Outcomes Associated with Weight Gain During Pregnancy:
A Rapid Review

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Key Messages

Gestational weight gain (GWG) is associated with a number of maternal and infant health outcomes:

1. For the mother, there is moderate evidence that excessive GWG is positively associated with caesarean birth, and postpartum weight retention, and that low GWG is associated with failure to initiate breastfeeding. There is weak evidence that high GWG is associated with stretch marks, induction of labour, and length of labour.

2. For the infant, there is strong evidence of a positive association between GWG and birth weight; moderate evidence that GWG is associated with preterm birth, neonatal death, and overweight or obesity in childhood; and weak evidence that GWG is linked to stillbirth.

3. There is inconclusive evidence regarding the association between GWG and pregnancy complications such as gestational diabetes and maternal hypertensive disorders.

Executive Summary

Research Question

Among pregnant women (in all pre-pregnancy body mass index categories) what is the effect of appropriate gestational weight gain on maternal and infant health outcomes?

Context

A woman's weight before and during pregnancy can influence the health of both herself and her infant. In 2014, more than a third (35%) of Peel women entered pregnancy overweight or obese. Approximately one quarter (26%) of women gained the appropriate amount of weight during pregnancy, while 37% gained above and 16% gained below the recommended weight gain range. Based on available data, the Family Health Division has prioritized the need for pregnant women and women of childbearing age to achieve and maintain a healthy body weight.

Methods and Results

A search of published literature returned 462 results. Twenty articles were reviewed in full. Two additional reviews were identified by screening reference lists. After assessing relevance, overlap, and quality, one guideline and five systematic reviews were included in this review.

Synthesis of Findings

Maternal outcomes associated with high gestational weight gain (GWG) include caesarean birth and postpartum weight retention. Low GWG is associated with failure to

initiate breastfeeding. For the infant, there is a positive association between GWG and birth weight; as well as evidence that GWG is associated with preterm birth, neonatal death, and overweight or obesity in childhood. The evidence is inconclusive regarding the relationship between GWG gestational diabetes or pregnancy induced hypertension.

Recommendations

1. Continue to monitor provincial and local data on maternal pre-pregnancy BMI and GWG and associated health outcomes to observe and report on trends.

2. Advocate at the provincial and local levels for:

    a. BORN Ontario to include demographic information (e.g., ethnicity) in the public health unit BORN data cube.

    b. Health care professionals, hospital partners and midwifery practice groups to report on pre-pregnancy BMI and GWG collected at uniform time points using objective measurements of height and weight.

3. Identify effective interventions to influence pre-pregnancy BMI for women of childbearing age and healthy weight gain during pregnancy.

4. Identify opportunities for partnerships and collaborate with relevant internal and external stakeholders.

5. Review and modify (where appropriate) messaging about healthy weight gain during pregnancy.

1 Issue

A woman's weight before and during pregnancy can influence the health of both herself and her infant.(1,2) Gestational weight gain[1] (GWG) is expected, and considered an important part of a healthy pregnancy as well as an indicator of maternal health and fetal development.(3,4) What constitutes healthy GWG can vary from one woman to another, however gaining within a recommended range based on a woman's pre-pregnancy body mass index (BMI) may decrease the risk of adverse outcomes.(2)

The prenatal period could be an ideal time to promote healthy weight gain since pregnant women may be motivated to make lifestyle changes to support the health and development of their baby.(3) Given that GWG is a modifiable risk factor, we need to understand the influence of appropriate weight gain during pregnancy on maternal and infant health. This will help to determine whether public health strategies to improve maternal, fetal and child health should be implemented to promote optimal GWG, or if focus should be to ensure that women enter pregnancy with a healthy BMI. **This rapid review will answer the practice question: If pregnant women gain the recommended amount of weight (according to their pre-pregnancy BMI) will it impact maternal and infant health outcomes?**

2 Context

Peel Public Health (PPH) is interested in all pregnant women experiencing a healthy pregnancy and having the healthiest newborn possible.(5) The Family Health Division at

[1] Gestational weight gain (GWG) refers to the amount of weight a woman gains during pregnancy from the time of conception until the onset of labour.(2)

PPH set a priority that pregnant women and women of childbearing age achieve and maintain a healthy body weight. The Family Health Division adopted the Institute of Medicine's (IOM's) guideline for weight gain during pregnancy which provides recommendations for the total amount and rate of weight gain during pregnancy according to a woman's pre-pregnancy BMI.(2) (See Appendix A). These guidelines are used to inform public health messaging and to interpret local data.

