu et al. (2008) (34) in the U.S., and Khashan and Kenny (2009) (35) and Mantakas and Farrell (2010) (37) in the U.K., increasing BMI in nulliparous pregnant women have a higher risk of caesarean delivery, higher risk of macrosomia, and stillbirth.

In addition to adverse outcomes during birth, there have been a few studies examining the long-term effects of maternal obesity on the offspring. A study in 2015 by Hussen, Persson, and Moradi studied the association between first trimester maternal BMI and type 1 diabetes in their children (39). This study utilized Sweden's comprehensive database system to follow up mothers and their children from birth in 1994 until diagnoses of diabetes or end of follow up in 2009 (39). Increased first trimester maternal BMI was associated with a significantly increased risk of type 1 diabetes in the children (IRR 1.33; 95% CI: 1.20 – 1.48) (39). Furthermore, an increasing body of evidence suggests that maternal pre-pregnancy BMI is a risk factor for obesity in the offspring (42). Obese maternal pre-pregnancy BMI is associated with higher childhood, teenage, and adult adiposity in the offspring (42). A 2017 literature review by Godfrey et al. examined and compiled evidence of the long-term health of the offspring influenced by maternal obesity (42).

Several studies have linked maternal obesity to obesity, coronary heart disease, stroke, type 2 diabetes, asthma, poorer cognitive performance, and increased risk of neurodevelopmental disorders in the offspring (42).

2.4.1 Morbid Obesity and Adverse Pregnancy Outcomes

A retrospective case-control study by Kumari (2000) studied the effects of morbid obesity defined by first trimester BMI ≥ 40 kg/m^2(27). One hundred and eighty-eight singleton pregnancies with BMI ≥ 40 kg/m^{2}who delivered in an Abu Dhabi hospital between 1996 – 1998 were studied. These women were compared to a control group with normal BMI and matched based on age and parity. Morbidly obese women with diabetes and hypertension predating the pregnancy were excluded in analyses. Results found that morbidly obese women had significantly increased incidence of adverse perinatal outcomes including hypertensive disorders in pregnancy (28.8% versus 2.9%), gestational diabetes (24.5% versus 2.2%), caesarean deliveries (15.2% versus 9.3%), and macrosomia (32.6% versus 9.3%). However, it was found that morbidly obese women had lower rates of premature births compared to women who were of normal BMI (0.5% versus 5.3%, $p<0.001$) (27).

A 2004 prospective cohort study by Cedergren investigated whether morbidly obese women had an increased risk of pregnancy complications and adverse neonatal outcomes in singleton pregnancies (43). Using the Swedish Birth Registry of births between 1992 to 2001, 12,698 obese women (BMI 30 – 39.9 kg/m^2) and 3,480 morbidly obese women (BMI ≥ 40 kg/m^2) were compared to 535,900 normal BMI women (BMI 19.8 – 26 kg/m^2) (43). Maternal weight and height were recorded from a woman's first visit at the maternity health centre and 90% of women presented themselves in the first trimester (43). Results showed that morbidly obese mothers had higher odds of preeclampsia (OR 4.82; 95% CI: 4.04 – 5.74), caesarean delivery (OR 2.69; 95% CI: 2.49 – 2.90), instrumental delivery (OR 1.34; 95% CI: 1.16 – 1.56), shoulder dystocia (OR 3.14; 95% CI: 1.86 – 5.31), meconium aspiration (OR 2.85; 95% CI: 1.60 – 5.07), fetal distress (OR 2.52; 95% CI: 2.12 – 2.99), and large-for-gestational age (LGA) infants (OR 3.82; 95% CI: 3.50 – 4.16) (43).

A national population-based prospective cohort in Australia in 2015 examined the prevalence, risk factors, and perinatal outcomes of super morbidly obese women (BMI $\geq$ 50 kg/m^2) (44). Using the Australasian Maternity Outcomes Surveillance System (AMOSS), women included in the study were identified by participating AMOSS sites between January to October 2010 (44). This surveillance system covers approximately 66% of all pregnant women giving birth at an Australian hospital (44). Women were classified as super-obese if at any point during their pregnancy they had a BMI of 50 kg/m^2 or weighed more than 140 kg; the comparison group were women who had a BMI < 50 kg/m^2 or weighed less than 140 kg (44). Study investigators' definition of super-obese of weight>140kg was clinician-informed and was regardless of the woman's BMI (44). Researchers observed that 2.1 out of 1000 births were to morbidly obese women (n=370) and that these women had higher odds of gestational diabetes (OR 2.36; 95% CI: 1.56 – 3.59), gestational hypertension (OR 9.33; 95% CI: 4.50 – 19.33), preeclampsia (OR 3.42; 95% CI: 1.85 – 6.35), induction of labour (OR 3.82; 95% CI: 2.75 – 5.28), caesarean delivery (OR 2.33; 95% CI: 1.79 – 3.65), LGA (OR 13.44; 95% CI: 5.22 – 34.57), and ICU admission (OR 4.56; 95% CI: 1.25 – 17.32) (44).

Women of reproductive age who are morbidly obese (BMI $\geq$ 40 kg/m^2) represent an increasing proportion of the pregnant population (2). The pregnancy risks of morbidly obese women are still not fully understood; therefore, Lutsiv et al. (2015) conducted the first comprehensive systematic review and meta-analysis investigating the pregnancy outcomes of Class III obese women compared to Class I or Class I/II obese women (40). Primary outcomes were preterm birth, small-for-gestational-age (SGA), and LGA and secondary outcomes included preeclampsia or gestational hypertension, gestational diabetes, GWG, caesarean section, operative vaginal delivery, antepartum haemorrhage, post-partum haemorrhage, 1st and 2nd degree perineal lacerations, 3rd or 4th degree perineal lacerations, duration of labour, length of hospital stay, NICU admission, assisted ventilation, and maternal death. In the 59 studies included in this systematic review, the authors had a sample group of 8,204,116 women with 213,111 morbidly obese women (BMI >40 kg/m^2), 1,436,586 class I/II women, and the rest were normal BMI women. In the pooled meta-analyses data, the overall risk for preterm birth for class III obese women was 31.0% (RR 1.31; 95% CI: 1.19 – 1.43) higher than class I obese women and 20.0% (RR 1.20; 95% CI: 1.13 – 1.27) higher than combined class I/class II obese women. Women with class III obesity were up to 88% (RR 1.88; 95% CI: 1.61 – 2.18) more likely to have a LGA child, but this estimate was based off a single study. Class III obese women had higher risks for preeclampsia (RR 2.00; 95% CI: 1.63 – 2.45), gestational diabetes (RR 1.84; 95% CI: 1.44 – 2.34); and caesarean section (RR 1.51; 95% CI: 1.41 – 1.60). It is important to also note that Lutsiv et al. did not include the previous studies mentioned above that examined maternal morbid obesity and pregnancy outcomes. Further, Lutsiv et al.'s estimates for their primary outcomes were based off unadjusted estimates and certain outcomes were reported from a small number of studies.

These studies suggest that obesity during pregnancy, based on prepregnancy BMI, is associated with negative outcomes during pregnancy and delivery. Obesity has adverse effects on the health of the mother and the baby and it is therefore important to understand ways in which to intervene and help manage these high-risk pregnancies. Obesity and gestational weight gain are possible modifiable risk factors that, if changed, may lead to better health for the mother and child.

2.5 Gestational Weight Gain (GWG)

The mother's pre-pregnancy BMI can help doctors to recommend the ideal amount of GWG throughout the pregnancy. The U.S. Institute of Medicine (IOM) (2009) developed guidelines for optimal gestational weight gain based on the woman's pre-pregnancy BMI and these guidelines are widely used internationally (7). See **Table 1,** below for GWG recommendations based on the mother's pre-pregnancy BMI. It is important to note that all three obese classes are grouped together for a single gestational weight gain recommendation of 11 – 20 pounds. The development of these recommendations for weight gain were based on available data from Class I obese women (based on their pre-pregnancy BMI) for the following outcomes: small for gestational age (SGA), large for gestational age (LGA), caesarean delivery, preterm delivery, and postpartum weight retention (8). Therefore, data for these recommendations are primarily targeted for women with a BMI of 30.0-34.9 kg/m^2 (8, 11). The committee who proposed the 2009 GWG guidelines found only 2 studies that provided data on class II and III obese women and few women gained less than 10 pounds; therefore, the IOM had insufficient evidence to develop more specific recommendations for GWG for women of higher obese classes (8).

Table 1. Table of Institute of Medicine (IOM) Gestational Weight Gain Recommendations by Pre-Pregnancy BMI (7)

Pre-pregnancy Weight Category	**Body Mass Index***	**Recommended Range**		**Recommended Rates of Weight Gain† in the Second and Third Trimesters**	
		Total Weight (lb)	**Total Weight (kg)**	**(Mean Range [lb/wk.])**	**(Mean Range [kg/wk.])**
Underweight	Less than 18.5	28–40	12.5 – 18	1 (1–1.3)	0.51 (0.44 – 0.58)
Normal Weight	18.5–24.9	25–35	11.5 – 16	1 (0.8–1)	0.42 (0.35 – 0.50)
Overweight	25.0–29.9	15–25	7 – 11.5	0.6 (0.5–0.7)	0.28 (0.23 – 0.33)
Obese (classes I, II, III)	30.0 and greater	11–20	5 – 9	0.5 (0.4–0.6)	0.22 (0.17 – 0.27)

*Body mass index is calculated as weight in kilograms divided by height in metres squared.
†Calculations assume a 1.1–4.4 lb weight gain in the first trimester.

2.5.1 Gestational Weight Gain for Obese Classes I, II, and III Should Be Different

As the IOM guidelines only provide one recommendation for all obese women, although there are 3 classes of obesity, some studies have suggested that this recommendation should not apply to all obese women as that weight gain less than the amount recommended in these guidelines (and in some cases weight loss) resulted in no significant differences in adverse neonatal and maternal outcomes for obese women (6, 10). As previously stated, the development of these guidelines for weight gain were based on available data from Class I obese women. Therefore, data for these recommendations are primarily targeted for women with a BMI of 30.0-34.9 kg/m^2 (8, 11). The committee who proposed the 2009 GWG guidelines found only 2 studies that provided data on class II and III obese women and few of those women gained less than 10 pounds (8). In 2009, the IOM had insufficient evidence to develop more specific recommendations for GWG tailored to women of heavier obese classes (8). Studies suggest that the 3 classes of obesity on the BMI scale are different enough to warrant different gestational weight gain recommendations (9, 12). As such, it is possible that the gestational weight gain recommendations in the 2009 IOM guidelines are not sufficient. The current recommendations group the 3 obese classes into one, advocating that all 3 classes gain 11-20 lbs during the pregnancy.

2.5.2 Gestational Weight Gain Restriction Effects on Morbid Obesity Pregnancy Outcomes

There appears to be contention in the literature whether gestational weight gain restriction during pregnancy for obese women would lead to better maternal and neonatal outcomes than gaining the recommended 11-20 lbs (5-9 kg).

In a prospective cohort study by Claesson et al. (2008), researchers explored the restriction of GWG in obese pregnant women to less than 15 lbs (7 kg) to see if this would yield better maternal and neonatal outcomes (6). The researchers hypothesized that their behavioural intervention programme that provided obese women with motivational speeches and regular physical activity throughout pregnancy would result in reduced weight gain (6). In a non-randomized interventional study, a total of 155 obese women accepted and completed the intervention programme and 193 women were enrolled in the control group. The intervention programme for the index group consisted of extra visits with a midwife for supportive motivational talks regarding weight control and participants were also invited to an aqua aerobics class designed for obese women. Results showed that 35.7% of women within the intervention programme had GWG below 7 kg compared to 20.5% of women in the control group (6). Although researchers observed a difference in the proportion of women gaining below 7kg ($p=0.003$), this difference in weight gain did not lead to a difference in maternal and neonatal outcomes such as instrumental delivery (intervention group: 10.0% vs control group: 9.8%; p=0.961), acute caesarean delivery (intervention group: 14.3% vs control group: 15.8%; p=0.698), and elective caesarean delivery (intervention group: 9.7% vs control group: 5.2%; p=0.106) (6). A limitation of this study were small sample sizes, no provided confidence intervals, lack of randomization of the intervention, and that there were significant differences in socio-economic status of those who participated and those who declined participation.

The findings of Claesson et al. (2008) were similar results by Johnson et al. (2013). Johnson et al. explored pregnancy outcomes of gestational weight gain above and below the 2009 IOM guidelines, researchers found that there were no consistent associations with insufficient weight gain and adverse outcomes (45). Although the sample of this study was large (Total N=9,969 and n=1,145 of obese pregnant women), this study was a secondary analysis of data that from a previous study meant to measure supplemental vitamin C and E to prevent complications with pregnancy-related hypertension. It is possible that women enrolled in this study altered their own habits by virtue of participation.

Conversely, a study in 2011 by Blomberg et al investigated whether weight loss or weight gain below the IOM guidelines in class I-III obese women would be associated with adverse maternal and neonatal outcomes compared to weight gain within the guidelines (10). This population-based cohort study included obese women from the Swedish Medical Birth Registry with a BMI 30 kg/m^2 or higher who had given birth between 1993 and 2008 (n=46,595 women). The women were then divided into 4 categories based on gestational weight gain: less than 0 kg (weight loss), 0-4.9kg (low weight gain), 5-9 kg (recommended weight gain), and more than 9 kg (excessive weight gain) (10). Results showed that obese women who lost weight during their pregnancy – regardless of obesity class – had a decreased risk of caesarean delivery (OR 0.77; 95% CI: 0.66 – 0.99) and LGA births (OR 0.64; 95% CI: 0.46 – 0.90) compared to women who gained the recommended 5-9 kg. Furthermore, obese class III women with weight loss during pregnancy compared to class III women who gained the recommended GWG were found not to be at increased risk for preeclampsia (OR 0.74; 95% CI: 0.51 – 1.08), excessive bleeding during pregnancy (OR 0.95; 95% CI: 0.57 – 1.59), instrumental delivery (OR 0.98; 95% CI: 0.59 – 1.63), or fetal distress (OR 0.68; 95% CI: 0.44 – 1.05) (10). Class III obese women with excessive weight gain were also not at an increased risk of any of the evaluated outcomes when compared to women who gained the recommended amount of weight (preeclampsia OR 1.14 (95% CI: 0.89 – 1.46); instrumental delivery OR 1.16 (95% CI: 0.81 – 1.67); caesarean delivery OR 1.12 (95% CI: 0.94 – 1.35)) (10). However, women in class I or II who had excessive weight gain had an increased risk of preeclampsia (class I: 1.6 (95% CI: 1.5-1.8); class II: 1.6 (1.3-1.8)), LGA (class I: 1.9 (1.8-2.1) ; class II: 1.9 (1.6-2.2)), caesarean delivery (class I: 1.2 (1.2-1.3); class II: 1.2 (1.1-1.3)), and fetal distress (class II: 1.20 (95% CI: 1.01 – 1.42)) (10). It is important to note that the results of this study were most likely affected by small sample sizes where some outcomes had data on less than 30 people.

Additionally, Oza-Frank and Keim (2013) examined associations between inadequate weight gain among obese women and maternal and neonatal outcomes based on data from the U.S. Collaborative Perinatal Project (11). Using data from a large prospective study (N=55,000 pregnancies) from 12 U.S. cities between 1959 to 1965, researchers analyzed only women with a pre-pregnancy BMI of ≥30 kg/m^2, resulting in a final sample size of 2,789 women. Inadequate weight gain, defined as less than the recommended 5kg for obese women, reduced the odds of preeclampsia (OR: 0.56; 95% CI: 0.37 – 0.84), gestational hypertension (OR: 0.66; 95% CI:0.47-0.92), and LGA (OR: 0.48; 95% CI: 0.38- 0.60). Gestational weight gained below guidelines increased the risk of SGA for class I obese women but not for class II/III obese women. Findings from Oza-Frank and Keim suggest that class I obese women need to gain the recommended amount of gestational weight compared to class II/III obese women to minimize the risk of SGA infants (OR 1.86; 95% CI: 1.18-2.91). Limitations of this study is the fact that it relies on older data from 50 years ago and since that time there have been major changes in the population's characteristics and more women are entering pregnancy obese (2) meaning that it is possible that this data may no longer be valid. This study was also restricted to include only obese women which reduced the sample size from 55,000 pregnancies to 3,000 (5% of original sample).

In a systematic review by Kapadia et al. (2015), researchers wanted to explore pregnancy outcomes of women with gestational weight loss compared to gestational weight gain. Primary outcomes considered were: small-for-gestational-age (SGA), large-for-gestational-age (LGA), and preterm birth (46). Six cohort studies were included and their total sample size was 60,913 obese pregnant women. None of the studies that Kapadia et al. included in their paper examined intentional versus unintentional gestational weight loss during pregnancy. Obese women who had gestational weight loss during pregnancy had higher odds of SGA with a significant graded relationship between the 3 obese categories (class I: OR 1.73; 95% CI 1.53–1.97; class II: OR 1.63; 95% CI 1.44–1.85 and class III: OR 1.39; 95% CI 1.17–1.66, respectively). Further, gestational weight loss was also associated with lower odds of a LGA (all classes: OR 0.57; 95% CI: 0.44 – 0.75; class I: OR 0.53 (95% CI: 0.30 – 0.95); class II: OR 0.48 (95% CI: 0.28 – 0.81);

class III: OR 0.51 (95% CI: 0.51 (95% CI: 0.33 – 0.78)) baby compared to weight gain within the guidelines (46). Although it is important to note that this systematic review did determine that the risk of obstetric interventions such as caesarean delivery (all classes: OR 0.81; 95% CI: 0.74 – 0.88; class I: OR 0.65 (95% CI: 0.44 – 0.95); class II: OR 0.69 (95% CI: 0.57 – 0.84); class III: OR 0.80 (95% CI: 0.68 – 0.95)) were lower in obese pregnant women with gestational weight loss. Kapadia et al. (2015) noted that they would not recommend gestational weight loss for obese women based on their findings (46). Limitations include how the authors were unable to find studies that examined gestational weight loss during pregnancy for some of their outcomes and how several included studies did not stratify by obesity classes.

Kapadia et al. (2015) published a second systematic review and meta-analysis asking whether it would be safe to recommend gestational weight gain below the 2009 IOM guidelines for all obese women (47). In this systematic review, the researchers found GWG below the guidelines had higher odds of preterm birth (OR1.46; 95% CI: 1.07–2.00) and SGA (OR 1.24; 95% CI 1.13–1.36) and lower odds of LGA (OR 0.77; 95% CI 0.73–0.81) than women with GWG within the guidelines. Decreased odds were seen for macrosomia (OR 0.64; 95% CI 0.54–0.77), gestational hypertension (OR, 0.70; 95% CI 0.53– 0.93), preeclampsia (OR 0.90; 95% CI 0.82–0.99) and caesarean delivery (OR 0.87; 95% CI 0.82–0.92). The authors advocated that gestational weight below IOM guidelines cannot be routinely recommended but that on occasion, this might be a solution for women based on a women's individual health history and known risk factors (47). Authors notes that there was not enough high quality evidence from the 18 included studies to synthesize information regarding the risk of gestational diabetes, induction of labour, low birth weight, and neonatal morbidity or mortality. For some of their outcomes of interest, the authors only had one study examining GWG below the guidelines in obese women and many did not stratify by obese class.

2.5.3 Summary of Outcomes Associated with Obesity and Gestational Weight Gain

In summary, literature as described above has shown that GWG is associated with a myriad of adverse outcomes such as ICU admission (48), 3rd or 4th degree perineal laceration (49), eclampsia (4, 28), unplanned hysterectomy (50), operative vaginal deliveries (51), caesarean delivery (50, 52), small-for-gestational age (48, 50, 52, 53), large-for-gestational age (48, 50, 52, 53), assisted ventilation (53), neonatal seizures (53), and neonatal sepsis (54).

2.6 Data Source

There are not many easily available datasets for pregnancy research with information on obesity, gestational weight gain, and pregnancy outcomes. One database that is commonly used and is publically available is the U.S. birth certificate dataset.

2.6.1 Validity and Reliability of the U.S. Birth Certificate Database

Birth certificate data is often used in epidemiologic studies in pregnancy research due to ease of access to a population-based data. The usefulness of these data is largely dependent on the accuracy and completeness of the information in the datasets. Considerations for use of datasets include the reliability and validity of the measures. Reliability pertains to the consistency of measurement, while validity is the extent to which the measurement corresponds to what is actually being measured (55).

The United States birth certificate data are publicly available for download for epidemiologic research studies. A study by Andrade et al. (2013) examined the validity and reliability of birth certificate data for pregnancy research (56). A retrospective study was undertaken among mothers and infants enrolled in in participating health plans sites who gave birth between 2001 to 2007. For the infants selected for chart review, validity of the following elements on birth certificate data were assessed: gestational age, birth weight, number of previous pregnancies and live births, and maternal/paternal characteristics. The positive predictive value (PPV) was high for birthweight (93%), gestational age (83%), maternal race/ethnicity (92%), infants with cardiac defects (71%), preterm birth (87%), and NICU admission (92%) (56). Overall, it was found that there was considerable agreement (a Positive Predictive Value (PPV) of >90%) between birth certificate data and medical charts that served as the gold standard (56).

Several studies have also examined the reliability and validity of 2003 U.S. birth certificate data (57-60). Findings suggested that there are item variations in validity and reliability of elements in birth certificate data. Accurate reporting was found in birth weight, demographic characteristics, and most delivery methods and some underreporting was found in pre-pregnancy weight, tobacco and alcohol use, obstetric procedures, and complications of labour and delivery (58, 59, 61, 62). A study by Bodnar et al. (2014) evaluated the validity of pre-pregnancy body mass index and gestational weight gain reported on birth certificates using medical records (63). Results showed that birth certificate derived pre-pregnancy BMI and medical record BMI agreement was high among normal, overweight, and obese class I, II, and III women but was only 51.7% agreement for Class I non-Hispanic Black women (63). The variation in agreement depended on the race/ethnicity of the mother. For gestational weight gain, agreement between birth certificate data and medical records varied between 40.9-83.3% of deliveries based on the pre-pregnancy BMI category where extreme GWG having the greatest degree of misclassification (63). A 2003 validation study by Roohan et al. of 400 birth certificates in 4 New York state counties found sensitivity to be moderate to excellent in gestational diabetes (83%), preeclampsia (62%), smoking/tobacco use (89%), vaginal birth (100%), primary caesarean delivery (100%), repeat caesarean delivery (98%), and low birthweight (100%) (58). In a recent validation study of the 2003 U.S. birth certificate, researchers assessed the validation of selected items to understand the accuracy of the data in New York City and Vermont (60). Dietz et al. (2015) calculated the sensitivity, specificity, PPV, and negative predictive value (NPV) of select variables reported on the birth certificate using the medical records as the gold standard (60). Results showed that overall, there was excellent specificity and NPV on most of the items on the birth certificate. Positive predictive values were moderate to excellent for items such as insurance coverage (91.6% for New York and 94.2% in Vermont), prior live births (98% for New York and 98% in Vermont), delivery method (>98% for both New York and Vermont), gestational diabetes (>80% for both New York and Vermont), and prior caesarean delivery (>95% for both New York and Vermont).

Selected items from the birth certificate that have been validated are: maternal demographic and characteristic data such as maternal race, education, and marital status (56, 57, 61), gestational age (57), Medicaid coverage (60), private insurance coverage (60), pre-pregnancy diabetes (57, 58, 60), gestational diabetes (57, 60), any previous live births (56, 60), previous caesarean section (57, 60), any hypertension in pregnancy (57, 60), gestational hypertension (57, 60), premature rupture of membranes (PROM) (57, 58, 60), induced labor (60), instrumental delivery

(61), parity (57), eclampsia (57, 58), augmented labor (60), delivery method (vaginal or caesarean) (57, 58, 60), birthweight (56-58), smoking (57, 58), neonatal seizures (62).

2.7 Summary

Obesity during pregnancy is a significant risk factor for adverse maternal and neonatal outcomes. Furthermore, the literature suggests that the 2009 IOM recommended GWG guidelines may be insufficient for class II and III obese women and that a modification of these guidelines to include GWG recommendations for each of the obesity classes separately may be needed. Additional literature has also suggested the possibility of restricted GWG for obesity class II and III for less adverse pregnancy outcomes. Previous studies within this field have been inadequate and not all have examined the same maternal and neonatal outcomes. The studies by Claesson et al. had a sample of 155 and Johnson et al. had a sample of 700. Although Oza-Frank and Keim (2013) studied restricted gestational weight gain, to our knowledge there are no specific studies are examining restricted gestational weight gain using current data. Furthermore, the information from the Oza-Frank study was based on a cohort from 1959-1965. Since then, there have been major changes in prenatal care and the rates of obesity in the population have increased dramatically. Studies within this field have had small sample sizes, lack of adjustment for possible confounders and modifying variables, use of data that is no longer valid, and

This current project to aims add some knowledge to help fill in the gaps currently in this field. Furthermore, this current study aims to investigate this issue with a more comprehensive list of maternal and neonatal outcomes including admission to the intensive care unit, 3rd or 4th degree perineal laceration, eclampsia, or unplanned hysterectomy, operative vaginal deliveries and cesarean delivery, small for gestational age (10^{th} percentile), LGA (90^{th} percentile), assisted ventilation, seizures, or sepsis.

2.8 Objective

To determine the risk of maternal, obstetric, and neonatal outcomes for class I, II and III obese pregnant women who either: lost weight during pregnancy, gained below the IOM guidelines, or gained above the IOM guidelines, compared to women who gained within the IOM guidelines (11-20 lbs)

Chapter Three: **METHODOLOGY**

The objective of our study was to determine whether the risk of adverse maternal and neonatal outcomes for class I, II and III obese pregnant women who either: lose weight during pregnancy, gained below IOM guidelines, or gained above IOM guidelines, compared to women who gained within IOM guidelines (11-20 lbs). Utilizing a cross-sectional approach, the present study investigated gestational weight gain (GWG) during pregnancy between the three obese classes and its association with adverse maternal and neonatal outcomes using a large population-level dataset of approximately 4 million live births in the United States.

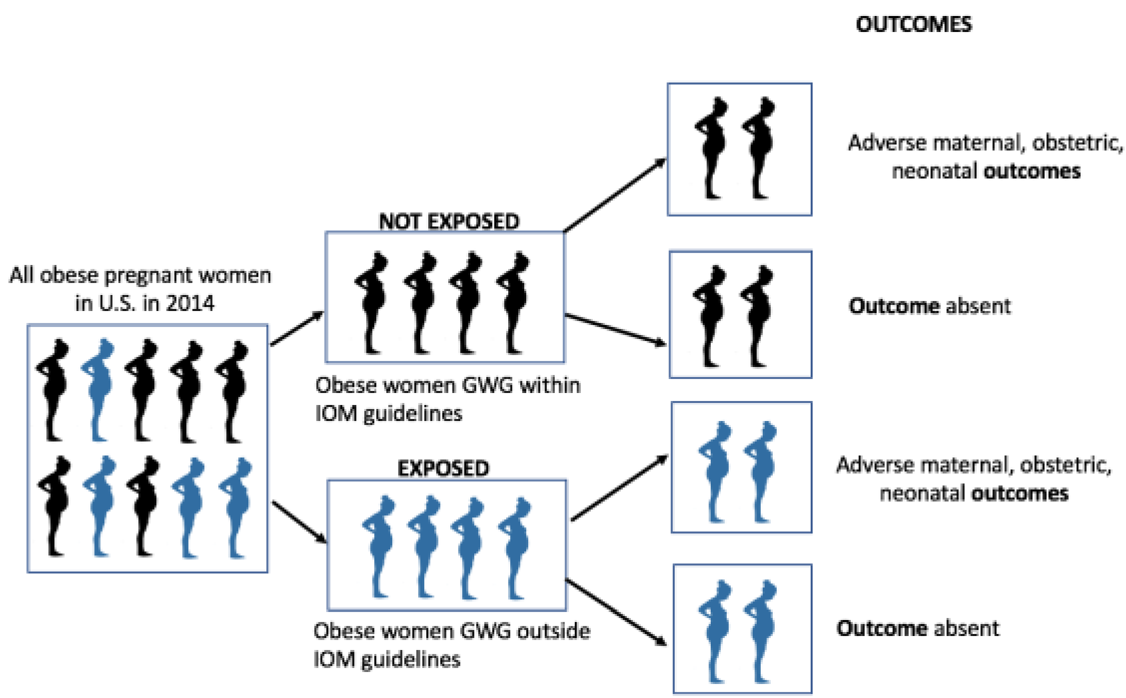

Figure 2. This study utilized a cross sectional study design, depicted above, where exposure and outcomes were assessed concurrently.

3.1 Data Source

This study used publicly available birth certificate data downloaded from the National Bureau of Economic Research (NBER) website: http://www.nber.org/data/vital-statistics-natality-data.html. Specifically, this present study used data of live births from 2014. Birth certificate data in the USA is comprehensive and includes information about parental education, ethnicity, obstetric history, pre-pregnancy weight, weight gained during pregnancy, risk factors in the current pregnancy, obstetric procedures, method of delivery, and neonatal outcomes. United States birth certificate data are limited to live births occuring within the United States to U.S. residents and non-residents. However, live births to non-residents were pre-excluded from the data file by the Centers for Disease Control and Prevention (CDC) and National Center for Health Statistics (NCHS). This dataset represents all live births registered within the 50 states and the District of Columbia. The CDC and NCHS receives data as electronic files prepared from individual records processed by each individual registration area, through the Vital Statistics Cooperative Program. A copy of a typical birth certificate is attached in **Appendix A.**

In 2014, there were 3,998,076 live births registered in the United States. More than 99% of live births in the United States are registered in birth certificate data (64). This dataset does not include live births from US territories as these are included in a separate dataset.

3.2 Inclusion/Exclusion Criteria

The following were the list of criteria that were used to identify inclusion in the study:

i. Singleton pregnancy ǂ

ii. BMI $\geq$ 30kg/m^2

iii. Women who delivered at term (37-40 weeks of gestation)

iv. No missing data on mother's height, pre-pregnancy weight, and weight at delivery

NOTES:

ǂThe choice of including only women with singleton pregnancies was due to the higher risks involved in pregnancies with multiples. Multiple gestation pregnancies also would have different GWG.

After the application of study inclusion criteria, the final study sample included information on 642,646 live births.

3.3 Measures

The three classes of obesity were defined as the following: I (BMI 30-34.9 kg/m^2), II (BMI 35-39.9 kg/m^2), and III (BMI $\geq$ 40 kg/m^2) which were calculated based on the woman's pre-pregnancy weight and height per the WHO and CDC classification (7). BMI was calculated using self-reported pre-pregnancy weight and measured height from the birth certificate database. GWG was calculated based on subtracting the woman's pre-pregnancy weight from the woman's weight at delivery taken from their medical record. A woman's weight at delivery was based on the medical chart per the CDC's instructions. For GWG categories, the current 2009

Institute of Medicine guidelines were followed, classifying GWG as: weight loss (<0 lbs), weight gain below the IOM guidelines (<11 lbs), weight gain within the IOM guidelines (11-20 lbs), and weight gain above the IOM guidelines (>20 lbs).

Outcomes of interest were organized into maternal morbidities, obstetric interventions, and neonatal morbidities (**Table 2**). All outcomes were coded as either outcome absent or outcome present. Severe maternal morbidities included the following: admission to the intensive care unit, 3^{rd} or 4^{th} degree perineal laceration (calculated from vaginal births), eclampsia, or unplanned hysterectomy. Obstetric interventions included: operative vaginal deliveries (forceps or vacuum) and caesarean delivery. Severe neonatal morbidities were defined as small for gestational age (10^{th} percentile) and large for gestational age (90^{th} percentile) using the WHO Growth Standard (65), assisted ventilation, seizures, or sepsis. Furthermore, the outcome of sepsis was based on birth data information for antibiotics received by the newborn due to suspected neonatal sepsis.

Table 2. Outcomes of interest

Severe Maternal Morbidities	**Obstetric Interventions**	**Severe Neonatal Morbidities**
ICU Admission	Operative Vaginal Delivery*	SGA (10^{th} percentile)
3^{rd} or 4^{th} Degree Perineal Laceration*	Caesarean Delivery	LGA (90^{th} percentile)
Eclampsia		Assisted Ventilation
Unplanned Hysterectomy		Seizures
		Sepsis

*3^{rd} or 4^{th} degree perineal laceration and operative vaginal deliveries were calculated based on vaginal deliveries
Operative vaginal deliveries (vacuum or forceps)
SGA, small-for-gestational age defined as below 10^{th} percentile
LGA, large-for-gestational age defined as above 90^{th} percentile
ǂ LGA and SGA based on INTERGROWTH-21^{st} Project Growth Charts

Covariates included maternal age, maternal education, marital status, maternal race, medical insurance, prenatal care utilization, and parity. Maternal age in the birth certificate database was continuous and was derived from reported date of birth. Maternal age were recoded and categorized into: <20 years of age, 20 – 34 years old, or ≥ 35 years old. Educational attainment of the mother were based on the checked box of the following categories: 8th grade or less, 9-12th grade, no diploma, high school or GED completed, some college but no degree, associate degree, bachelor's degree, master's degree, doctorate. Maternal education categories were collapsed into: less than high school, high school diploma, some post-secondary with no degree/diploma, or post-secondary with degree/diploma. Marital status was based on maternal report of marital status of either married or unmarried. U.S. birth certificates defined maternal race based on a checked box of 15 categories (and could check more than one race/races that the mother identified herself). The current study collapsed maternal race into the following categories: white, black, American Indian/Alaskan Native, Asian/Native Hawaiian/Pacific Islander, Hispanic, or more than one race. Medical insurance was based on source of payment for the current delivery of pregnancy and defined as the following: Medicaid, Private insurance, self-pay, or other (Indian Health Service, CHAMPUS/TRICARE, or other government). Prenatal care was recoded in the current study using the Revised Graduated prenatal care INDEX (R-GINDEX) based on the trimester that prenatla care began, number of prenatal care visits, and gestational age into the following categories: intensive prenatal care utilization, adequate prenatal care utilization, intermediate prenatal care utilization, inadequate prenatal care utilization, and no prenatal care utilization (66). Parity in the current study was defined and recoded based on the number of live births that the mother has had and categorized as either primiparous (no previous live births) or multiparous (≥ 1 previous live births).

Other covariates included previous caesarean history, smoking, pre-pregnancy diabetes, and gestational diabetes. Previous caesarean, pre-pregnancy diabetes, and gestational diabetes were reported by the mother (either yes or no). Smoking was defined and coded as either smoked cigaretters during pregnancy as reported by the mother (anytime during 1st, 2nd, or 3rd trimester) or not.

3.4 Analyses

Statistical analyses were performed using STATA I/C version 14©. Descriptive statistics were used to characterize the population (maternal age, maternal education, marital status, maternal race, medical insurance, prenatal care utilization, and parity) and were reported as proportions and 95% confidence intervals. An initial analysis was carried out to examine the association between maternal pre-pregancy BMI and GWG using a chi-square test. Chi-square tests were also used to examine the bivariate association between categories of GWG and adverse maternal and neonatal outcomes for women with class I, II and III obesity individually with the outcomes described in **Table 2**. Mean and median gestational weight loss (GWL) and GWG were calculated for all obese women who lost weight during pregnancy, gained below the IOM guidelines, gained above the IOM guidelines, and women who gained within IOM guidelines.

It is important to note however, that although outcomes were tested separately using an alpha-level of 0.05 for significance, doing this meant that at least one of the tested outcomes might not be truly significant per the problem of multiple comparisons. In order to address the problem of multiple hypothesis testing, a Bonferroni correction was used. The Bonferroni correction is an adjustment to the alpha level of significance by dividing the p-critical value by the number of comparisons being made. The alpha-level 0.05 was divided by the 11 outcomes that were being tested therefore, an alpha-level of 0.0045 was deemed to be significant.

Log-binomial regression models using the Poisson distribution were built to examine the relative risks of adverse maternal and neonatal outcomes for obese women who lost weight during pregnancy, gained below the IOM guidelines or gained above the IOM guidelines compared to women who gained within the IOM guidelines with adjustment for maternal age, socio-economic status using education as a proxy, marital status, parity, medical insurance coverage, and maternal race. Variables were selected based on the literature and entered the model using backwards selection where all pre-selected exposures and covariates entered the full model and non-significant covariates were removed until the final model was obtained. The number needed to treat (NNT) was calculated for all outcomes comparing the inverse of the absolute risk reduction (ARR) of obese women who gained within IOM guidelines to a collapsed category consisting of obese women who lost weight during pregnancy, gained below the IOM guidelines or gained above the IOM guidelines.

3.5 Ethics

Ethics approval was obtained from the Conjoint Health Research Ethics Board (CHREB) (ethics ID: REB16-1903).

Chapter Four: **RESULTS**

Of the 3,998,076 births in 2014 in the U.S and after the application of inclusion criteria, data were available for N=642,646 mother/infant pairs for women who had class I, II, and III obesity. Of these, 55.4% (95% CI: 55.3 – 55.6) of women had obese Class I, 26.3% (95% CI: 26.2 – 26.4) had Class II, and 18.3% (95% CI: 18.3 – 18.3) had Class III obesity. Descriptive characteristics of obese women in this study are presented in **Table 3**. The majority of births to these women with obesity were 20-34 years old (79.7%), who had at least a high school diploma (84.4%), some type of insurance (either Medicaid or private insurance) (92.6%), and were primiparous (68.8%). Approximately one half of these women were married (55.6%) and were white (49.2%).

Table 3. Births in the United States in 2014 to obese mothers (N=642,646).

Characteristic	n	% (95% CI)
Maternal age		
<20 years	26,440	4.1 (4.07 – 4.16)
20 – 34 years	511,966	79.7 (79.6 – 79.8)
≥ 35 years	104,240	16.2 (16.2 – 16.3)
Maternal education		
Less than high school	99,156	15.6 (15.5 – 15.7)
High school diploma	184,291	28.9 (28.8 – 29.0)
Some post-secondary, no degree/diploma	165,492	25.9 (25.9 – 26.1)
Post-secondary degree/diploma	188,165	29.5 (29.4 – 29.7)
Marital Status		
Married	357,299	55.6 (55.5 – 55.7)
Unmarried	285,347	44.4 (44.3 – 44.5)
Maternal race		
White	316,173	49.2 (49.1 – 49.3)
Black	120,727	18.8 (18.7 – 18.9)
American Indian/Alaskan Native	7,899	1.2 (1.20 – 1.26)
Asian/Native Hawaiian/Pacific Islander	14,160	2.2 (2.16 – 2.24)
Hispanic	166,722	25.9 (25.8 – 26.1)
More than one race	13,429	2.09 (2.05 – 2.12)
Medical Insurance		
Medicaid	326,686	50.8 (50.7 – 50.9)
Private insurance	268,165	41.7 (41.6 – 41.9)
Self-pay	17,696	2.75 (2.71 – 2.79)
Other (government or other not stated)	25,308	3.94 (3.89 – 3.99)
Prenatal Care		
Intensive Prenatal Care Utilization	414,978	66.2 (66.0 – 66.3)
Adequate Prenatal Care Utilization	129,799	20.7 (20.6 – 20.8)
Intermediate Prenatal Care Utilization	50,822	8.10 (8.03 – 8.17)
Inadequate Prenatal Care Utilization	24,987	3.98 (3.93 – 4.03)
No Prenatal Care Utilization	6,708	1.07 (1.04 – 1.10)
Parity		
Primiparous	200,326	31.2 (31.1 – 31.3)
Multiparous	441,259	68.8 (68.7 – 68. 9)

4.1 Pre-pregnancy BMI and Gestational Weight Gain

The relationship between pre-pregnancy BMI and weight gain were examined per the IOM recommendations and it was found that most of the women (55.14%; 95% CI: 55.02 – 55.26) gained above the IOM guidelines (Class I: 61.57%; Class II: 50.66%; Class III: 41.08%) but as BMI severity increased, fewer women had excessive gestational weight gain (**Table 4**). Overall, approximately one in five (23.48%; 95% CI: 23.39 – 23.59) women gained weight within the IOM guidelines, and with a slightly higher proportion of women with Class II or Class III obesity had gained weight within the guidelines. Around one in ten women lost weight during their pregnancy, and as BMI severity increased, higher proportions of the women lost weight. Between 10 to 20% of women gained below the IOM recommendations. The median GWG for all 3 obese classes were calculated and displayed in **Table 4** and **Figure 3**. The median GWG for those who gained: below the IOM guidelines, within the IOM guidelines, and above the IOM guidelines were the same for all 3 classes. As obesity severity increased, median gestational weight loss (GWL) also increased.