In 2014, 49% of Peel women for whom we have data, were classified as having a normal BMI prior to pregnancy, 6% were classified as underweight, but almost 35% were in the overweight or obese category.(6)[2] Across all pre-pregnancy BMI categories, approximately one quarter (26%) of women gained the appropriate amount of weight during pregnancy, while 37% gained above and 16% gained below the recommended weight gain range.(7) The majority of women who entered pregnancy overweight or obese gained above the recommended weight while pregnant.(6) (See Appendix B)

Maternal BMI and GWG have been linked to a number of maternal and infant health outcomes which include but are not limited to: gestational diabetes, pregnancy induced hypertension, preterm births, caesarean section, infant birthweight, breastfeeding, postpartum weight retention and childhood obesity.(2,4) Specifically, research indicates that a woman's pre-pregnancy BMI is an independent predictor of short-and long-term maternal health outcomes.(2) Overall, in 2014, 14,869 Peel women gave birth to 15,162 infants (both live and stillbirth).(8) During that year, a higher proportion of pregnant women residing in Peel developed gestational diabetes (8.6%) and/or gestational

[2] Due to a high proportion of missing records for pre-pregnancy BMI and GWG, data are reported for a subpopulation of 51% of Peel women in the Better Outcomes Registry and Network (BORN). Comparable data are not available for Ontario.

hypertension (4.0%) when compared to Ontario (5.8% and 3.4% respectively).(9,10) The rate of Caesarean births in Peel (28%) was similar to Ontario (27%)(11) and the rate of preterm births was marginally higher in Peel (8.7%) compared to Ontario (8.0%).(12) In addition, the rate of low birth weight (LBW) (<2,500g) (multiple and stillbirths included) was higher in Peel (8.3%) compared to Ontario (6.6%).(13) Many factors may contribute to these health issues.

When the relationship between pre-pregnancy BMI and pregnancy outcomes is examined using the local data available for 2014, the rates of gestational hypertension, gestational diabetes, caesarean section and high birth weight were greater for women with a high pre-pregnancy BMI compared to those who were normal weight for height.(14) In addition, being underweight prior to pregnancy was associated with an increased rate of preterm birth and low birth weight compared to normal weight women.(14) When stratifying by pre-pregnancy BMI, GWG above recommended was associated with an increased rate of caesarean birth, while low GWG was associated with increased rates of preterm births, gestational diabetes and LBW in Peel.(14)

Peel data are not available for maternal weight in the postpartum period, however as a proxy, pre-pregnancy BMI can be compared between primiparous and multiparous women in the subpopulation of data described. These data indicate that multiparous women are heavier as they enter pregnancy (37% overweight or obese) compared to primiparous women (30% overweight or obese).(14) Although a number of factors influence a woman's BMI, it is possible that the weight retained from a previous pregnancy could affect a woman's weight status in the future.(2)

In summary, local data indicate that many women in Peel are overweight or obese as they enter pregnancy and that a significant proportion of women are gaining weight during pregnancy outside of what is recommended. Healthy weights for women in their childbearing years and appropriate GWG are modifiable risk factors for adverse outcomes of pregnancy. Since pre-pregnancy BMI and weight gain during pregnancy are related, it can be difficult to determine which outcomes of pregnancy are influenced significantly by GWG alone. The findings of this rapid review will assist PPH with determining the effect of appropriate GWG on maternal and infant health outcomes.

3 Conceptual Framework

We adapted a conceptual framework of determinants and consequences of GWG from the IOM's guideline on weight gain during pregnancy.(2) The resulting concept map (Appendix C) was developed to depict the factors that influence a woman's weight before, during and after pregnancy (in the preconception, prenatal, postpartum and interpregnancy periods) and the associated health outcomes. This concept map illustrates numerous individual, social and environmental factors that may impact weight gain during pregnancy. It also shows that gestational weight gain is a potential risk factor for a number of health outcomes for both the mother and her infant.