Table 4. Percentages of maternal BMI pre-pregnancy categories and gestational weight gain

Maternal pre-pregnancy BMI	n	% (95% CI) ‡	Median Weight Gain (lbs)	Mean Weight Gain (lbs)
Obesity I 30.0-34.9 (n=355,923)				
Gained within IOM guidelines (11-20 lbs)	79,723	22.4 (22.3 – 22.5)	16	16.1
Lost weight (<0 lbs)	18,372	5.16 (5.09 – 5.23)	-1	-4.27
Gained below IOM guidelines (11-20 lbs)	38,681	10.9 (10.8 – 10.9)	7	6.47
Gained above IOM guidelines (> 20 lbs)	219,147	61.6 (61.4 – 61.7)	33	35.9
Obesity II 35-39.9 (n=169,000)				
Gained within IOM guidelines (11-20 lbs)	41,756	24.7 (24.5 – 24.9)	16	15.9
Lost weight (<0 lbs)	15,435	9.13 (9.00 – 9.27)	-3	-5.62
Gained below IOM guidelines (11-20 lbs)	26,195	15.5 (15.3 – 15.7)	7	6.28
Gained above IOM guidelines (> 20 lbs)	85,614	50.7 (50.4 – 50.9)	32	35.1
Obesity III ≥40 (n=117,173)				
Gained within IOM guidelines (11-20 lbs)	28,710	24.5 (24.3 – 24.8)	16	15.8
Lost weight (<0 lbs)	18,282	15.6 (15.4 – 15.8)	-5	-7.42
Gained below IOM guidelines (11-20 lbs)	22,052	18.8 (18.6 – 19.0)	6	6.13
Gained above IOM guidelines (> 20 lbs)	48,129	41.1 (40.8 – 41.4)	31	34.6

‡ *All proportions were significant p<0.0045*

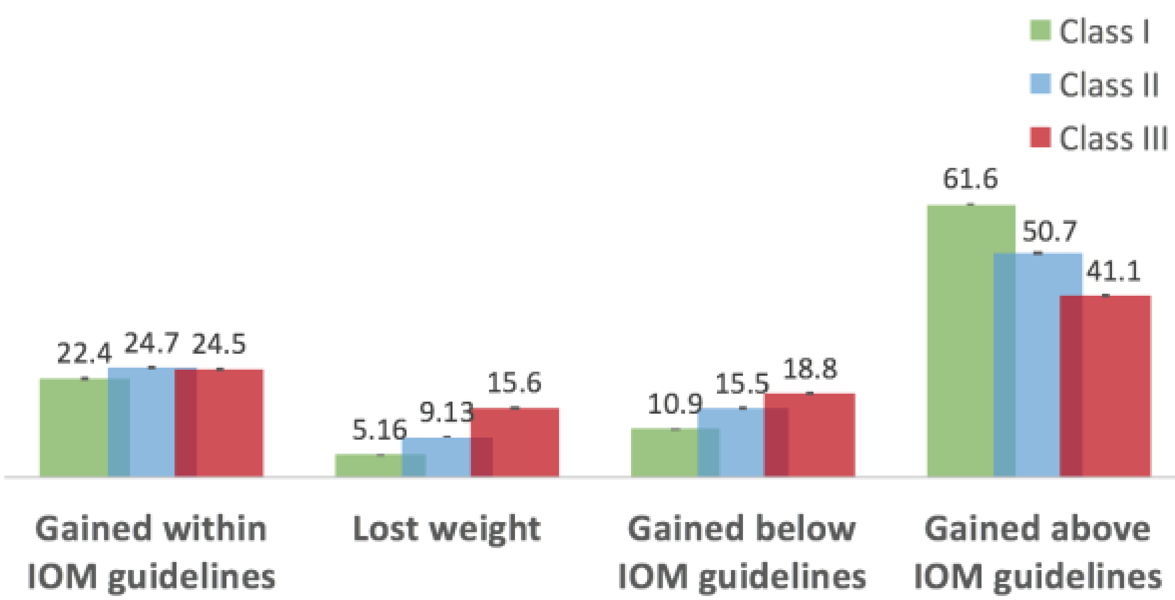

Figure 3. Gestational weight gain by maternal pre-pregnancy body mass index and class of obesity.

Results were organized by the following categories: severe maternal morbidities, obstetric interventions, and severe neonatal morbidities. Each section includes tables describing:

- the proportion of outcomes with 95% confidence intervals stratified by obese classes
- the proportion of outcomes with 95% confidence interval stratified by GWG
- the adjusted risk ratios (95% confidence intervals) of each outcome for each GWG category. Outcomes were stratified by pre-pregnancy BMI and a log binomial multivariate logistic regression model of relative risks was used to compare women who lost weight during pregnancy (<0 lbs.), gained below (<11 lbs.) IOM recommendations, or gained above (>20 lbs.) IOM recommendations to women who gained within IOM recommendations (11 – 20 lbs.) adjusted for maternal age, maternal education, marital status, parity, medical insurance, and maternal race
- the number needed to treat (NNT) or number needed to harm (NNH) for each outcome for each obese class comparing women who gained within IOM guidelines to obese women lost weight, gained below IOM guidelines, and gained above IOM guidelines, combined

4.2 Severe Maternal Morbidity

Severe maternal morbidity consists of intensive care unit (ICU) admission, 3rd or 4th degree perineal laceration, eclampsia, and unplanned hysterectomy. Results are presented in **Tables 5 – 9**.

Table 5. Percentages of severe maternal morbidity for all obese women (BMI based on pre-conception weight) stratified by obese class.

Outcome	***All Obese Women (N=642,646)*** **% (95% CI)**	***Class I (BMI 30-34.9 kg/m²)*** **n=355,923 % (95% CI)**	***Class II (BMI 35-39.9 kg/m²)*** **n=169,000 % (95% CI)**	***Class III (BMI ≥40 kg/m²)*** **n=117,173 % (95% CI)**	**Chi-Square P-value***
Admission to ICU	**0.10 (0.09 – 0.11)**	**0.09 (0.08 – 0.11)**	**0.13 (0.12 – 0.16)**	**0.10 (0.09 – 0.11)**	**<0.001**
3rd/4th degree perineal laceration†	**1.04 (1.01 – 1.07)**	**1.08 (1.04 – 1.13)**	**1.00 (0.94 – 1.06)**	**0.94 (0.86 – 1.02)**	**0.003**
Eclampsia	**0.30 (0.27 – 0.31)**	**0.24 (0.23 – 0.26)**	**0.32 (0.30 – 0.35)**	**0.43 (0.40 – 0.47)**	**<0.001**
Unplanned hysterectomy	0.03 (0.02 – 0.03)	0.03 (0.02 – 0.04)	0.03 (0.03 – 0.04)	0.03 (0.02 – 0.04)	0.867

GWG, gestational weight gain
**P* values are from Chi-Square test. Chi Square test p-value denotes comparison between Class I, II, and III.
†3rd or 4th degree perineal laceration based only on vaginal births (n=375,531)
Bolded if significance p<0.0045

Table 6. Percentages of severe maternal morbidity for all obese women (BMI based on pre-conception weight) stratified by gestational weight gain (GWG) (N=642,646).

Outcome	**Lost Weight (<0 lbs) % (95% CI)**	**Below IOM Guidelines (<11 lbs) % (95% CI)**	**Within IOM Guidelines (11-20 lbs) % (95% CI)**	**Above IOM Guidelines (>20 lbs) % (95% CI)**	**Chi-Square P-value***
Admission to ICU	0.10 (0.08 – 0.14)	0.09 (0.07 – 0.11)	0.10 (0.08 – 0.12)	0.10 (0.09 – 0.12)	0.747
3rd or 4th degree perineal laceration	**0.87 (0.78 – 0.98)**	**0.85 (0.78 – 0.94)**	**0.93 (0.87 – 1.00)**	**1.17 (1.12 – 1.21)**	**<0.001**
Eclampsia	**0.26 (0.22 – 0.31)**	**0.22 (0.19 – 0.25)**	**0.23 (0.21 – 0.26)**	**0.35 (0.33 – 0.37)**	**<0.001**
Unplanned hysterectomy	0.03 (0.01 – 0.04)	0.03 (0.02 – 0.04)	0.03 (0.02 – 0.04)	0.03 (0.03 – 0.04)	0.472

GWG, gestational weight gain
**P* values are from Chi-Square test
Bolded if significance p<0.0045

Table 7. Percentages of maternal outcomes by gestational weight gain by pre-pregnancy BMI.

Maternal pre-pregnancy BMI	ICU Admission % (95% CI)	3rd or 4th Degree Laceration‡ % (95% CI)	Eclampsia† % (95% CI)	Unplanned Hysterectomy % (95% CI)
Obesity I 30.0-34.9				
Lost weight (<0 lbs)	0.11 (0.07 – 0.16)	1.00 (0.84 – 1.19)	**0.19 (0.14 – 0.20)**	0.01 (0.00 – 0.04)
Gained below IOM guidelines (< 11 lbs)	0.09 (0.06 – 0.12)	0.83 (0.73 – 0.96)	**0.17 (0.13 – 0.21)**	0.02 (0.01 – 0.04)
Gained within IOM guidelines (11-20 lbs)	0.09 (0.07 – 0.11)	0.97 (0.89 – 1.06)	**0.17 (0.14 – 0.20)**	0.03 (0.02 – 0.04)
Gained above IOM guidelines (> 20 lbs)	0.08 (0.07 – 0.10)	1.19 (1.13 – 1.25)	**0.27 (0.24 – 0.29)**	0.03 (0.02 – 0.04)
Obesity II 35-39.9				
Lost weight (<0 lbs)	0.09 (0.06 – 0.12)	0.83 (0.72 – 0.95)	**0.22 (0.18 – 0.26)**	0.03 (0.02 – 0.05)
Gained below IOM guidelines (< 11 lbs)	0.10 (0.06 – 0.16)	0.81 (0.65 – 1.02)	**0.28 (0.21 – 0.37)**	0.04 (0.01 – 0.08)
Gained within IOM guidelines (11-20 lbs)	0.10 (0.07 – 0.14)	0.89 (0.75 – 1.04)	**0.24 (0.19 – 0.31)**	0.03 (0.01 – 0.06)
Gained above IOM guidelines (> 20 lbs)	0.10 (0.08 – 0.12)	1.17 (1.08 – 1.28)	**0.38 (0.34 – 0.42)**	0.03 (0.02 – 0.05)
Obesity III ≥40				
Lost weight (<0 lbs)	0.10 (0.07 – 0.16)	0.77 (0.61 – 0.97)	**0.32 (0.25 – 0.40)**	0.03 (0.01 – 0.06)
Gained below IOM guidelines (< 11 lbs)	0.10 (0.06 – 0.14)	0.85 (0.70 – 1.04)	**0.27 (0.21 – 0.34)**	0.03 (0.01 – 0.06)
Gained within IOM guidelines (11-20 lbs)	0.12 (0.09 – 0.17)	0.96 (0.81 – 1.14)	**0.37 (0.31 – 0.45)**	0.03 (0.01 – 0.05)
Gained above IOM guidelines (> 20 lbs)	0.18 (0.14 – 0.22)	1.02 (0.89 – 1.16)	**0.53 (0.47 – 0.59)**	0.03 (0.02 – 0.05)

† **Bolded** if significance p<0.0045
‡ Restricted to vaginal births

Table 8. Adjusted Risk Ratios (95% CI) of BMI weight gain and maternal morbidity.

BMI	**Weight Gain**	**ICU Admission‡ RR (95% CI)**	**3rd or 4th Degree Perineal Laceration†* RR (95% CI)**	**Eclampsia‡ RR (95% CI)**	**Unplanned Hysterectomy§ RR (95% CI)**
Class I (30-34.9 kg/m²)	Lost weight	1.15 (0.71-1.86)	1.06 (0.86-1.27)	1.00 (0.69-1.47)	0.38 (0.09-1.61)
	< 11 lbs	0.79 (0.52-1.21)	0.92 (0.79-1.08)	0.92 (0.68-1.24)	0.77 (0.36-1.67)
	11–20 lbs	1	1	1	1
	> 20 lbs	0.94 (0.72-1.23)	1.02 (0.93 -1.13)	1.51 (1.25-1.81)	1.25 (0.77-2.01)
Class II (35-39.9 kg/m²)	Lost weight	0.98 (0.52-1.86)	1.06 (0.81-1.38)	1.36 (0.96-1.95)	1.35 (0.46-3.95)
	< 11 lbs	1.09 (0.65-1.84)	1.16 (0.94-1.44)	1.13 (0.82-1.56)	1.23 (0.49-3.12)
	11–20 lbs	1	1	1	1
	> 20 lbs	1.18 (0.79 -1.74)	1.24 (1.06 -1.46)	1.69 (1.34-2.13)	1.69 (0.83 -3.45)
Class III (≥ 40kg/m²)	Lost weight	0.78 (0.75-0.82)	0.86 (0.64-1.15)	0.75 (0.55-1.03)	1.29 (0.39-4.24)
	< 11 lbs	0.88 (0.84-0.91)	0.93 (0.72-1.22)	0.69 (0.51-0.94)	1.69 (0.59-4.88)
	11–20 lbs	1	1	1	1
	> 20 lbs	1.20 (1.16-1.24)	0.97 (0.78-1.20)	1.51 (1.25-1.81)	1.83 (0.72 -4.65)

‡ Adjusted for maternal age, maternal education, marital status, parity, medical insurance, and maternal race
† Adjusted for maternal age, maternal education, marital status, parity, medical insurance, maternal race, and operative vaginal deliveries
§ Adjusted for maternal age, maternal education, marital status, parity, medical insurance, maternal race, and mode of delivery
*Restricted to vaginal births
Bolded if significance p<0.0045

Table 9. Number Needed to Treat (NNT)/Number Needed to Harm (NNH) of adverse maternal outcomes of women gaining within the IOM guidelines compared to women gaining outside the IOM guidelines by obesity class.

BMI	**ICU Admission‡**	**3rd/4th Degree Laceration‡**	**Eclampsia‡**	**Unplanned Hysterectomy‡**
Class I (30-34.9 kg/m²)	9450	682	-1130	294819
Class II (35-39.9 kg/m²)	7932	441	752	8591
Class III (≥ 40 kg/m²)	167109	-2994	2948	7393

‡ Outcomes were not clinically relevant
Note: NNT's are displayed as positive numbers while NNH's are displayed as negative numbers.

4.2.1 Admission to ICU

The rate of ICU admission among the women with obesity was 0.10% (95% CI: 0.09 – 0.11) (**Table 5**). Among all obese women, bivariate analyses showed that class II obese women had the highest proportions of ICU admission and class I obese women had the lowest proportion of ICU admission; this was statistically significant at ($p<0.001$) (**Table 5**). The proportions of those who were admitted to ICU did not differ statistically between obese women who lost weight during pregnancy, gained below IOM guidelines, gained within IOM guidelines, and above IOM GWG guidelines (**Table 6**). Women who lost weight, gained below IOM guidelines, or gained above IOM guidelines did not differ significantly compared to women who gained weight within IOM guidelines (**Table 7**). Adjusted risk ratios for ICU admission showed no significant associations for any GWG categories by obese class (**Table 8**). The number of obese mothers who need to gain within IOM guidelines (NNT) for the prevention of one additional woman being admitted to ICUfor class I, II, and III – on average – are 9450, 7932, and 167109 (**Table 9**), which was clinically not meaningful.

4.2.2 3rd or 4th Degree Perineal Laceration

The overall proportion of women experiencing a 3rd or 4th degree perineal laceration was 0.61% (95% CI: 0.59 – 0.63); this differed between the 3 obesity classes where the proportion of 3rd or 4th degree perineal lacerations decreased as BMI severity increased ($p<0.001$) (**Table 5**). The relationship between 3rd and 4th degree perineal laceration and GWG categories was significant when looking at the overall cohort of obese women as the proportion of maternal lacerations increased as GWG increased (**Table 6**) but was no longer significant once it was stratified by obese class (**Table 7**). The proportion of women who gained within the IOM GWG guidelines and had a 3rd or 4th degree perineal laceration were Class I: 0.67 (0.61 – 0.72), Class II: 0.51

(0.45 – 0.58), and Class III: 0.51 (0.44 – 0.59) (**Table 6**). Compared to women who lost weight, gained below IOM guidelines, and above IOM GWG guidelines, the proportion of women who gained within the IOM guidelines did not statistically differ when comparing within each of the obese classes (**Table 7**). The adjusted risk ratios for 3rd or 4th degree perineal laceration were not statistically significant (**Table 8**). NNT/NNH's were calculated for 3rd or 4th degree perineal for how many obese women need to gain within IOM guidelines compared to women who gain outside of the IOM guidelines for the prevention of one additional woman from having 3rd or 4th degree perineal lacerations (**Table 9**). NNT's/NNH's were not clinically meaningful.

4.2.3 Eclampsia

The overall proportion of women with eclampsia was 0.30% (95% CI: 0.27 – 0.31) which differed significantly between the 3 obese classes; as BMI severity increased, the proportion of women with eclampsia as increased (**Table 5**). When examining the overall cohort, there appeared to be a statistically significant difference between women who lost weight, gained below IOM guidelines, gained within IOM guidelines, and gained above guidelines; as GWG increased, as did the proportion of women with eclampsia (**Table 6**). The proportion of those who developed eclampsia and gained within the IOM guidelines for Class I, II, and III were 0.17 (0.14 – 0.20), 0.22 (0.18 – 0.26), and 0.37 (0.31 – 0.45), respectively. The proportion of obese women who had eclampsia increased as BMI severity and GWG increased to 0.53% (95% CI: 0.47 – 0.59) among women with Class II obesity with gains > 20 pounds (**Table 7**). However, adjusted risk ratios were not significant (**Table 8**). NNT's/NNH's were calculated for eclampsia and presented in **Table 9**. NNT's/NNH's were not clinically meaningful.

4.2.4 Unplanned Hysterectomy

The rate of unplanned hysterectomy was 0.03% (95% CI: 0.02 – 0.03) and bivariate analyses showed no significant association between gestational weight gain in any obese class (**Table 5**). Further analyses of the overall cohort found that women who lost weight during pregnancy, gained below IOM guidelines, gained within IOM guidelines, or gained above IOM guidelines also did not differ statistically (**Table 6**). NNT's/NNH's were calculated for unplanned hysterectomies and presented in **Table 9**. NNT's/NNH's were not clinically meaningful.

4.3 Obstetric Interventions

Obstetric interventions consisted of operative vaginal deliveries (defined as vacuum and forceps) and caesarean deliveries. Results are presented in **Tables 10 – 14**.

Table 10. Percentages of obstetric interventions for all obese women (BMI based on pre-conception weight) stratified by obese class.

Outcome	***All Obese Women (N=642,646)*** **% (95% CI)**	***Class I (BMI 30-34.9 kg/m²)*** **n=355,923 % (95% CI)**	***Class II (BMI 35-39.9 kg/m²)*** **n=169,000 % (95% CI)**	***Class III (BMI ≥40 kg/m²)*** **n=117,173 % (95% CI)**	**Chi-Square P-value***
Operative vaginal delivery‡	**3.95 (3.88 – 4.01)**	**4.03 (3.95 – 3.91)**	**3.79 (3.67 – 3.91)**	**3.85 (3.70– 14.02)**	**0.002**
Caesarean delivery	**41.55 (41.43–41.67)**	**37.18 (37.03–37.34)**	**43.35 (43.11–43.59)**	**52.18 (51.89–52.47)**	**<0.001**

**P* values are from Chi-Square test. Chi Square test p-value denotes comparison between Class I, II, and III.
‡ Operative vaginal deliveries, defined as vacuum or forceps
Bolded if significance p<0.0045

Table 11. Percentages of obstetric interventions for all obese women (BMI based on pre-conception weight) stratified by gestational weight gain (GWG) (N=642,646).

	Lost Weight	**Below IOM**	**Within IOM**	**Above IOM**	**Chi-**

Outcome	(<0 lbs) % (95% CI)	Guidelines (<11 lbs) % (95% CI)	Guidelines (11-20 lbs) % (95% CI)	Guidelines (>20 lbs) % (95% CI)	Square P-value*
Operative vaginal delivery‡	**3.58 (3.38 – 3.79)**	**3.42 (3.27 – 3.58)**	**3.56 (3.44 – 3.68)**	**4.32 (4.23 – 4.41)**	**<0.001**
Caesarean delivery	**36.88 (36.47-37.29)**	**38.13 (37.81-38.45)**	**39.67 (39.42-39.92)**	**43.88 (43.71-44.04)**	**<0.001**

**P* values are from Chi-Square test
‡ Operative vaginal deliveries, defined as vacuum or forceps
Bolded if significance p<0.0045

Table 12. Percentages of maternal outcomes by gestational weight gain by pre-pregnancy BMI.

Maternal pre-pregnancy BMI	Operative Vaginal Delivery‡	Caesarean Delivery
Obesity I 30.0-34.9		
Lost weight (<0 lbs)	**3.65 (3.33 – 3.99)**	**29.63 (28.98-30.30)**
Gained below IOM guidelines (< 11 lbs)	**3.49 (3.27 – 3.72)**	**31.66 (31.20-32.13)**
Gained within IOM guidelines (11-20 lbs)	**3.60 (3.44 – 3.76)**	**34.39 (34.06-34.72)**
Gained above IOM guidelines (> 20 lbs)	**4.35 (4.24 – 4.46)**	**39.82 (39.61-40.02)**
Obesity II 35-39.9		
Lost weight (<0 lbs)	**3.67 (3.31 – 4.07)**	**38.70 (38.11-39.29)**
Gained below IOM guidelines (< 11 lbs)	**3.47 (3.20 – 3.76)**	**41.13 (40.86-41.81)**
Gained within IOM guidelines (11-20 lbs)	**3.35 (3.13 – 3.59)**	**35.12 (34.37-35.87)**
Gained above IOM guidelines (> 20 lbs)	**4.15 (3.97 – 4.34)**	**47.24 (46.91-47.58)**
Obesity III ≥40		
Lost weight (<0 lbs)	**3.34 (2.99 – 3.72)**	**45.65 (44.93-46.38)**
Gained below IOM guidelines (< 11 lbs)	**3.19 (2.87 – 3.53)**	**48.77 (48.11-49.43)**
Gained within IOM guidelines (11-20 lbs)	**3.74 (3.44 – 4.07)**	**51.88 (51.31-52.46)**
Gained above IOM guidelines (> 20 lbs)	**4.51 (4.23 – 4.80)**	**56.40 (55.96-56.84)**

‡ Operative vaginal deliveries, defined as vacuum or forceps
Bolded if significance p<0.0045

Table 13. Adjusted Risk Ratios (95% CI) of BMI weight gain and obstetric interventions

BMI	Weight Gain	Operative Vaginal Delivery‡ RR (95% CI)	Caesarean Delivery§ RR (95% CI)
Class I (30-34.9 kg/m^2)	Lost weight	0.99 (0.89-1.09)	**0.92 (0.90-0.94)**
	< 11 lbs	1.01 (0.94-1.09)	**0.96 (0.94-0.97)**
	11–20 lbs	1	1
	> 20 lbs	1.06 (1.01-1.12)	**1.11 (1.10-1.12)**
Class II (35-39.9 kg/m^2)	Lost weight	1.10 (0.98-1.25)	**0.91 (0.89-0.93)**
	< 11 lbs	1.06 (0.96-1.18)	**0.96 (0.94-0.97)**
	11–20 lbs	1	1
	> 20 lbs	1.11 (1.02-1.20)	**1.10 (1.09-1.11)**
Class III (≥ 40kg/m^2)	Lost weight	0.92 (0.80-1.06)	**0.92 (0.90-0.93)**
	< 11 lbs	0.88 (0.77-1.00)	**0.96 (0.95-0.97)**
	11–20 lbs	1	1
	> 20 lbs	1.10 (0.99-1.22)	**1.06 (1.05-1.07)**

‡ Adjusted for maternal age, maternal education, marital status, parity, medical insurance, and maternal race
§ Adjusted for maternal age, maternal education, marital status, parity, medical insurance, maternal race, and previous caesarean section
Bolded if significance p<0.0045

Table 14. Number Needed to Treat (NNT)/Number Needed to Harm (NNH) obstetric intervention outcomes of women gaining within the IOM guidelines compared to women gaining outside the IOM guidelines by obesity class.

BMI	Operative Vaginal Delivery‡§	Caesarean Delivery
Class I (30-34.9 kg/m^2)	177	12
Class II (35-39.9 kg/m^2)	170	13
Class III (≥ 40 kg/m^2)	728	6

‡ Operative vaginal deliveries, defined as vacuum or forceps
§ Outcomes were clinically insignificant
Note: NNT's are displayed as positive numbers while NNH's are displayed as negative numbers.

4.3.1 Operative Vaginal Delivery (Vacuum or Forceps)

The overall proportion of operative vaginal deliveries in obese women was 2.31% (95% CI: 2.27 – 2.34). Bivariate analyses showed that this relationship was significant between obese classes – as BMI severity increased, there was a decrease in the proportion of operative vaginal deliveries (**Table 10**). As GWG increased, the proportion of operative vaginal deliveries also increased and this was statistically significant (**Table 11**). As BMI severity and GWG increased, there was a decrease in the proportion of operative vaginal deliveries (**Table 12**). Adjusted risk ratios were not found to be statistically significant (**Table 13**). NNT/NNH's were calculated for operative vaginal delivery for each obese class and are presented in **Table 14**.

4.3.2 Caesarean Delivery

Overall, 41.55% of all obese women had a caesarean delivery (the rate of caesarean delivery for obese class I: 37.18% (37.03–37.34); II: 43.35% (43.11–43.59); and III: 52.18% (51.89–52.47)) (**Table 10**). The proportions of caesarean deliveries by amount of gestational weight gain, stratified by obese class can be seen in **Table 10.** Women – in all obese classes – who lost weight during their pregnancy or gained below IOM guidelines had lower proportions of caesareans while those who gained above IOM guidelines had a higher proportion of caesareans. Chi-square tests between GWG and caesarean delivery were found to be significant (p-value <0.004) (**Table 12**).

The patterns of association between gestational weight gain and caesarean delivery were similar for all 3 obesity classes (**Table 13**). Obese women who lost weight during pregnancy (RR (95%CI) I: 0.92 (0.90-0.94); II: 0.91 (0.89-0.93); III: 0.92 (0.90-0.93)) or gained less weight (RR (95%CI) I: 0.96 (0.94-0.97); II: 0.96 (0.94-0.97); III: 0.96 (0.95-0.97)) than IOM GWG recommendations had decreased risk of caesarean delivery compared to women who gained within IOM guidelines (Table 11). While weight gain greater than IOM guidelines were associated with an increased risk of caesarean delivery (RR (95%CI) I: 1.11 (1.10-1.12); II: 1.10 (1.09-1.11); III: 1.06 (1.05-1.07)). The risk ratios of the relationship between GWG and caesarean delivery is visually represented in **Figure 4**.

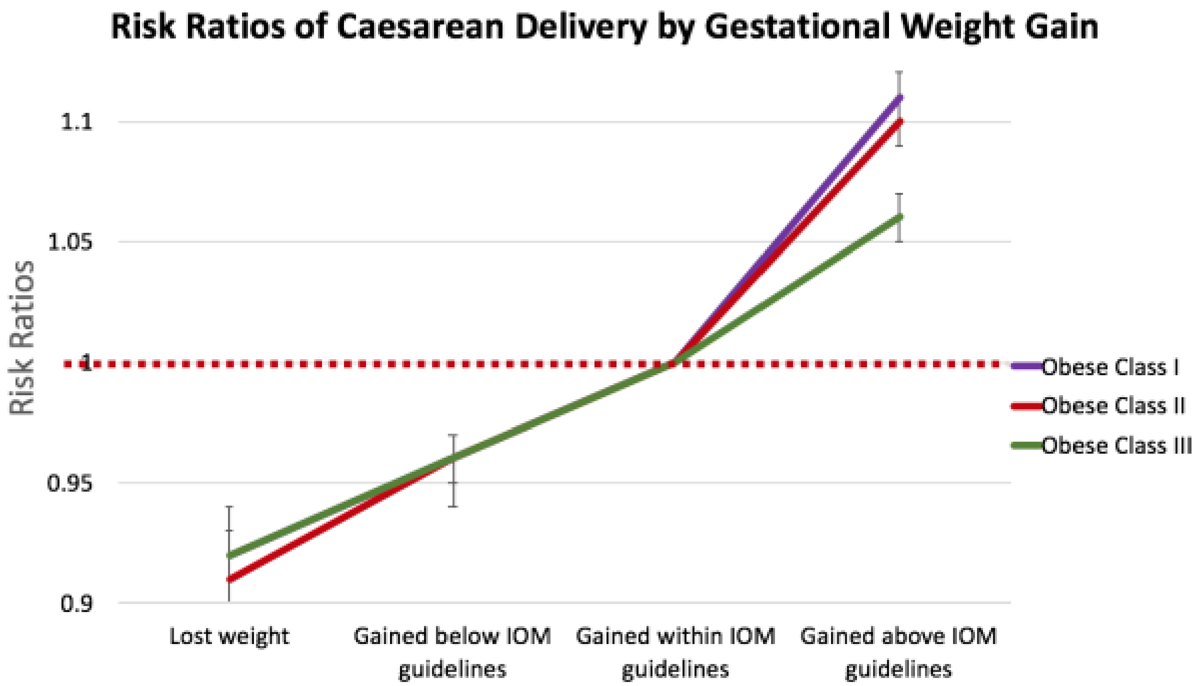

Figure 4. Visual representation of adjusted risk ratios for caesarean delivery by obese class and gestational weight gain.

NNT's and NNH's were calculated and presented in **Table 14**. The number of obese mothers who have to gain within IOM guidelines compared to losing weight, gaining below, or gaining above IOM guidelines for the prevention of one additional woman – on average – to not have a caesarean delivery for class I, II, and III are 12, 13, and 6, respectively.

4.4 Severe Neonatal Morbidity

Severe neonatal morbidity consisted of small-for-gestational age (SGA, defined as below 10^{th} percentile), large-for-gestational age (LGA, defined as above 90^{th} percentile), assisted ventilation (defined > 6 hours), seizures, and suspected neonatal sepsis. Results are presented in **Tables 15 – 19**.

Table 15. Percentages of severe neonatal morbidity for all obese women and their neonates (BMI based on pre-conception weight) stratified by obese class.

Outcome	***All Obese Women (N=642,646)*** **% (95% CI)**	***Class I (BMI 30-34.9 kg/m²)*** **n=355,923 % (95% CI)**	***Class II (BMI 35-39.9 kg/m²)*** **n=169,000 % (95% CI)**	***Class III (BMI ≥40 kg/m²)*** **n=117,173 % (95% CI)**	**Chi-Square P-value***
Small for gestational age†	5.59 (5.52 – 5.65)	5.50 (5.41 – 5.59)	5.66 (5.53 – 5.79)	5.76 (5.60 – 5.92)	0.007
Large for gestational age§	**28.98 (28.87–29.09)**	**27.30 (27.16– 27.45)**	**30.08 (29.86– 30.31)**	**32.46 (32.19– 32.73)**	**<0.001**
Assisted ventilation	**0.52 (0.51 – 0.54)**	**0.45 (0.43 – 0.47)**	**0.50 (0.47 – 0.53)**	**0.76 (0.71 – 0.81)**	**<0.001**
Seizures	0.03 (0.03 – 0.04)	0.03 (0.03 – 0.04)	0.04 (0.03 – 0.05)	0.04 (0.03 – 0.05)	0.752
Suspected neonatal sepsis	**1.48 (1.45 – 1.51)**	**1.41 (1.37 – 1.48)**	**1.47 (1.41 – 1.53)**	**1.71 (1.64 – 1.79)**	**<0.001**

**P* values are from Chi-Square test. Chi Square test p-value denotes comparison between Class I, II, and III.
† Small for gestational age (SGA) defined as birth weight below the 10th percentile
§ Large for gestational age (LGA) defined as birth weight above the 90th percentile
Bolded if significance p<0.0045

Table 16. Percentages of severe neonatal morbidity for all obese women (BMI based on pre-conception weight) stratified by gestational weight gain (GWG) (N=642,646).

Outcome	**Lost Weight (<0 lbs) % (95% CI)**	**Below IOM Guidelines (<11 lbs) % (95% CI)**	**Within IOM Guidelines (11-20 lbs) % (95% CI)**	**Above IOM Guidelines (>20 lbs) % (95% CI)**	**Chi-Square P-value***
Small for gestational age†	**7.89 (7.64 – 8.15)**	**6.45 (6.27 – 6.64)**	**5.77 (5.64 – 5.91)**	**4.85 (4.76 – 4.94)**	**<0.001**
Large for gestational age§	**20.35 (20.00-20.71)**	**22.44 (22.16-22.73)**	**25.93 (25.70-26.15)**	**33.08 (32.92-33.24)**	**<0.001**
Assisted ventilation	**0.56 (0.50 – 0.63)**	**0.47 (0.42 – 0.52)**	**0.48 (0.45 – 0.52)**	**0.54 (0.52 – 0.57)**	**0.003**
Seizures	0.02 (0.01 – 0.03)	0.03 (0.02 – 0.04)	0.03 (0.02 – 0.04)	0.04 (0.03 – 0.05)	0.028
Suspected neonatal sepsis	**1.40 (1.31 – 1.51)**	**1.36 (1.29 – 1.44)**	**1.34 (1.28 – 1.39)**	**1.58 (1.54 – 1.62)**	**<0.001**

GWG, gestational weight gain
**P* values are from Chi-Square test
† Small for gestational age (SGA) defined as birth weight below the 10th percentile
§ Large for gestational age (LGA) defined as birth weight above the 90th percentile
Bolded if significance p<0.0045

Table 17. Percentages of neonatal outcomes by gestational weight gain by pre-pregnancy BMI.

Maternal pre-pregnancy BMI	SGA 10th percentile	LGA 90th percentile	Assisted Ventilation	Neonatal Seizures	Suspected Neonatal Sepsis
Obesity I 30.0-34.9					
Lost weight (<0 lbs)	**8.44 (8.01 – 8.89)**	**17.47 (16.90 – 18.04)**	0.46 (0.38 – 0.56)	0.02 (0.01 – 0.05)	**1.26 (1.11 – 1.42)**
Gained below IOM guidelines (<11 lbs)	**6.97 (6.70 – 7.26)**	**18.46 (18.07 – 18.86)**	0.39 (0.34 – 0.46)	0.03 (0.02 – 0.05)	**1.32 (1.22 – 1.41)**
Gained within IOM guidelines (11-20 lbs)	**5.96 (5.77 – 6.14)**	**22.83 (22.53 – 23.12)**	0.42 (0.38 – 0.46)	0.03 (0.02 – 0.04)	**1.29 (1.22 – 1.37)**
Gained above IOM guidelines (> 20 lbs)	**4.71 (4.60 – 4.81)**	**31.22 (31.03 – 31.42)**	0.48 (0.46 – 0.51)	0.04 (0.03 – 0.05)	**1.57 (1.51 – 1.61)**
Obesity II 35-39.9					
Lost weight (<0 lbs)	**7.85 (7.39 – 8.34)**	**20.26 (19.61 – 20.92)**	0.48 (0.39 – 0.59)	0.02 (0.01 – 0.06)	**1.48 (1.31 – 1.66)**
Gained below IOM guidelines (<11 lbs)	**6.34 (6.02 – 6.69)**	**23.68 (23.16 – 24.22)**	0.40 (0.33 – 0.48)	0.04 (0.02 – 0.07)	**1.33 (1.32 – 1.47)**
Gained within IOM guidelines (11-20 lbs)	**5.58 (5.32 – 5.84)**	**27.37 (26.94 – 27.81)**	0.48 (0.42 – 0.55)	0.03 (0.02 – 0.06)	**1.37 (1.27 – 1.48)**
Gained above IOM guidelines (> 20 lbs)	**4.98 (4.80 – 5.16)**	**35.04 (34.71 – 35.36)**	0.55 (0.51 – 0.60)	0.04 (0.03 – 0.06)	**1.67 (1.59 – 1.75)**
Obesity III ≥40					
Lost weight (<0 lbs)	**7.29 (6.88 – 7.73)**	**23.30 (22.67 – 23.93)**	0.71 (0.61 – 0.83)	0.02 (0.01 – 0.06)	**1.45 (1.30 – 1.62)**
Gained below IOM guidelines (<11 lbs)	**5.57 (5.22 – 5.93)**	**27.82 (27.22 – 28.43)**	0.67 (0.58 – 0.78)	0.03 (0.01 – 0.06)	**1.60 (1.45 – 1.76)**
Gained within IOM guidelines (11-20 lbs)	**5.49 (5.18 – 5.81)**	**32.33 (31.78 – 32.89)**	0.72 (0.63 – 0.81)	0.04 (0.02 – 0.07)	**1.64 (1.51 – 1.78)**
Gained above IOM guidelines (> 20 lbs)	**5.33 (5.08 – 5.58)**	**38.04 (37.60 – 38.48)**	0.81 (0.74 – 0.88)	0.05 (0.03 – 0.08)	**1.93 (1.82 – 2.05)**

Bolded if significance $p<0.0045$

Table 18. Adjusted Risk Ratios (95% CI) of BMI weight gain and neonatal outcomes.

BMI	Weight Gain	SGA (10th percentile) § RR (95% CI)	LGA (90th percentile) † RR (95% CI)	Assisted Ventilation‡ RR (95% CI)	Seizures‡ RR (95% CI)	Suspected Sepsis‡ RR (95% CI)
Class I (30-34.9 kg/m^2)	Lost weight	**1.34 (1.26-1.43)**	**0.80 (0.77-0.83)**	1.14 (0.90-1.45)	0.61 (0.18-2.06)	0.98 (0.85-1.13)
	< 11 lbs	**1.17 (1.11-1.23)**	**0.81 (0.79-0.83)**	0.95 (0.78-1.15)	1.14 (0.54-2.38)	1.05 (0.94-1.17)
	11–20 lbs	1	1	1	1	1
	> 20 lbs	**0.75 (0.72-0.78)**	**1.40 (1.38-1.42)**	1.18 (1.04-1.34)	1.30 (0.79-2.14)	1.08 (1.01-1.16)
Class II (35-39.9 kg/m^2)	Lost weight	**1.38 (1.28-1.49)**	**0.76 (0.73-0.78)**	0.95 (0.72-1.24)	0.82 (0.27-2.52)	1.13 (0.97-1.32)
	< 11 lbs	**1.16 (1.08-1.25)**	**0.86 (0.84-0.88)**	0.85 (0.67-1.8)	1.00 (0.42-2.42)	1.01 (0.88-1.15)
	11–20 lbs	1	1	1	1	1
	> 20 lbs	**0.84 (0.79-0.89)**	**1.32 (1.30-1.35)**	1.13 (0.95-1.33)	1.14 (0.60-2.18)	1.12 (1.02-1.24)
Class III (≥ 40 kg/m^2)	Lost weight	**1.35 (1.24-1.46)**	**0.73 (0.70-0.75)**	1.00 (0.81-1.24)	0.24 (0.05-1.08)	0.93 (0.80-1.08)
	< 11 lbs	1.05 (0.96-1.15)	**0.85 (0.83-0.87)**	0.94 (0.77-1.16)	0.52 (0.19-1.47)	1.00 (0.87-1.15)
	11–20 lbs	1	1	1	1	1
	> 20 lbs	**0.90 (0.84-0.97)**	**1.22 (1.20-1.25)**	1.07 (0.90-1.27)	0.95 (0.48-1.88)	1.11 (0.99-1.24)

‡ Adjusted for maternal age, maternal education, marital status, parity, medical insurance, maternal race, infant sex, and birthweight
§ Adjusted for maternal age, maternal education, marital status, parity, medical insurance, maternal race, pre-pregnancy diabetes, and gestational diabetes, and smoking
† Adjusted for maternal age, maternal education, marital status, parity, medical insurance, maternal race, pre-pregnancy diabetes, and gestational diabetes
Bolded if significance p<0.0045

Table 19. Number Needed to Treat (NNT)/Number Needed to Harm (NNH) of adverse neonatal outcomes of women gaining within IOM guidelines compared to women gaining outside the IOM guidelines by obesity class.