4 Literature Review Question

Among pregnant women (in all pre-pregnancy body mass index categories) what is the effect of appropriate gestational weight gain on maternal and infant health outcomes?

Population (P)	Pregnant women (all BMI categories); singleton pregnancy

Exposure (E)	Appropriate gestational weight gain (according to a valid standard)
Comparison (C)	Gestational weight gain outside of the recommendations (inadequate or excessive, high or low)
Outcome(s) (O)	Maternal, birth and infant health outcomes

5 Literature Search

A public health librarian conducted a search of published literature in May 2016. The search included: Medline, Cochrane Database of Systematic Reviews, Healthstar, Global Health, Cumulative Index for Nursing and Allied Health (CINAHL), and Academic Search Premier. Searches were limited to include English language publications, synthesized evidence (e.g. guidelines or systematic reviews), and articles published from 2006 onwards. In addition, the reference lists of the relevant documents were screened for additional reviews or guidelines. A grey literature search was not conducted. See Appendix D for the complete search strategy.

6 Relevance Assessment

One reviewer screened all titles and abstracts for inclusion. If relevance was still unclear after full text review, a second reviewer was consulted. Any disagreements were discussed with the knowledge broker and the review team. The search results were assessed for relevance based on the following criteria:

- Inclusion criteria: focus on pregnant women (all/any BMI categories) with singleton pregnancies; exposure to appropriate gestational weight gain; any maternal, birth or infant health outcomes; English language; published in the last ten years; review or guideline level evidence; settings similar to Canada.

- Exclusion criteria: focused on the effectiveness of an intervention; data duplication (more than 75% overlap between included studies).

7 Results of the Search

Searches yielded 462 titles. Twenty articles were reviewed in full. One guideline and seven systematic reviews were identified for inclusion. Two additional reviews were identified by screening reference lists. Overlap assessment reduced included documents to one guideline and five systematic reviews. See Appendix E.

8 Critical Appraisal

Two independent reviewers completed the critical appraisal. The Health Evidence Quality Assessment tool was used for the five systematic reviews (15); and the AGREE II tool (16) was used for the guideline. Reviewers met to discuss any discrepancies in scoring and consensus was reached. All five systematic reviews and the guideline were rated strong quality.

9 Description of Included Studies

The following guideline and five systematic reviews were included:

- Institute of Medicine (IOM) and National Research Council (NRC). (2009). Weight gain during pregnancy: Re-examining the guidelines.(2)
- Brunner, S. et al. (2015). Excessive gestational weight gain prior to glucose screening and the risk of gestational diabetes: a meta-analysis.(17)
- Han, Z. et al. (2011). Low gestational weight gain and the risk of preterm birth and low birthweight: a systematic review and meta-analyses.(18)

- Kapadia, M.Z. et al. (2015). Can we safely recommend gestational weight gain below the 2009 guidelines in obese women? A systematic review and meta-analysis.(19)
- Lau E.Y. et al. (2014). Maternal weight gain in pregnancy and risk of obesity among offspring: A systematic review.(20)
- Mannan, M. et al. (2013). Association between weight gain during pregnancy and postpartum weight retention and obesity: a bias-adjusted meta-analysis.(21)

Although all of these documents are focused on the exposure to GWG, this research literature consistently uses appropriate GWG as the comparison, and focuses on excessive, high, inadequate or low total or rate of GWG as the exposure. We were unable to locate any review level evidence in our search that focuses on appropriate GWG as the main exposure of interest.

All included papers considered whether the primary research adjusted for potential confounders. However, only some analyses in the primary studies report adjusted data.

9.1 Institute of Medicine (IOM) (2009) (2)

This guideline (rated strong quality) reviewed the evidence on the relationship between weight patterns before, during and after pregnancy, and maternal and child health outcomes, and updated the GWG recommendations from 1990. The guideline included: a systematic review of 150 studies on maternal and child outcomes associated with GWG, a literature review, consultation with experts, and four commissioned data analyses. Outcomes such as: gestational diabetes, hypertensive disorders, preterm birth, caesarean birth, birth weight, size for gestational age, lactation, postpartum weight

retention and childhood obesity were included. The guideline developers graded the strength of available evidence[3] (strong, moderate or weak) based on the quality of the research, quantity of studies, and the consistency of findings for each outcome. The guideline authors note it was difficult to quantitatively summarize the effect of GWG on each outcome due to heterogeneity in study designs, differences in the definitions of high and low GWG, and variation in how each outcome was defined and/or measured. For many of the outcomes discussed in this guideline, summary effect sizes were not reported. See Appendix F.