BMI	SGA 10th percentile†	LGA 90th percentile§	Assisted Ventilation‡	Neonatal Seizures‡	Suspected Neonatal Sepsis‡
Class I (30-34.9 kg/m^2)	-149	10	1493	10316	461
Class II (35-39.9 kg/m^2)	772	14	2736	17136	486
Class III (≥ 40 kg/m^2)	244	274	2386	8786	754

† Small for gestational age (SGA) defined as birth weight below the 10th percentile
§ Large for gestational age (LGA) defined as birth weight above the 90th percentile
‡ Outcomes were not clinically meaningful
Note: NNT’s are displayed as positive numbers while NNH’s are displayed as negative numbers.

4.4.1 Small for Gestational Age (SGA, 10th percentile)

The overall proportion of SGA 10th percentile was 5.59% (95% CI: 5.51 – 5.65). There was no statistical significant difference between obese classes and the proportion of SGA births (**Table 15**). Analyses of the overall cohort and SGA births and GWG categories were statistically significant; as GWG increased, the proportion of SGA births decreased (**Table 16**). Bivariate analyses of SGA and amount of GWG showed that the proportion of obese women who gained within IOM guidelines for Class I, II, and III were 5.96 (5.77 – 6.14), 5.58 (5.32 – 5.84), and 5.49 (5.18 – 5.81). Women in all obese classes had a higher proportion of SGA neonates if they lost weight or gained below IOM guidelines. While those who gained above IOM guidelines had lower proportions of SGA infants. These were all found to be significant with chi-square tests ($p<0.001$) (**Table 17**).

The pattern of association was the same between gestational weight gain and small for gestational age between all 3 classes of obesity. Obese women who lost weight during pregnancy (RR (95%CI) I: 1.34 (1.26-1.43); II: 1.38 (1.28-1.49); III: 1.35 (1.24-1.46)) or gained less weight (RR (95%CI) I: 1.17 (1.11-1.23); II: 1.16 (1.08-1.25); III: 1.05 (0.96-1.15)) than IOM GWG recommendations had increased risk of SGA (birthweight < 10th percentile) babies compared to women who gained within IOM guidelines (**Table 18**). While weight gain greater than IOM guidelines were associated with an decreased risk of SGA (10th percentile) infants (RR (95%CI) I: 0.75 (072-0.78); II: 0.84 (0.79-0.89); III: 0.90 (0.84-0.97)). On average, 149 class I obese mothers would have to gain within IOM guidelines during pregnancy (NNH) for one additional mother to not have a SGA neonate (**Table 19**). The number of obese class II and III mothers who have to gain within IOM guidelines compared to losing weight, gaining below, or gaining above

IOM guidelines for the prevention of one additional woman – on average – to not have a SGA neonate are 772 and 244. The risk ratios of the relationship between GWG and SGA is visually represented in **Figure 5**.

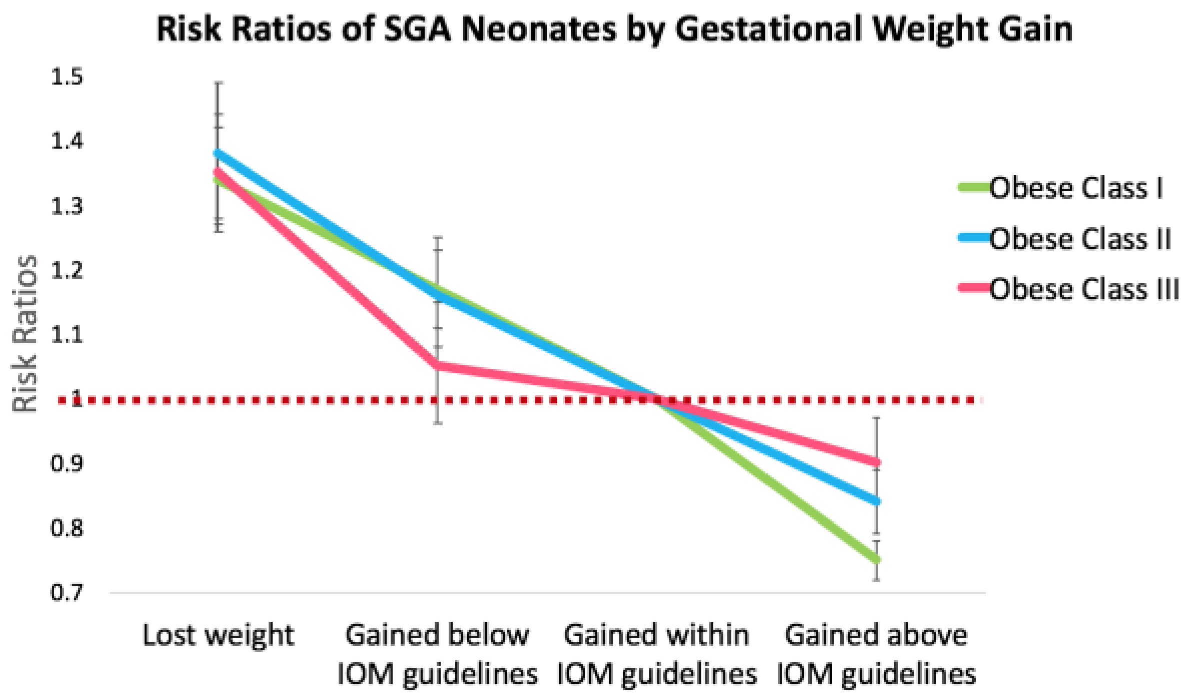

Figure 5. Visual representation of adjusted risk ratios for small for gestational age (10th percentile) by obese class and gestational weight gain.

4.4.2 Large for Gestational Age (LGA, 90th percentile)

Overall, the proportion of infants who were large for gestational age at the 90th percentile was 28.98% (95 CI: 28.87 – 29.09). As BMI severity increased, the proportion of LGA 90th percentile also increased (p<0.001) (**Table 15**). The chi-square tests between LGA births and GWG was found to be significant (p<0.001); as GWG increased, the proportion of LGA births also increased (**Table 16**). The proportion of women who gained within IOM guidelines and had a LGA infant was 28.83% (22.53 – 23.12) for class I, 27.37 (26.94 – 27.81) for class II, and

32.33 (31.78 – 32.89) for class III (**Table 17**). Women who lost weight or gained below IOM GWG guidelines had lower proportions of LGA infants while those who gained above IOM guidelines had higher proportions. This association was seen regardless of obesity class. While those who gained above IOM guidelines had a higher proportion of LGA births. Chi-square tests between GWG and LGA was found to be significant (p-value <0.004).

The patterns of association between gestational weight gain and LGA births were similar for all 3 obesity classes (**Table 18**). Obese women who lost weight during pregnancy (RR (95%CI) I: 0.80 (0.77-0.83); II: 0.76 (0.73-0.78); III: 0.73 (0.70-0.75)) or gained less weight (RR (95%CI) I: 0.81 (0.79-0.83); II: 0.86 (0.84-0.88); III: 0.85 (0.83-0.87)) than IOM GWG recommendations had decreased risk of LGA births compared to women who gained within IOM guidelines (Table 16). While weight gain greater than IOM guidelines were associated with an increased risk of LGA births (RR (95%CI) I: 1.40 (1.38-1.42); II: 1.32 (1.30-1.35); III: 1.22 (1.20-1.25)).
On average, 9.57 class I obese mothers would have to gain within IOM guidelines during pregnancy (NNT) for the prevention of one additional mother – on average – having a LGA neonate (**Table 19**). The number of obese class II and III mothers who have to gain within IOM guidelines compared to losing weight, gaining below, or gaining above IOM guidelines for the prevention of one additional woman – on average – to not have a LGA neonate are higher: 13.92 and 273.85, respectively. The risk ratios of the relationship between GWG and LGA is visually represented in **Figure 6**.

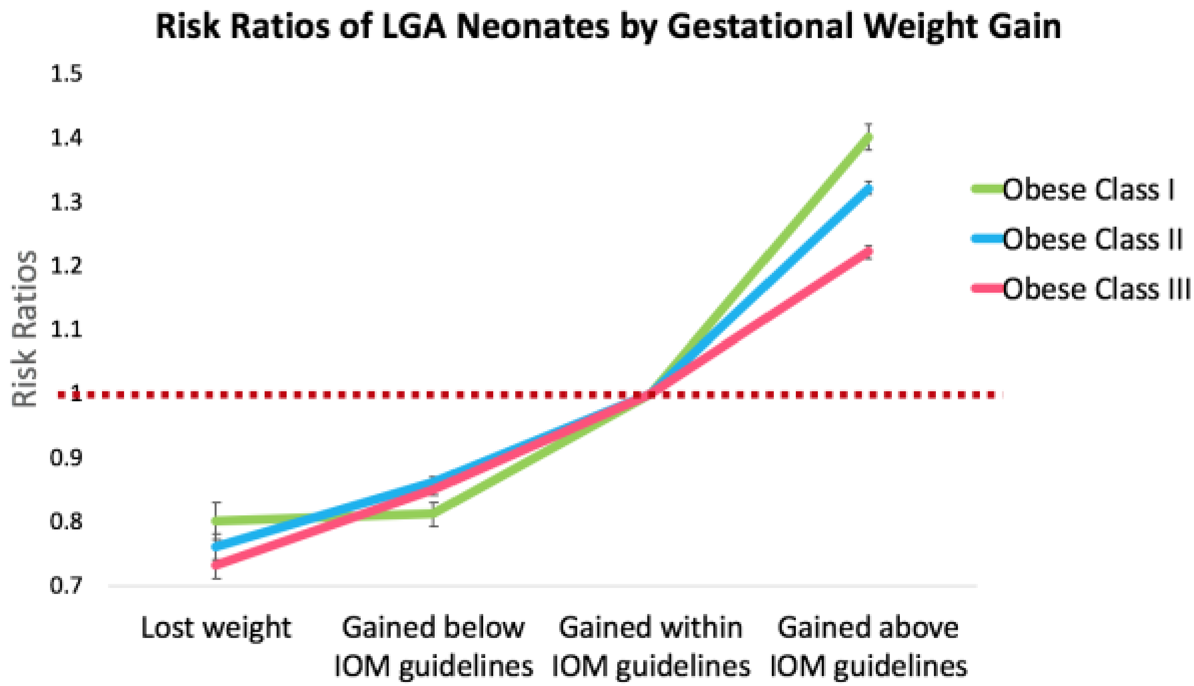

Figure 6. Visual representation of adjusted risk ratios for large for gestational age (90th percentile) by obese class and gestational weight gain.

4.4.3 Assisted Ventilation

Overall, the proportion of infants of obese mothers who needed assisted ventilation was 0.52% (95% CI: 0.51 – 0.54) (**Table 15**). As BMI severity increased, the proportion of neonates needing assisted ventilation increased; assisted ventilation statistically differed between obese classes (p<0.001). However, the proportion of neonates needing assisted ventilation was not found to statistically differ between GWG categories (**Table 16**). The proportion of women who gained within IOM GWG and had a neonate with assisted ventilation for class I, II, and III were 0.42 (0.38 – 0.46), 0.48 (0.42 – 0.55), and 0.72 (0.63 – 0.81) (**Table 17**). For all 3 obese classes, those who lost weight (<0 lbs), gained below IOM guidelines, or gained above IOM guidelines had the same proportion of neonates needing assisted ventilation as the proportion of women who gained within IOM guidelines. Chi-square tests were not significant between GWG and assisted ventilation. Adjusted risk were not statistically significant (**Table 18**). NNT/NNH's were calculated for assisted ventilation for each obese class and are presented in **Table 19**. NNT/NNH's were not found to be clinically significant.

4.4.4 Neonatal Seizures

Overall, the proportion of infants of obese mothers who had neonatal seizures was 0.03% (95% CI: 0.03 – 0.04) (**Table 15**). The relationship between infants with neonatal seizures did not statistically differ between obese classes or by GWG category (**Table 16**). The proportion of women who gained within IOM GWG and had a neonate with seizures for class I, II, and III were 0.03 (0.02 – 0.04), 0.03 (0.02 – 0.04), and 0.04 (0.02 – 0.07) (**Table 17**). For all 3 obese classes, those who lost weight (<0 lbs), gained below IOM guidelines, or gained above IOM guidelines had the same proportion of neonates needing assisted ventilation as the proportion of women who gained within IOM guidelines. Adjusted risk were not statistically significant (**Table 18**). NNT/NNH's were calculated for neonatal seizures for each obese class and are presented in **Table 19**. NNT/NNH's were not found to be clinically significant.

4.4.5 Suspected Neonatal Sepsis

Overall, the proportion of infants of obese mothers who were suspected of neonatal sepsis was 1.48% (95% CI: 1.45 – 1.51) (**Table 15**). As BMI severity increased and as GWG increased, the proportion of neonates with suspected neonatal sepsis also increased (p<0.001) (**Table 15 and 16**). The proportion of women who gained within IOM GWG and had a neonate with suspected sepsis for class I, II, and III were 1.29 (1.22 – 1.37), 1.37 (1.27 – 1.48), and 1.64 (1.51 – 1.78), respectively. In obese class I, the proportion of women who lost weight and had a neonate with suspected sepsis was lower than those who gained within IOM guidelines while the proportion of women in class II and III with neonates with suspected sepsis who lost weight had higher proportions. Women in all obese classes who gained below IOM and gained above IOM had higher proportions of infants with suspected sepsis. The differences between GWG categories and the proportion of suspected neonatal sepsis were statistically different ($p<0.001$) but did not appear to be clinically significant (**Table 16**). Adjusted risk were not statistically significant (**Table 18**). NNT/NNH's were calculated for suspected neonatal sepsis for each obese class and are presented in **Table 19**. NNT/NNH's were not found to be clinically significant.

Chapter Five: **DISCUSSION**

5.1 Key findings

Most women who were obese did not gain within the IOM guidelines for GWG. Obese women who lost weight during pregnancy or gained below the IOM recommendations were at a significantly decreased risk for caesarean delivery large-for-gestational age (LGA) births-but had a significantly increased risk of small-for-gestational age (SGA) births compared to women who had GWG within IOM guidelines. Obese women who gained above IOM guidelines were at an increased risk for caesarean delivery and LGA births but are at a decreased risk for SGA births. The observed pattern of association was the same between all 3 obese classes indicating evidence for a single GWG recommendation for all 3 classes of obesity.

5.2 Amount of Gestational Weight Gain by Obese Women During Pregnancy

The results of the present study found that most obese women (class I, II, and III) had gestational weight gain (GWG) above the IOM guidelines and only one in five obese women gained within the IOM guidelines. These results are comparable to the findings of other studies (10, 14, 67, 68). Furthermore, 15% of obese class III women lost weight during pregnancy, consistent with other studies (10, 14, 67, 69). Of concern, 62% of obese women in the present study gained above the IOM recommendations, this is important as excessive GWG has repeatedly been shown to be associated with higher risk of caesarean delivery, preeclampsia, LGA births, and many other adverse outcomes (45, 70-74).

5.3 Risks of Gestational Weight Loss or Gestational Weight Gain Below the Institute of Medicine Guidelines

The results of this large population-based study found that obese women – of all classes – who lost weight during pregnancy or gained below the IOM guidelines are at a decreased risk of caesarean delivery and LGA age births and at no significant increased risk for ICU admission, 3rd or 4th degree perineal lacerations, eclampsia, unplanned hysterectomies, operative vaginal deliveries, neonates with seizures, suspected neonatal sepsis, and neonates needing assisted ventilation >6 hours compared to obese women who had GWG within IOM guidelines. However, obese women (class I, II, and III) who lost weight during pregnancy or gained below the IOM guidelines are at an increased risk for small-for-gestational age (SGA) births compared to women who had GWG within the IOM guidelines. These results are concordant with previous studies' findings of the decreased odds of caesarean deliveries and LGA births, and increased odds of SGA births to women who gained below the IOM recommendations (10, 11, 46, 47).

Several studies have found results that differ from this study, that obese women who had GWG below the IOM recommendations were not adversely associated with maternal and neonatal outcomes (10, 11, 67, 72, 75, 76). In 2015, Bogaerts et al. examined the association between weight loss during pregnancy for 18,053 obese women with maternal and neonatal outcomes (75). Obese class I women who had low GWG had decreased odds of gestational hypertension (OR for weight loss ≥5 kg: 0.31, 95% CI: 0.11 – 0.84; OR for weight loss between 0-5kg: 0.46, 95% CI: 0.21 – 0.99; OR for low GWG (0-<5kg): 0.71, 95% CI: 0.54 – 0.93)(75). Obese class II women had lower odds of caesarean delivery for GWG below the IOM guidelines (OR for weight loss more than 5 kg: 0.24, 95% CI: 0.07 – 0.78; OR for weight loss between 0-5kg: 0.50, 95% CI: 0.26 – 0.97; OR for low GWG (0-<5kg): 0.55, 95% CI: 0.38 – 0.79) and obese class III women had lower odds of delivering macrosomic infants (OR for weight loss more than 5 kg: 0.15, 95% CI: 0.05 – 0.49; OR for weight loss between 0-5kg: 0.37, 95% CI: 0.15 – 0.90; OR for low GWG (0-<5kg): 0.67, 95% CI: 0.43 – 1.02) (75). Another study in 2016 by Cox Bauer et al. that examined maternal and neonatal outcomes in 10,734 obese women who lost weight during pregnancy found no significant differences in preterm birth, caesarean delivery, gestational hypertension/preeclampsia, gestational diabetes, and macrosomic babies between women who lost weight during pregnancy and those who gained within the IOM guidelines (76). However, obese women in the Cox Bauer study who lost weight during pregnancy were found to have increased odds for low birth weight babies (<2500 g) (OR 2.03; 95% CI: 1.06 – 3.89) (76). Study findings such as those from the present study, Cox Bauer et al., Bogaerts et al., and others suggest that a re-evaluation of the current IOM guidelines is needed.

5.4 Risks of Gestational Weight Gain Above Institute of Medicine Guidelines

Obese women – of all classes – who gained above the IOM guidelines are at an increased risk for caesarean delivery, LGA births, and at no significant increased risk for ICU admission, 3^{rd} or 4^{th} degree perineal lacerations, eclampsia, unplanned hysterectomies, operative vaginal deliveries, neonates with seizures, suspected neonatal sepsis, and neonates needing assisted ventilation >6 hours compared to women who gain within the IOM guidelines. Conversely, obese women (class I, II, and III) gain above the IOM guidelines are at a decreased risk for SGA births compared to women who had GWG within the IOM guidelines. These findings were similar to previous studies examining excessive GWG (10, 11, 54, 72).

Women who had GWG above the IOM recommendations are more likely to have gestational hypertension or preeclampsia during pregnancy (OR 2.35; 95% CI: 1.61 – 3.43) and macrosomic babies (OR 3.94; 95% CI: 1.58 – 9.80) as found by a 2016 cross-sectional U.S. study (76). In 2011, a longitudinal study by Fraser et al. investigated the long-term effects of excess gestational weight gain on maternal health (77). Using data from the Avon Longitudinal Study of Parents and Children (ALSPAC) which is a prospective population based birth cohort study from Avon, United Kingdom 14,541 women were recruited between 1991 to 1992 (77). Researchers wanted to examine the associations of pre-pregnancy BMI and GWG 16 years after pregnancy and they found that women who had GWG above the 2009 IOM guidelines had a greater mean BMI, waist circumference, systolic blood pressure, and diastolic blood pressure (77). Fraser et al. found that women with GWG above the IOM guidelines had greater odds of maternal obesity later in life (OR of overweight/obesity 16 years after pregnancy: 3.58; 95% CI: 2.61 – 4.93) (77).

There have been a few longitudinal studies exploring obese mothers exceeding the IOM guidelines and the effects on offspring. Excessive gestational weight gain during pregnancy has been found to be associated with adverse outcomes for the offspring (78-80). Kaar et al. found that in 313 mother/child pairs, obese mothers who gained above the IOM guidelines had offspring (mean = 10.4 years old) with increased BMI, increased waist circumference, increased subcutaneous adipose tissue, and increased visceral adipose tissue (80). A 2015 systematic review by Pérez-Morales et al. concluded that mothers with GWG above the IOM guidelines had children with greater adiposity, increased childhood obesity, and increased child BMI compared to children of the same age whose mothers gained within IOM guidelines.

In addition to the risks of SGA and LGA births, the present study found that obese women had far higher proportions of caesarean and LGA births and lower proportions of SGA births than non-obese women when stratified by GWG. It would be expected that 10% of births would be SGA in the 10^{th} percentile and that 10% would be LGA 90^{th} percentile. However, findings of the present study do not correlate with this information. Although non-obese women followed these expected proportions, in the present study found that obese women had far higher proportions.

5.5 A Singular Gestational Weight Gain Recommendation for All Obese Women

Overall, the pattern of association for all outcomes in the present study was not different between the obese classes signifying that it is possible to have a singular GWG recommendation. This finding is in direct contrast to studies calling for GWG guidelines tailored to obesity severity. Although a Swedish study by Blomberg (2011) found risks of operative vaginal deliveries, caesarean deliveries, SGA, and LGA births similar to the present study, the author recommended that GWG guidelines for obese women class II and III be different than class I women (10). Blomberg stratified by obese class (defined as class I: 30-34.9 kg/m^2, class II: 35-39.9 kg/m^2, class III: $\geq$40 kg/m^2) and gestational weight gain which were defined as below 0 kg (0 lbs), 0-4.9kg (<11 lbs), 5-9kg (11-20 lbs), and more than 9 kg (>20 lbs) similar to what was done in the present study and had 32, 991 obese class I, 10,068 obese class II, and 3536 obese class III women (10). Furthermore, the author stated that it was reasonably safe for obese women in classes II and III to lose weight during their pregnancy (10). Blomberg's study used Sweden's large birth registry database of births from 1993 to 2008 to conduct her study; however, many cells in her analyses had numbers less than 30 after stratifying on gestational weight gain and obesity severity (10). Given that the present study had similar results to Blomberg yet endorses that a single GWG recommendation is possible between the 3 obese classes, the difference in recommendations could be due to Blomberg not examining the patterns of association between the 3 obese classes but instead looked at individual outcomes of different GWG for each BMI category.

A 2013 study by Oza-Frank and Keim using data from a large prospective study in the U.S. from 1959 – 1965 found that obese class I women were at increased risk of SGA births (OR 2.41; 95% CI: 1.49 – 3.87) but not women who were class II/III obese (OR 1.82; 95% CI: 0.91 – 3.64) (11). The study by Oza-Frank and Keim found statistically significant associations between GWG (defined as inadequate, <5kg (<l1 lbs) compared to excessive, >9 kg (>20 lbs)) and preeclampsia (OR 0.43, 95% CI: 0.25-0.73), gestational hypertension (OR 0.55, 95% CI: 0.36-0.85), and LGA births (OR 0.40, 95% CI: 0.30-0.53) for class I women and found no association for class II/III obese women leading to their conclusion for obese-class specific GWG recommendations (11). Limitations of this study is the fact that it relies on older data from 50 years ago and since that time there have been major changes in the population's characteristics and more women than ever are entering pregnancy obese (2) meaning that it is possible that this data may no longer be valid.

A systematic review by Faucher and Barger in 2015 synthesized information from 740,000 obese women from 10 studies from 4 different countries, and concluded that GWG guidelines may need modification based on the severity of obesity (69). Of the studies included, Faucher and Barger found that obesity severity significantly modified associations between GWG and LGA births, SGA births, caesarean deliveries (69). Previous studies have shown that GWG and maternal and neonatal outcomes were modified by obesity severity and that IOM recommendations needed to be stratified by obesity class. However, the overall the pattern of association was the same between all 3 obese classes in these previous studies. The present study contrasts the findings of multiple studies calling for obese class specific GWG guideline recommendations (13, 14, 69, 75, 81, 82).

5.6 Reconsideration of IOM GWG Guidelines for Obese Women – Should Women Gain Less than 11-20 Pounds?

Adverse maternal and neonatal outcomes in the present study occur less frequently when gestational weight gain is lower than current IOM recommendations for obese women. As previously mentioned, obese women – for all classes – who lost weight or gained below the IOM recommendations had a decreased risk of caesarean delivery and LGA birth and at no increased risk for ICU admission, 3rd or 4th degree perineal laceration, eclampsia, unplanned hysterectomy, operative vaginal delivery, neonate requiring assisted ventilation, neonatal seizures, or suspected neonatal sepsis. However, obese women who gained below the IOM guidelines were at increased risk of SGA births. This begs the question whether the current 2009 IOM GWG guidelines are sufficient and if obese women should have lower GWG recommendations. A 2007 Swedish population study by Cedergren explored optimal GWG for each pre-pregnancy BMI based on risk estimates of adverse maternal and neonatal outcomes (83). Studying births between 1994 to 2004, Cedergren grouped women into 21 total weight gain classes from 0-44 lbs and compared individuals in each weight gain grouping to other weight gain classes within each obese class with regards to the different maternal and fetal outcomes (preeclampsia, eclampsia, postpartum haemorrhage, shoulder dystocia, fetal respiratory disorders, fetal bacterial sepsis, etc.) (83). The optimal weight gain recommendation were based on odds ratios of each outcome within the obesity classes that were below the null value of 1 (83). The optimal GWG for obese individuals was recommended to be less than 13 lbs (83).

A study by Kominiarek et al. (2013) found that weight loss was associated with decreased odds of caesarean sections for class I women (OR 0.21, 95%CI: 0.11−0.42), decreased odds of delivering LGA infants in class II and III women (class II OR 0.5, 95% CI: 0.3 – 0.9; class III OR 0.48, 95% CI: 0.3 – 0.8), and increased odds of delivering SGA infants (class I OR 1.8, 95% CI: 1.3−2.5; class II OR 2.2, 95% CI: 1.5−3.2; class III OR 1.7, 95% CI: 1.1−2.6) (84). Kominiarek et al. concluded that although optimal outcomes were associated with lower GWG, further study was required before a change of the current IOM guidelines (84).

This present study provides evidence for – in addition to the current literature – to support a reconsideration in the 2009 IOM GWG recommendation of 11-20 pounds for obese women as adverse maternal and neonatal outcomes in the present study occur less frequently when gestational weight gain is lower than current IOM recommendations for obese women. (6, 11, 12, 25, 26, 46, 47, 54, 67, 72, 74-76, 82, 83, 85-89).

5.7 Adherence to Gestational Weight Gain Guidelines is Low

The present study found that approximately 25% of obese women gained weight within IOM guidelines. Low adherence to these GWG guidelines are not new. Many studies have found similar rates of GWG within the IOM guidelines (10, 14, 69, 72, 73, 90). Results of the present study found that most obese women – in all classes – exceeded the IOM GWG guidelines where up to 62% of obese women gained weight above the IOM recommendations. A reason for this lack of adherence in GWG guidelines could be because of obese women's lack of accurate knowledge of their BMI and correct GWG recommendations may explain why many women are exceeding their GWG recommendations.

In 2008, a study examined the association of misperceived BMI and excessive weight gain (91). Researchers found that the odds of excessive GWG in overweight/obese BMI under-assessors was 7.6 times the odds of excessive GWG compared to women who accurately assessed their BMI (91). A study from New Zealand in 2016 investigated pregnant women's knowledge of their BMI and their knowledge of gestational weight gain guidelines (92). Of the 644 women in the study, 66% correctly identified their BMI but only 31% correctly identified their correct GWG recommendation, and women who were overweight or obese were more likely to overestimate their GWG recommendation (92). Similar results to the New Zealand study were found in a 2016 Australian study examining pregnant women's awareness of the IOM GWG guidelines (93). Lack of awareness of IOM GWG recommendations was not limited to Australia and New Zealand. The lack of adherence to the appropriate IOM GWG recommendations was also examined by researchers in 2 hospitals in New York (94). Researchers found that overweight and obese pregnant women were less likely to be informed about GWG recommendations and almost 50% of those were given recommendations inconsistent with the IOM guidelines (94). A 2016 systematic review was published that evaluated qualitative studies that investigated women's perceptions, understanding, and their values regarding their GWG (95). Findings from this systematic review suggest that although women are highly motivated in their pregnancies to change behaviours to improve the health of their infants, many women do not recognize the association between excessive GWG and adverse maternal and neonatal outcomes (95).

A systematic review was conducted in 2015 investigating the psychological factors that precede excessive GWG (96). A number of factors were found to be associated with excessive GWG such as weight concerns, barriers to healthy eating, negative attitudes toward weight, knowledge about weight gain, body image dissatisfaction, inaccuracy of perceived body weight, target weight gain greater than recommended, depression, and emotional instability (96). Additionally, obese women identified barriers to achieving GWG within clinical guidelines such as feelings of guilt, shame, and humiliation when discussing weight or GWG matters with healthcare professionals, fear of judgment or cruel treatment due to past insensitive remarks by healthcare professionals, lack of clear and consistent messaging about healthy weight gain during pregnancy, and many other barriers (physical, social, socioeconomic) (95). A 2017 qualitative study by Nikolopoulos et al. explored women's perception of GWG discussions with their health care providers during pregnancy (97). Five focus groups were conducted across Alberta and results showed that GWG is important to women for their health and that of their baby but that discussions about GWG with their healthcare provider are not happening (97). Women from this study desire the opportunity to be able to discuss GWG issues, that all women should have these GWG discussions with their doctors/healthcare providers, and that their healthcare providers should be the ones to initiate these conversations by asking women how they feel about discussing their weight (97). These studies highlight the need for GWG counselling by healthcare professionals that is clear, sensitive, and provides mitigating resources for women who may be disadvantaged.

5.8 Solutions to Try and Improve the Rate of Adequate GWG

To come up with solutions to try and increase adequate GWG, researchers need to figure out the differences between women who gain adequate GWG compared to women who gain inadequate GWG. A study was done in 2015 by Deputy et al. exploring the prevalence of GWG and examined the demographic, behavioural, psychosocial, and medical characteristics associated with women who gain adequate GWG compared to those who gain inadequate GWG (68). Using cross-sectional data from 2010-2011 in 28 states in the United States, the researchers estimated that 20.9% of women gained inadequate weight, 32% gained adequate weight, and 47.2% gained weight during pregnancy excessively (68). Most characteristics associated with weight gain adequacy were demographic, such as racial or ethnic minority status and education, and varied by pre-pregnancy BMI and the only behavioral characteristic that was found significant was smoking cessation which was associated with excessive gain among normal weight and obese women (68).

A possible solution for women to gain within the IOM guidelines and be healthy during pregnancy could be based on a 2012 randomized control trial by Price et al. investigating the effect of exercising in pregnancy on maternal, obstetric, and neonatal infants(98). Patients were women with BMI <39 kg/m^2, enrolled at 12-14 weeks' gestation and randomized to either a sedentary group or a group that had to perform aerobic exercise for 45-60 minutes 4 days a week until 36 weeks' gestation (98). Researchers had 31 subjects in each group and found that women who were active – compared to sedentary women – delivered comparable sized babies ($p=0.87$), had fewer caesarean deliveries ($p<0.01$), and recovered faster postpartum ($p<0.05$) (98). However, most of the women in the study by Price et al. were mostly white and not overweight or obese. A study by Wang et al. in 2017 focused on overweight and obese women in a randomized trial of exercise to prevent gestational diabetes mellitus and improve pregnancy outcomes (99). Evidence from this study and from other studies suggest that exercise in pregnancy is only effective if the exercise intervention is started <15 weeks' gestation otherwise the intervention would not work (99). Three hundred overweight and obese women at 10 weeks' gestation were recruited and placed in either an exercise or control group where the control group continued normal daily activities and the exercise group were asked to exercise 3 times a week for 30 min per session via a cycling program (99). Results from the randomized trial by Wang et al. found that the exercise group had lower incidence of gestational diabetes (22% vs 40%, $p<0.001$), and had significantly less gestational weight gain by 25 weeks' gestation (4.08 kg±3.02 vs 5.98kg±2.58, $p<0.001$) and by the end of pregnancy(8.38 kg±3.65 vs 10.47kg±3.33, $p<0.001$) (99). However, the babies born to women in the exercise group had significantly lower birthweights ($p=0.049$) (99). From the studies by Price et al. and Wang et al., it seems promising that moderate exercise during pregnancy could aid women in gaining adequate GWG but there are not many other randomized trials exploring this intervention.

A non-invasive solution to excessive GWG that was proposed by some researchers in 2016 was health coaching (100). Skouteris et al. tried to evaluate the efficacy of a health coaching intervention that tried to facilitate healthy behaviours such as healthy eating and being physically active compared to a group that received education on excessive GWG alone (100). Two-hundred and sixty-one pregnant women were enrolled at 18 weeks' gestation and were randomized into either the health coaching group or the education group (100). The health coaching intervention comprised of an individual one-on-one session and educational group sessions (total time was 6 hours over the pregnancy) (100). The education group received the usual standard prenatal care in Australia that involved assessment of pre-pregnancy BMI and BMI-specific GWG recommendations (100). Researchers found that there was no statistical difference in the amount of GWG between the women who received health coaching and the women who received standard pre-pregnancy BMI-specific GWG recommendations (100). Although, as previously mentioned studies have shown that obese pregnant women from Australia and New Zealand were less likely to be informed about GWG recommendations and almost 50% of those were given recommendations inconsistent with the IOM guidelines (93, 94).

A study by Shulman and Kottke (2016) assessed whether knowledge of GWG recommendations in pregnancy was associated with actual weight gain among women (101). Utilizing a cross-sectional study with data chart linkage, researchers enrolled participants from an urban health centre and tested women's knowledge of how much weight should be gained during pregnancy against the 2009 IOM guidelines. Although Shulman and Kottke's study sample had low knowledge of GWG guidelines, accurate knowledge of the gestational weight gain recommendations was associated with appropriate weight gain in pregnancy (p=0.02) (101). Additionally, women who had accurate knowledge of their own pre-pregnancy BMI (p=0.004) and who could correctly identified their pre-pregnancy weight category (p=0.005) were associated with appropriate GWG (101).

The lack of accurate knowledge women about their BMI and GWG recommendations based on that BMI as described by Bookari et al., Wrotniak et al., and Shulman and Kottke highlights that it is possible that health professionals might also need education (93, 94, 101). Considering that

GWG gain counselling of patients would not be an intensive intervention and that Shulman and Kottke's study make a case for how women's accurate knowledge of GWG might translate to adequate GWG, more needs to be done to improve the rate of adequate GWG in obese women. A qualitative study on clinicians' gestational weight gain counselling and tracking by Oken et al. tried to investigate strategies that would encourage obstetric clinicians to counsel their patients regarding GWG (102). Clinicians in this study indicated that an electronic medical record (EMR) based support tool would help remind them to counsel their patient about excessive weight gain and would help improve the frequency and accuracy of GWG tracking (102). Future directions of study could be ways to increase GWG counselling in health care practitioners as well as increase knowledge of BMI and GWG recommendations based on BMI.

5.9 Strengths and Limitations

5.9.1 Strengths

This study has both strengths and limitations. The present study used a large population-level dataset that is nationally representative of the United States and, therefore, is generalizable. As birth certificate data covers almost 100% of all births that occur within the United States, non-response bias was not a problem of the current study and supplements the generalizability of the findings. Due to the large sample size, this present study also had many cases even when stratified by multiple factors and outcomes were assessed beyond what was included in the IOM guidelines. The development of the IOM recommendations for weight gain were based on available data from Class I obese women (based on their pre-pregnancy BMI) for the following outcomes: small for gestational age (SGA), large for gestational age (LGA), caesarean delivery, preterm delivery, and postpartum weight retention (8). Further, this is the first study that analyzed all live births of the United States to obese pregnant women rather than an individual state. The present study also used relative risks (RR) compared to odds ratios (OR) which are not only easier to interpret but overcomes the problem of OR that overestimates the risk of common outcomes (103). Many studies using OR state that they found significance but in some cases this was weak. In the study by Kapadia et al. (2015), researchers found that the odds of preterm birth in women who gained below the IOM guidelines to be OR 1.46, 95% CI: 1.07 – 2.00 but it is possible that this significant finding is not significant at all due to the overestimation of risks by OR (47). This present study is the first to quantify the possible effectiveness of GWG counselling through the NNTs of maternal and neonatal outcomes.

5.9.2 Limitations

Limitations of this present include: that the rate of GWG throughout the pregnancy could not be assessed, certain variables could not be controlled for in the logistic regression models, possible misclassification bias, and that the results of this study are limited to term, singleton pregnancies.

The present study did not have information to the rate of GWG in the US birth certificate database. The rate of GWG throughout the pregnancy is important as GWG during the first trimester is different in comparison to GWG in the second/third trimester (104-108). Studies by Josefson et al. and Davenport et al. found that women who had excessive GWG early in the first trimester were more likely to have neonates that had higher birth weights and body fat percentage compared to women who had steady and moderate GWG (108, 109). Cho et al. investigated early GWG rate and adverse pregnancy outcomes in Korean women and researchers found that early GWG rate was associated with pregnancy induced hypertension, macrosomia, LGA and SGA births, and caesarean deliveries (105). A 2011 study by Durie et al examining effect of second and third trimester rate of GWG had on maternal and neonatal outcomes such as caesarean delivery, SGA births, LGA births, induction of labour, gestational diabetes, and NICU admission (104). Inadequate rate of GWG in the second and third trimester were associated with increased odds of SGA births for all BMI classes except class II and III obese women while inadequate rate of GWG was associated with increased odds of LGA births (except in underweight and class III obese women) (104).

Although logistic regression models were adjusted for various factors such as maternal age, maternal education, parity, smoking status, race, etc., it remains that not all variables that were related to certain outcomes could not be controlled for. The relationship between GWG in obese women and ICU admission is a bit tenuous and the mechanism related to it can be undermined by various other factors such as haemorrhage, emergency hysterectomies, and septicemia; factors that could not all be adjusted for. An uncontrolled factor in the current study's regression models for 3rd or 4th degree perineal lacerations was episiotomy which has been shown to be an important risk factor (110). Risk factors for preeclampsia/eclampsia include genetics, previous history of preeclampsia/eclampsia, chronic hypertension, obesity, and severe anemia; some of which were not possible to adjust for (111, 112).

Furthermore, even though there have been several validation studies on items from birth certificate data. there is still the possibility of misclassification bias. Women are known to underestimate their weight (113) which could mean that the present study might misclassify women as not being obese. However, the author believes that this misclassification is nondifferential between women who gain within and outside the IOM guidelines meaning that the overall measure of association is underestimating the true effect.

Obese women (class I, II, III) can have a singular GWG recommendation during pregnancy, but that the current IOM recommendations may need to be updated. The present study found that obese women who lost weight during pregnancy or gained below the IOM recommendations were at a significant decreased risk for caesarean delivery and LGA births and at no significant increased risk for intensive care unit (ICU) admission, 3rd or 4th degree perineal lacerations, eclampsia, unplanned hysterectomies, operative vaginal deliveries, neonates with seizures, suspected neonatal sepsis, and neonates needing assisted ventilation >6 hours compared to obese women who had gestational weight gain (GWG) within the IOM guidelines. However, obese women (class I, II, and III) who lost weight during pregnancy or gained below the IOM guidelines are at an increased risk for small-for-gestational age (SGA) births compared to women who had GWG within the IOM guidelines. Furthermore, obese women – of all classes – who gain above the IOM guidelines are at an increased risk for caesarean delivery, LGA births, and at no significant increased risk for ICU admission, 3rd or 4th degree perineal lacerations, eclampsia, unplanned hysterectomies, operative vaginal deliveries, neonates with seizures, suspected neonatal sepsis, and neonates needing assisted ventilation >6 hours compared to women who gain within the IOM guidelines. Obese women (class I, II, and III) who gain above the IOM guidelines are at a decreased risk for SGA births compared to women who had GWG within the IOM guidelines. The patterns of association were the same for all outcomes in the present study and contrary to current literature, the present study believes that it is possible to have a singular GWG recommendation for all obese women. There is evidence to suggest that a single GWG recommendation for all obese women is possible but that the 2009 IOM guidelines may need to be updated as current recommendations may be too high. Future studies will need to focus on finding the ideal GWG recommendation for obese pregnant women for optimal health outcomes and increasing GWG counselling to improve the rate of adequate GWG.

5.10 Significance

This present study helps provide evidence that a singular GWG guideline is possible for all obese classes contrary to previous studies. Furthermore, it is possible that GWG counselling during pregnancy with healthcare professionals can help reduce adverse maternal and neonatal outcomes as evidenced by the NNTs as women during pregnancy are more likely to alter health behaviours for the sake of the baby.

5.11 Conclusion

In conclusion, the present study found that women are not gaining within the IOM guidelines for gestational weight during pregnancy but that the pattern of association of outcomes between the three classes of obesity are the same. There is evidence for a single gestational weight gain recommendation for all obese women.

REFERENCES

1. Flegal KM, Kruszon-Moran D, Carroll MD, Fryar CD, Ogden CL. Trends in obesity among adults in the united states, 2005 to 2014. JAMA. 2016;315(21):2284-91.
2. Fisher SC, Kim SY, Sharma AJ, Rochat R, Morrow B. Is obesity still increasing among pregnant women? Prepregnancy obesity trends in 20 states, 2003-2009. Prev Med. 2013;56(6):372-8.
3. Organization WH. Obesity and overweight Fact Sheet [Fact Sheet]. World Health Organization; 2016 [updated June 2016; cited 2017. Available from: http://www.who.int/mediacentre/factsheets/fs311/en/.
4. Bhattacharya S, Campbell DM, Liston WA, Bhattacharya S. Effect of Body Mass Index on pregnancy outcomes in nulliparous women delivering singleton babies. BMC Public Health. 2007;7:168.
5. Cnattingius S, Villamor E, Johansson S, Edstedt Bonamy AK, Persson M, Wikstrom AK, et al. Maternal obesity and risk of preterm delivery. Jama. 2013;309(22):2362-70.
6. Claesson IM, Sydsjo G, Brynhildsen J, Cedergren M, Jeppsson A, Nystrom F, et al. Weight gain restriction for obese pregnant women: a case-control intervention study. BJOG. 2008;115(1):44-50.
7. Institute of Medicine, National Research Council Committee to Reexamine IOMPWG. Weight Gain During Pregnancy. Institute of Medicine; 2009.
8. Institute of Medicine, National Research Council Committee to Reexamine IOMPWG. The National Academies Collection: Reports funded by National Institutes of Health. In: Rasmussen KM, Yaktine AL, editors. Weight Gain During Pregnancy: Reexamining the Guidelines. Washington (DC): National Academies Press (US) National Academy of Sciences.; 2009.
9. Artal R, Lockwood CJ, Brown HL. Weight gain recommendations in pregnancy and the obesity epidemic. Obstetrics and gynecology. 2010;115(1):152-5.
10. Blomberg M. Maternal and neonatal outcomes among obese women with weight gain below the new Institute of Medicine Recommendations. Obstetrics & Gynecology. 2011;117(5):1065-70.
11. Oza-Frank R, Keim SA. Should Obese Women Gain Less Weight in Pregnancy Than Recommended? Birth. 2013;40(2):107-14.
12. Park S, Sappenfield WM, Bish C, Salihu H, Goodman D, Bensyl DM. Assessment of the Institute of Medicine Recommendations for Weight Gain During Pregnancy: Florida, 2004–2007. Maternal and Child Health Journal. 2011;15(3):289-301.
13. Bodnar LM, Siega-Riz AM, Simhan HN, Himes KP, Abrams B. Severe obesity, gestational weight gain, and adverse birth outcomes. The American journal of clinical nutrition. 2010;91(6):1642-8.
14. Hinkle SN, Sharma AJ, Dietz PM. Gestational weight gain in obese mothers and associations with fetal growth. The American journal of clinical nutrition. 2010;92(3):644-51.
15. Munro JF. Obesity. Res Medica. 2014;7(1).
16. Leddy MA, Power ML, Schulkin J. The Impact of Maternal Obesity on Maternal and Fetal Health. Reviews in Obstetrics and Gynaecology 2008;1(4):170-8.
17. HealthCanada. Body Mass Index (BMI) Nomogram: Health Canada; [July 4, 2016]. Available from: http://www.hc-sc.gc.ca/fn-an/nutrition/weights-poids/guide-ld-adult/bmi_chart_java-graph_imc_java-eng.php.
18. BMI Classification: World Health Organization (WHO); [cited 2016. Available from: http://apps.who.int/bmi/index.jsp?introPage=intro_3.html.

19. Defining Adult Overweight and Obesity Center for Disease Control (CDC); [Available from: https://www.cdc.gov/obesity/adult/defining.html.
20. CDC. Body Mass Index: Considerations for Practictioners: Center for Disease Control and Prevention; [Available from: https://www.cdc.gov/obesity/downloads/bmiforpactitioners.pdf.
21. McDonald SD, Han, Z., Mulia, S., Lutsiv, O., Lee, T., Beyene, J. High gestational weight gain and the risk of preterm birth and lbw-sys review and meta-analyses. Journal of Obstetrics and Gynaecology Canada. 2015;33(12):1223-33.
22. Dzakpasu S, Fahey J, Kirby RS, Tough SC, Chalmers B, Heaman MI, et al. Contribution of prepregnancy body mass index and gestational weight gain to adverse neonatal outcomes: population attributable fractions for Canada. BMC Pregnancy Childbirth. 2015;15(21).
23. Gaillard R, Welten M, Oddy WH, Beilin LJ, Mori TA, Jaddoe V, et al. Associations of maternal prepregnancy body mass index and gestational weight gain with cardio-metabolic risk factors in adolescent offspring: a prospective cohort study. BJOG. 2016;123(2):207-16.
24. Crane JMG, White J, Murphy P, Burrage L, Hutchens D. The Effect of Gestational Weight Gain by Body Mass Index on Maternal and Neonatal Outcomes. Journal of Obstetrics and Gynaecology Canada. 2009;31(1):28-35.
25. Faucher MA, Hastings-Tolsma M, Song JJ, Willoughby DS, Bader SG. Gestational weight gain and preterm birth in obese women: a systematic review and meta-analysis. BJOG. 2016;123(2):199-206.
26. Gesche J, Nilas L. Pregnancy Outcome According to Pre-Pregnancy Body Mass Index and Gestational Weight Gain. Int J Obes 2015;129:240-5.
27. Kumari AS. Pregnancy outcome in women with morbid obesity. International Journal of Gynecology & Obstetrics. 2001;73(2):101-7.
28. Abenhaim HA, Kinch RA, Morin L, Benjamin A, Usher R. Effect of prepregnancy body mass index categories on obstetrical and neonatal outcomes. Archives of Gynecology and Obstetrics. 2007;275(1):39-43.
29. Sahu MT, Agarwal A, Das V, Pandey A. Impact of maternal body mass index on obstetric outcome. Journal of Obstetrics and Gynaecology Research. 2007;33(5):655-9.
30. Driul L, Cacciaguerra G, Citossi A, Martina MD, Peressini L, Marchesoni D. Prepregnancy body mass index and adverse pregnancy outcomes. Archives of Gynecology and Obstetrics. 2008;278(1):23-6.
31. Hauger MS, Gibbons L, Vik T, Belizan JM. Prepregnancy weight status and the risk of adverse pregnancy outcome. Acta Obstetricia et Gynecologica Scandinavica. 2008;87(9):953-9.
32. Leung TY, Leung TN, Sahota DS, Chan OK, Chan LW, Fung TY, et al. Trends in maternal obesity and associated risks of adverse pregnancy outcomes in a population of Chinese women. BJOG: An International Journal of Obstetrics & Gynaecology. 2008;115(12):1529-37.
33. Roman H, Goffinet F, Hulsey TF, Newman R, Robillard PY, Hulsey TC. Maternal body mass index at delivery and risk of caesarean due to dystocia in low risk pregnancies. Acta Obstetricia et Gynecologica Scandinavica. 2008;87(2):163-70.
34. Salihu HM, Lynch ON, Alio AP, Liu J. Obesity Subtypes and Risk of Spontaneous versus Medically Indicated Preterm Births in Singletons and Twins. American Journal of Epidemiology. 2008;168(1):13-20.
35. Khashan AS, Kenny LC. The Effects of Maternal Body Mass Index on Pregnancy Outcome. European Journal of Epidemiology. 2009;24(11):697-705.

36. Briese V, Voigt M, Hermanussen M, Wittwer-Backofen U. Morbid obesity: Pregnancy risks, birth risks and status of the newborn. HOMO - Journal of Comparative Human Biology. 2010;61(1):64-72.
37. Mantakas A, Farrell T. The influence of increasing BMI in nulliparous women on pregnancy outcome. European Journal of Obstetrics & Gynecology and Reproductive Biology. 2010;153(1):43-6.
38. McDonald SD, Han Z, Mulla S, Beyene J, Knowledge Synthesis G. Overweight and obesity in mothers and risk of preterm birth and low birth weight infants: systematic review and meta-analyses. BMJ. 2010;341:c3428.
39. Hussen HI, Persson M, Moradi T. Maternal overweight and obesity are associated with increased risk of type 1 diabetes in offspring of parents without diabetes regardless of ethinicity. Diabetologia. 2015;58:1464-73.
40. Lutsiv O, Mah J, Beyene J, McDonald SD. The effects of morbid obesity on maternal and neonatal health outcomes: a systematic review and meta-analyses. Obes Rev. 2015;16(7):531-46.
41. Pugh SJ, Richardson GA, Hutcheon JA, Himes KP, Brooks MM, Day NL, et al. Maternal obesity and excessive gestational weight gain are associated with components of child cognition. The Journal of Nutrition. 2015;145:2562-9.
42. Godfrey KM, Reynolds RM, Prescott SL, Nyirenda M, Jaddoe VW, Eriksson JG, et al. Influence of maternal obesity on the long-term health of offspring. The lancet Diabetes & endocrinology. 2017;5(1):53-64.
43. Cedergren MI. Maternal morbid obesity and the risk of adverse pregnancy outcome. Obstetrics and gynecology. 2004;103(2):219-24.
44. Sullivan EA, Dickinson JE, Vaughan GA, Peek MJ, Ellwood D, Homer CS, et al. Maternal super-obesity and perinatal outcomes in Australia: a national population-based cohort study. BMC Pregnancy Childbirth. 2015;15:322.
45. Johnson J, Clifton RG, Roberts JM, Myatt L, Hauth JC, Spong CY, et al. Pregnancy outcomes with weight gain above or below the 2009 Institute of Medicine guidelines. Obstetrics & Gynecology. 2013;121(5):969-75.
46. Kapadia MZ, Park CK, Beyene J, Giglia L, Maxwell C, McDonald SD. Weight Loss Instead of Weight Gain within the Guidelines in Obese Women during Pregnancy: A Systematic Review and Meta-Analyses of Maternal and Infant Outcomes. PLoS One. 2015;10(7):e0132650.
47. Kapadia MZ, Park CK, Beyene J, Giglia L, Maxwell C, McDonald SD. Can we safely recommend gestational weight gain below the 2009 guidelines in obese women? A systematic review and meta-analysis. Obes Rev. 2015;16(3):189-206.
48. Baugh N, Harris DE, Aboueissa A-M, Sarton C, Lichter E. The Impact of Maternal Obesity and Excessive Gestational Weight Gain on Maternal and Infant Outcomes in Maine: Analysis of Pregnancy Risk Assessment Monitoring System Results from 2000 to 2010. Journal of pregnancy. 2016;2016:5871313.
49. Fuchs F, Bouyer J, Rozenberg P, Senat M-V. Adverse maternal outcomes associated with fetal macrosomia: what are the risk factors beyond birthweight? BMC Pregnancy and Childbirth. 2013;13:90-.
50. Yee LM, Caughey AB, Cheng YW. 583: Gestational weight gain in the obese and morbidly obese: how much is too much? American Journal of Obstetrics & Gynecology.214(1):S313.

51. Morken N-H, Klungsøyr K, Magnus P, Skjærven R. Pre-pregnant body mass index, gestational weight gain and the risk of operative delivery. Acta Obstetricia et Gynecologica Scandinavica. 2013;92(7):809-15.
52. MacSween K, Whelan E, Woolcott CG. Gestational Weight Gain and Perinatal Outcomes in Adolescent Mothers: A Retrospective Cohort Study. Journal of obstetrics and gynaecology Canada : JOGC = Journal d'obstetrique et gynecologie du Canada : JOGC. 2016;38(4):338-45.
53. Stotland NE, Cheng YW, Hopkins LM, Caughey AB. Gestational weight gain and adverse neonatal outcome among term infants. Obstetrics and gynecology. 2006;108(3 Pt 1):635-43.
54. Crane JM, White J, Murphy P, Burrage L, Hutchens D. The effect of gestational weight gain by body mass index on maternal and neonatal outcomes. Journal of obstetrics and gynaecology Canada : JOGC = Journal d'obstetrique et gynecologie du Canada : JOGC. 2009;31(1):28-35.
55. Reliability and Validity http://www.socialresearchmethods.net/kb/relandval.php: Web Center for Social Research Methods; 2006 [cited 2016. Available from: http://www.socialresearchmethods.net/kb/relandval.php.
56. Andrade SE, Scott PE, Davis RL, Li D-K, Getahun D, Cheetham TC, et al. Validity of health plan and birth certificate data for pregnancy research. Pharmacoepidemiology and Drug Safety. 2013;22(1):7-15.
57. DiGiuseppe DL, Aron DC, Ranbom L, Harper DL, Rosenthal GE. Reliability of Birth Certificate Data: A Multi-Hospital Comparison to Medical Records Information. Maternal and Child Health Journal. 2002;6(3):169-79.
58. Roohan PJ, Josberger RE, Acar J, Dabir P, Feder HM, Gagliano PJ. Validation of Birth Certificate Data in New York State. Journal of Community Health. 2003;28(5):335-46.
59. Northam S, Knapp TR. The reliability and validity of birth certificates. JOGNN: Journal of Obstetric, Gynecologic & Neonatal Nursing. 2006;35(1):3-12 0p.
60. Dietz P, Bombard J, Mulready-Ward C, Gauthier J, Sackoff J, Brozicevic P, et al. Validation of selected items on the 2003 U.S. standard certificate of live birth: New York City and Vermont. Public health reports (Washington, DC : 1974). 2015;130(1):60-70.
61. Reichman NE, Hade EM. Validation of Birth Certificate Data: A Study of Women in New Jersey's HealthStart Program. Annals of Epidemiology. 2001;11(3):186-93.
62. Reichman NE, Schwartz-Soicher O. Accuracy of birth certificate data by risk factors and outcomes: analysis of data from New Jersey. American Journal of Obstetrics and Gynecology. 2007;197(1):32.e1-.e8.
63. Bodnar LM, Abrams B, Bertolet M, Gernand AD, Parisi SM, Himes KP, et al. Validity of birth certificate-derived maternal weight data. Paediatr Perinat Epidemiol. 2014;28(3):203-12.
64. User Guide to the 2014 Natality Public Use File. Center for Disease Control and Prevention.
65. World Health Organization. WHO Child Growth Standards. 2009.
66. Alexander GR, Kotelchuck M. Quantifying the Adequacy of Prenatal Care: A Comparison of Indices. Public Health Reports. 1996;111:408 - 18.
67. Bodnar LM, Pugh SJ, Lash TL, Hutcheon JA, Himes KP, Parisi SM, et al. Low Gestational Weight Gain and Risk of Adverse Perinatal Outcomes in Obese and Severely Obese Women. Epidemiology (Cambridge, Mass). 2016;27(6):894-902.
68. Deputy NP, Sharma AJ, Kim SY, Hinkle SN. Prevalence and characteristics associated with gestational weight gain adequacy. Obstetrics and gynecology. 2015;125(4):773-81.
69. Faucher MA, Barger MK. Gestational weight gain in obese women by class of obesity and select maternal/newborn outcomes: A systematic review. Women and Birth. 2015;28:e70-e9.

70. Berggren EK, Stuebe AM, Boggess KA. Excess Maternal Weight Gain and Large for Gestational Age Risk among Women with Gestational Diabetes. American journal of perinatology. 2015;32(3):251-6.
71. Hung T-H, Chen S-F, Hsu J-J, Hsieh Ts-Ta. Gestational weight gain and risks for adverse perinatal outcomes: A retrospective cohort study based on the 2009 Institute of Medicine guidelines. Taiwanese journal of obstetrics & gynecology. 2015;54(4):421-5.
72. Asvanarunat E. Outcomes of gestational weight gain outside the Institute of Medicine Guidelines. Journal of the Medical Association of Thailand = Chotmaihet thangphaet. 2014;97(11):1119-25.
73. Baugh N, Harris DE, Aboueissa AM, Sarton C, Lichter E. The Impact of Maternal Obesity and Excessive Gestational Weight Gain on Maternal and Infant Outcomes in Maine: Analysis of Pregnancy Risk Assessment Monitoring System Results from 2000 to 2010. Journal of pregnancy. 2016;2016:5871313.
74. Restrepo E, Elizabeth R, Fuqin L. Maternal and Neonatal Outcomes among Obese Women with Gestational Weight Gain above the New Institute of Medicine (IOM) Recommendations. International journal of women's health and reproduction sciences.3(2):78-83.
75. Bogaerts A, Ameye L, Martens E, Devlieger R. Weight loss in obese pregnant women and risk for adverse perinatal outcomes. Obstetrics and gynecology. 2015;125(3):566-75.
76. Cox Bauer CM, Bernhard KA, Greer DM, Merrill DC. Maternal and neonatal outcomes in obese women who lose weight during pregnancy. Journal of perinatology : official journal of the California Perinatal Association. 2016;36(4):278-83.
77. Fraser A, Tilling K, Macdonald-Wallis C, Hughes R, Sattar N, Nelson SM, et al. Associations of gestational weight gain with maternal body mass index, waist circumference, and blood pressure measured 16 y after pregnancy: the Avon Longitudinal Study of Parents and Children (ALSPAC). The American journal of clinical nutrition. 2011;93(6):1285-92.
78. Harpsoe, Maria C., Basit S, Bager P, Wohlfahrt J. Maternal obesity, gestational weight gain, and risk of asthma and atopic disease in offspring: a study within the Danish National Birth Cohort. Journal of allergy and clinical immunology. 2013;131(4):1033-40.
79. Pérez-Morales ME, Bacardi-Gascon M, Jimenez-Cruz A. Association of excessive GWG with adiposity indicators and metabolic diseases of their offspring: systematic review. ASOCIACIÓN DE GANANCIA DE PESO EXCESIVA DURANTE EL EMBARAZO CON INDICADORES DE ADIPOSIDAD Y ENFERMEDADES METABÓLICAS DE SUS DESCENDIENTES: REVISIÓN SISTEMÁTICA. 2015;31(4):1473-80.
80. Kaar JL, Kaar JL, Crume T, Brinton JT, Bischoff KJ. Maternal Obesity, Gestational Weight Gain, and Offspring Adiposity: The Exploring Perinatal Outcomes among Children Study. The Journal of pediatrics. 2014;165(3):509-15.
81. Kiel DW, Dodson, E.A., Artal, R., Boehner, T.K. Gestational Weight Gain and Pregnancy Outcomes. Obstetrics & Gynaecology. 2007;110(4):752-58.
82. Swank ML, Marshall NE, Caughey AB, Main EK, Gilbert WM, Melsop KA, et al. Pregnancy outcomes in the super obese, stratified by weight gain above and below institute of medicine guidelines. Obstetrics and gynecology. 2014;124(6):1105-10.
83. Cedergren MI. Optimal gestational weight gain for body mass index categories. Obstetrics and gynecology. 2007;110(4):759-64.

84. Kominiarek MA, Seligman NS, Dolin C, Gao W, Berghella V, Hoffman M, et al. Gestational Weight Gain and Obesity: Is 20 Pounds Too Much? Am J Obstet Gynecol. 2013;209(3):214.e1-.e11.
85. Catalano PM, Mele L, Landon MB, Ramin SM, Reddy UM, Casey B, et al. Inadequate weight gain in overweight and obese pregnant women: what is the effect on fetal growth? Am J Obstet Gynecol. 2014;211(2):137.e1-7.
86. Kiel DW, Dodson EA, Artal R, Boehmer TK, Leet TL. Gestational Weight Gain and Pregnancy Outcomes in Obese Women: How Much Is Enough? Obstetrics & Gynecology. 2007;110(4):752-8.
87. Kurnit KC, Overcash RT, Ramos GA, LaCoursiere DY. The impact of inadequate gestational weight gain in obese diabetic women. Journal of perinatology : official journal of the California Perinatal Association. 2016;36(2):86-9.
88. Liu L, Hong Z, Zhang L. Associations of prepregnancy body mass index and gestational weight gain with pregnancy outcomes in nulliparous women delivering single live babies. Scientific reports. 2015;5:12863.
89. Moehlecke M, Costenaro F, Reichelt AA, Oppermann ML, Leitao CB. Low Gestational Weight Gain in Obese Women and Pregnancy Outcomes. AJP reports. 2016;6(1):e77-82.
90. Jarman M, Yuan Y, Pakseresht M, Shi Q, Robson PJ, Bell RC. Patterns and trajectories of gestational weight gain: a prospective cohort study. CMAJ open. 2016;4(2):E338-45.
91. Herring SJ, Oken E, Haines J, Rich-Edwards JW, Rifas-Shiman SL, Kleinman Sc DK, et al. Misperceived pre-pregnancy body weight status predicts excessive gestational weight gain: findings from a US cohort study. BMC Pregnancy Childbirth. 2008;8:54.
92. Jeffs E, Haszard JJ, Sharp B, Gullam J, Paterson H. Pregnant women lack accurate knowledge of their BMI and recommended gestational weight gain. The New Zealand medical journal. 2016;129(1439):37-45.
93. Bookari K, Yeatman H, Williamson M. Australian Pregnant Women's Awareness of Gestational Weight Gain and Dietary Guidelines: Opportunity for Action. Journal of pregnancy. 2016;2016:8162645.
94. Wrotniak BH, Dentice S, Mariano K, Salaam EM, Cowley AE, Mauro EM. Counseling About Weight Gain Guidelines and Subsequent Gestational Weight Gain. Journal of women's health (2002). 2015;24(10):819-24.
95. Vanstone M, Kandasamy S, Giacomini M, DeJean D, McDonald SD. Pregnant women's perceptions of gestational weight gain: a systematic review and meta-synthesis of qualitative research. Maternal & child nutrition. 2016.
96. Kapadia MZ, Gaston A, Van Blyderveen S, Schmidt L, Beyene J, McDonald H, et al. Psychological antecedents of excess gestational weight gain: a systematic review. BMC Pregnancy Childbirth. 2015;15:107.
97. Nikolopoulos H, Mayan M, MacIsaac J, Miller T, Bell RC. Women's perceptions of discussions about gestational weight gain with health care providers during pregnancy and postpartum: a qualitative study. BMC Pregnancy Childbirth. 2017;17(1):97.
98. Price BB, Amini SB, Kappeler K. Exercise in pregnancy: effect on fitness and obstetric outcomes-a randomized trial. Medicine and science in sports and exercise. 2012;44(12):2263-9.
99. Wang C, Wei Y, Zhang X, Zhang Y, Xu Q, Sun Y, et al. A randomized clinical trial of exercise during pregnancy to prevent gestational diabetes mellitus and improve pregnancy outcome in

overweight and obese pregnant women. American Journal of Obstetrics & Gynecology. 2017;216(4):340-51.
100. Skouteris H, McPhie S, Hill B, McCabe M, Milgrom J, Kent B, et al. Health coaching to prevent excessive gestational weight gain: A randomized-controlled trial. British journal of health psychology. 2016;21(1):31-51.
101. Shulman R, Kottke M. Impact of maternal knowledge of recommended weight gain in pregnancy on gestational weight gain. Am J Obstet Gynecol. 2016;214(6):754.e1-7.
102. Oken E, Switkowski K, Price S, Guthrie L, Taveras EM, Gillman M, et al. A qualitative study of gestational weight gain counseling and tracking. Matern Child Health J. 2013;17(8):1508-17.
103. Davies HTO, Crombie IK, Tavakoli M. When can odds ratios mislead? Bmj. 1998;316(7136):989-91.
104. Durie DE, Thornburg LL, Glantz JC. Effect of second-trimester and third-trimester rate of gestational weight gain on maternal and neonatal outcomes. Obstetrics and gynecology. 2011;118(3):569-75.
105. Cho EH, Hur J, Lee KJ. Early Gestational Weight Gain Rate and Adverse Pregnancy Outcomes in Korean Women. PLoS One. 2015;10(10):e0140376.
106. Bayer O, Ensenauer R, Nehring I, von Kries R. Effects of trimester-specific and total gestational weight gain on children’s anthropometrics. BMC Pregnancy and Childbirth. 2014;14(1):351.
107. Ruchat SM, Allard C, Doyon M, Lacroix M, Guillemette L, Patenaude J, et al. Timing of Excessive Weight Gain During Pregnancy Modulates Newborn Anthropometry. Journal of obstetrics and gynaecology Canada : JOGC = Journal d'obstetrique et gynecologie du Canada : JOGC. 2016;38(2):108-17.
108. Davenport MH, Ruchat SM, Giroux I, Sopper MM, Mottola MF. Timing of excessive pregnancy-related weight gain and offspring adiposity at birth. Obstetrics and gynecology. 2013;122(2 Pt 1):255-61.
109. Josefson JL, Simons H, Zeiss DM, Metzger BE. Excessive gestational weight gain in the first trimester among women with normal glucose tolerance and resulting neonatal adiposity. Journal of perinatology : official journal of the California Perinatal Association. 2016;36(12):1034-8.
110. Landy HJ, Laughon SK, Bailit J, Kominiarek MA, Gonzalez-Quintero VH, Ramirez M, et al. Characteristics Associated With Severe Perineal and Cervical Lacerations During Vaginal Delivery. Obstetrics and gynecology. 2011;117(3):627-35.
111. Bilano VL, Ota E, Ganchimeg T, Mori R, Souza Jã P. Risk Factors of Pre-Eclampsia/Eclampsia and Its Adverse Outcomes in Low- and Middle-Income Countries: A WHO Secondary Analysis. PLoS One. 2014;9(3).
112. Cormick G, Betrán AP, Ciapponi A, Hall DR, Hofmeyr GJ. Inter-pregnancy interval and risk of recurrent pre-eclampsia: systematic review and meta-analysis. Reproductive Health. 2016;13.
113. Engstrom JL, Paterson SA, Doherty A, Trabulsi M, Speer KL. Accuracy of Self-Reported Height and Weight in Women: An Integrative Review of the Literature. The Journal of Midwifery & Women’s Health. 2003;48(5):338-45.

APPENDIX A: U.S BIRTH CERTIFICATE

A.1. Standard Birth Certificate Form

U.S. STANDARD CERTIFICATE OF LIVE BIRTH

LOCAL FILE NO.

BIRTH NUMBER:

CHILD

1. CHILD'S NAME (First, Middle, Last, Suffix)
2. TIME OF BIRTH (24 hr)
3. SEX
4. DATE OF BIRTH (Mo/Day/Yr)
5. FACILITY NAME (If not institution, give street and number)
6. CITY, TOWN, OR LOCATION OF BIRTH
7. COUNTY OF BIRTH

MOTHER

8a. MOTHER'S CURRENT LEGAL NAME (First, Middle, Last, Suffix)

8b. DATE OF BIRTH (Mo/Day/Yr)

8c. MOTHER'S NAME PRIOR TO FIRST MARRIAGE (First, Middle, Last, Suffix)

8d. BIRTHPLACE (State, Territory, or Foreign Country)

9a. RESIDENCE OF MOTHER-STATE

9b. COUNTY

9c. CITY, TOWN, OR LOCATION

9d. STREET AND NUMBER

9e. APT. NO.

9f. ZIP CODE

9g. INSIDE CITY LIMITS? □ Yes □ No

FATHER

10a. FATHER'S CURRENT LEGAL NAME (First, Middle, Last, Suffix)

10b. DATE OF BIRTH (Mo/Day/Yr)

10c. BIRTHPLACE (State, Territory, or Foreign Country)

CERTIFIER

11. CERTIFIER'S NAME: ______________________
TITLE: □ MD □ DO □ HOSPITAL ADMIN. □ CNM/CM □ OTHER MIDWIFE
□ OTHER (Specify)______________________
12. DATE CERTIFIED ____/____/________ MM DD YYYY
13. DATE FILED BY REGISTRAR ____/____/________ MM DD YYYY

INFORMATION FOR ADMINISTRATIVE USE

MOTHER

14. MOTHER'S MAILING ADDRESS: 9 Same as residence, or: State: City, Town, or Location:
Street & Number: Apartment No.: Zip Code:
15. MOTHER MARRIED? (At birth, conception, or any time between) □ Yes □ No
IF NO, HAS PATERNITY ACKNOWLEDGEMENT BEEN SIGNED IN THE HOSPITAL? □ Yes □ No
16. SOCIAL SECURITY NUMBER REQUESTED FOR CHILD? □ Yes □ No
17. FACILITY ID. (NPI)
18. MOTHER'S SOCIAL SECURITY NUMBER:
19. FATHER'S SOCIAL SECURITY NUMBER:

INFORMATION FOR MEDICAL AND HEALTH PURPOSES ONLY

MOTHER

20. MOTHER'S EDUCATION (Check the box that best describes the highest degree or level of school completed at the time of delivery)
□ 8th grade or less
□ 9th - 12th grade, no diploma
□ High school graduate or GED completed
□ Some college credit but no degree
□ Associate degree (e.g., AA, AS)
□ Bachelor's degree (e.g., BA, AB, BS)
□ Master's degree (e.g., MA, MS, MEng, MEd, MSW, MBA)
□ Doctorate (e.g., PhD, EdD) or Professional degree (e.g., MD, DDS, DVM, LLB, JD)
21. MOTHER OF HISPANIC ORIGIN? (Check the box that best describes whether the mother is Spanish/Hispanic/Latina. Check the "No" box if mother is not Spanish/Hispanic/Latina)
□ No, not Spanish/Hispanic/Latina
□ Yes, Mexican, Mexican American, Chicana
□ Yes, Puerto Rican
□ Yes, Cuban
□ Yes, other Spanish/Hispanic/Latina
(Specify)______________________
22. MOTHER'S RACE (Check one or more races to indicate what the mother considers herself to be)
□ White
□ Black or African American
□ American Indian or Alaska Native (Name of the enrolled or principal tribe)______________
□ Asian Indian
□ Chinese
□ Filipino
□ Japanese
□ Korean
□ Vietnamese
□ Other Asian (Specify)______________________
□ Native Hawaiian
□ Guamanian or Chamorro
□ Samoan
□ Other Pacific Islander (Specify)______________________
□ Other (Specify)______________________

FATHER

23. FATHER'S EDUCATION (Check the box that best describes the highest degree or level of school completed at the time of delivery)
□ 8th grade or less
□ 9th - 12th grade, no diploma
□ High school graduate or GED completed
□ Some college credit but no degree
□ Associate degree (e.g., AA, AS)
□ Bachelor's degree (e.g., BA, AB, BS)
□ Master's degree (e.g., MA, MS, MEng, MEd, MSW, MBA)
□ Doctorate (e.g., PhD, EdD) or Professional degree (e.g., MD, DDS, DVM, LLB, JD)
24. FATHER OF HISPANIC ORIGIN? (Check the box that best describes whether the father is Spanish/Hispanic/Latino. Check the "No" box if father is not Spanish/Hispanic/Latino)
□ No, not Spanish/Hispanic/Latino
□ Yes, Mexican, Mexican American, Chicano
□ Yes, Puerto Rican
□ Yes, Cuban
□ Yes, other Spanish/Hispanic/Latino
(Specify)______________________
25. FATHER'S RACE (Check one or more races to indicate what the father considers himself to be)
□ White
□ Black or African American
□ American Indian or Alaska Native (Name of the enrolled or principal tribe)______________
□ Asian Indian
□ Chinese
□ Filipino
□ Japanese
□ Korean
□ Vietnamese
□ Other Asian (Specify)______________________
□ Native Hawaiian
□ Guamanian or Chamorro
□ Samoan
□ Other Pacific Islander (Specify)______________________
□ Other (Specify)______________________

Mother's Name

Mother's Medical Record No.

26. PLACE WHERE BIRTH OCCURRED (Check one)
□ Hospital
□ Freestanding birthing center
□ Home Birth: Planned to deliver at home? 9 Yes 9 No
□ Clinic/Doctor's office
□ Other (Specify)______________________
27. ATTENDANT'S NAME, TITLE, AND NPI
NAME: ______________________ NPI:________
TITLE: □ MD □ DO □ CNM/CM □ OTHER MIDWIFE
□ OTHER (Specify)______________________
28. MOTHER TRANSFERRED FOR MATERNAL MEDICAL OR FETAL INDICATIONS FOR DELIVERY? □ Yes □ No
IF YES, ENTER NAME OF FACILITY MOTHER TRANSFERRED FROM:
____

REV. 11/2003

MOTHER

29a. DATE OF FIRST PRENATAL CARE VISIT
____/____/______ (MM DD YYYY) □ No Prenatal Care

29b. DATE OF LAST PRENATAL CARE VISIT
____/____/______ (MM DD YYYY)

30. TOTAL NUMBER OF PRENATAL VISITS FOR THIS PREGNANCY
______________ (If none, enter A0".)

31. MOTHER'S HEIGHT
______ (feet/inches)

32. MOTHER'S PREPREGNANCY WEIGHT
________ (pounds)

33. MOTHER'S WEIGHT AT DELIVERY
________ (pounds)

34. DID MOTHER GET WIC FOOD FOR HERSELF DURING THIS PREGNANCY? □ Yes □ No

35. NUMBER OF PREVIOUS LIVE BIRTHS (Do not include this child)

- 35a. Now Living — Number ____ □ None
- 35b. Now Dead — Number ____ □ None

36. NUMBER OF OTHER PREGNANCY OUTCOMES (spontaneous or induced losses or ectopic pregnancies)

- 36a. Other Outcomes — Number ____ □ None

37. CIGARETTE SMOKING BEFORE AND DURING PREGNANCY
For each time period, enter either the number of cigarettes or the number of packs of cigarettes smoked. IF NONE, ENTER A0".

Average number of cigarettes or packs of cigarettes smoked per day.

	# of cigarettes		# of packs
Three Months Before Pregnancy	______	OR	______
First Three Months of Pregnancy	______	OR	______
Second Three Months of Pregnancy	______	OR	______
Third Trimester of Pregnancy	______	OR	______

38. PRINCIPAL SOURCE OF PAYMENT FOR THIS DELIVERY

- □ Private Insurance
- □ Medicaid
- □ Self-pay
- □ Other (Specify) ____________

35c. DATE OF LAST LIVE BIRTH
____/______ (MM YYYY)

36b. DATE OF LAST OTHER PREGNANCY OUTCOME
____/______ (MM YYYY)

39. DATE LAST NORMAL MENSES BEGAN
____/____/______ (MM DD YYYY)

40. MOTHER'S MEDICAL RECORD NUMBER

MEDICAL AND HEALTH INFORMATION

41. RISK FACTORS IN THIS PREGNANCY (Check all that apply)

Diabetes
- □ Prepregnancy (Diagnosis prior to this pregnancy)
- □ Gestational (Diagnosis in this pregnancy)

Hypertension
- □ Prepregnancy (Chronic)
- □ Gestational (PIH, preeclampsia)
- □ Eclampsia

- □ Previous preterm birth
- □ Other previous poor pregnancy outcome (Includes perinatal death, small-for-gestational age/intrauterine growth restricted birth)
- □ Pregnancy resulted from infertility treatment-If yes, check all that apply:
  - □ Fertility-enhancing drugs, Artificial insemination or Intrauterine insemination
  - □ Assisted reproductive technology (e.g., in vitro fertilization (IVF), gamete intrafallopian transfer (GIFT))
- □ Mother had a previous cesarean delivery
  If yes, how many ________
- □ None of the above

42. INFECTIONS PRESENT AND/OR TREATED DURING THIS PREGNANCY (Check all that apply)

- □ Gonorrhea
- □ Syphilis
- □ Chlamydia
- □ Hepatitis B
- □ Hepatitis C
- □ None of the above

43. OBSTETRIC PROCEDURES (Check all that apply)

- □ Cervical cerclage
- □ Tocolysis

External cephalic version:
- □ Successful
- □ Failed

- □ None of the above

44. ONSET OF LABOR (Check all that apply)

- □ Premature Rupture of the Membranes (prolonged, ∃12 hrs.)
- □ Precipitous Labor (<3 hrs.)
- □ Prolonged Labor (∃ 20 hrs.)
- □ None of the above

45. CHARACTERISTICS OF LABOR AND DELIVERY (Check all that apply)

- □ Induction of labor
- □ Augmentation of labor
- □ Non-vertex presentation
- □ Steroids (glucocorticoids) for fetal lung maturation received by the mother prior to delivery
- □ Antibiotics received by the mother during labor
- □ Clinical chorioamnionitis diagnosed during labor or maternal temperature $\geq$38°C (100.4°F)
- □ Moderate/heavy meconium staining of the amniotic fluid
- □ Fetal intolerance of labor such that one or more of the following actions was taken: in-utero resuscitative measures, further fetal assessment, or operative delivery
- □ Epidural or spinal anesthesia during labor
- □ None of the above

46. METHOD OF DELIVERY

A. Was delivery with forceps attempted but unsuccessful?
□ Yes □ No

B. Was delivery with vacuum extraction attempted but unsuccessful?
□ Yes □ No

C. Fetal presentation at birth
- □ Cephalic
- □ Breech
- □ Other

D. Final route and method of delivery (Check one)
- □ Vaginal/Spontaneous
- □ Vaginal/Forceps
- □ Vaginal/Vacuum
- □ Cesarean
  If cesarean, was a trial of labor attempted?
  - □ Yes
  - □ No

47. MATERNAL MORBIDITY (Check all that apply) (Complications associated with labor and delivery)

- □ Maternal transfusion
- □ Third or fourth degree perineal laceration
- □ Ruptured uterus
- □ Unplanned hysterectomy
- □ Admission to intensive care unit
- □ Unplanned operating room procedure following delivery
- □ None of the above

NEWBORN

NEWBORN INFORMATION

48. NEWBORN MEDICAL RECORD NUMBER

49. BIRTHWEIGHT (grams preferred, specify unit)
____________ 9 grams 9 lb/oz

50. OBSTETRIC ESTIMATE OF GESTATION:
____________ (completed weeks)

51. APGAR SCORE:
Score at 5 minutes: ____________
If 5 minute score is less than 6,
Score at 10 minutes: ____________

52. PLURALITY - Single, Twin, Triplet, etc.
(Specify) ____________

53. IF NOT SINGLE BIRTH - Born First, Second, Third, etc. (Specify) ____________

54. ABNORMAL CONDITIONS OF THE NEWBORN (Check all that apply)

- □ Assisted ventilation required immediately following delivery
- □ Assisted ventilation required for more than six hours
- □ NICU admission
- □ Newborn given surfactant replacement therapy
- □ Antibiotics received by the newborn for suspected neonatal sepsis
- □ Seizure or serious neurologic dysfunction
- □ Significant birth injury (skeletal fracture(s), peripheral nerve injury, and/or soft tissue/solid organ hemorrhage which requires intervention)
- 9 None of the above

55. CONGENITAL ANOMALIES OF THE NEWBORN (Check all that apply)

- □ Anencephaly
- □ Meningomyelocele/Spina bifida
- □ Cyanotic congenital heart disease
- □ Congenital diaphragmatic hernia
- □ Omphalocele
- □ Gastroschisis
- □ Limb reduction defect (excluding congenital amputation and dwarfing syndromes)
- □ Cleft Lip with or without Cleft Palate
- □ Cleft Palate alone
- □ Down Syndrome
  - □ Karyotype confirmed
  - □ Karyotype pending
- □ Suspected chromosomal disorder
  - □ Karyotype confirmed
  - □ Karyotype pending
- □ Hypospadias
- □ None of the anomalies listed above

56. WAS INFANT TRANSFERRED WITHIN 24 HOURS OF DELIVERY? 9 Yes 9 No
IF YES, NAME OF FACILITY INFANT TRANSFERRED TO: ____________________

57. IS INFANT LIVING AT TIME OF REPORT?
□ Yes □ No □ Infant transferred, status unknown

58. IS THE INFANT BEING BREASTFED AT DISCHARGE?
□ Yes □ No

Mother's Name ____________

Mother's Medical Record No. ____________