9.2 Brunner, S. et al. (2015) (17)

This strong quality systematic review examined the association between excessive GWG prior to screening for gestational diabetes mellitus (GDM) and risk of GDM. It included eight studies published since the updated IOM guideline. The review included women with singleton pregnancies who did not have a previous diagnosis of diabetes. Measured or recorded GWG was used to determine whether weight gain was excessive, recommended or inadequate based on women's self-reported pre-pregnancy BMI. There was variation between studies in the number of weeks gestation when GWG was measured. Most study authors did not explicitly report how GWG recommendations were used to classify weight gain. Women's exposure to excessive weight gain prior to screening for GDM was compared to women with non-excessive GWG (grouping together both recommended and inadequate weight gain) in this meta-analysis. A sensitivity analysis of the four studies that reported excessive compared to

[3] The definition of strength of evidence ratings can be found in the data extraction tables on page 43 in Appendix F.

recommended GWG was also conducted. The diagnostic criteria for GDM differed across the included studies. See Appendix F.

9.3 Han, Z. et al. (2011) (18)

The objective of this systematic review (rated strong) was to determine the relationship between low GWG, and preterm birth (PTB) or LBW among pregnant women in developed and developing countries. This review included 55 cohort or case-control studies; the majority conducted in developed nations. Studies included singleton pregnancies and used objective or self-reported GWG to compare low GWG to adequate GWG according to 2009 IOM recommendations for total or rate of weight gain during pregnancy. Some studies did not report maternal pre-pregnancy BMI, and therefore GWG could not be categorized according to IOM recommendations. The primary outcomes of this review were spontaneous or induced PTB (<37weeks) and LBW (<2,500g). Secondary outcomes included PTB from 32-36 weeks gestation or <32 weeks, very LBW (<1,500g) or extremely LBW (<1,000g). See Appendix F.

9.4 Kapadia, M.Z. et al. (2015) (19)

This strong quality meta-analysis assessed the risk of adverse pregnancy outcomes related to inadequate GWG compared to appropriate GWG (according to IOM 2009 guidelines) among obese pregnant women. All 18 cohort studies included obese women with singleton pregnancies. GWG was obtained from medical records (10 studies) or self-reported (7 studies) and in one study it was not specified how GWG was acquired. The primary health outcomes for this review were small for gestational age (SGA); large

for gestational age (LGA); and PTB. See Appendix F for secondary maternal and infant outcomes.

9.5 Lau, E.Y. et al. (2014) (20)

This narrative systematic review (rated strong) synthesized observational research on the association between GWG and offspring's body weight between two and 18.9 years. It included 22 cohort studies, more than half of which had a prospective design. This review examined the relationship between total, net or rate of GWG and offspring body weight. There was variation in how GWG was defined and assessed in the included studies. Outcome measures for child body weight included BMI z-scores and overweight status, however there was some variation in the growth charts and/or child body weight cut off points. The majority of studies measured child body weight objectively, however some outcomes were self-reported (4 studies), parent reported (2 studies) or clinically recorded (1 study). Most studies did not adjust for shared family characteristics such as genetics or lifestyle factors and none reported whether they were sufficiently powered to detect the interactive effects of pre-pregnancy BMI. A meta-analysis was not conducted due to heterogeneity however the direction of the association from study findings are presented rather than the magnitude of the effect.

9.6 Mannan, M. et al. (2013) (21)

The objective of this systematic review (rated strong) was to determine the association between GWG and postpartum weight retention (PPWR) or maternal BMI over time. Nine prospective and three retrospective cohort studies were included. The majority of study participants were Caucasian and had similar socioeconomic status. The review

compared women who experienced inadequate or excessive GWG with appropriate GWG (according to IOM recommendations from 1990 or 2009). The outcome measures included postpartum weight retention as a continuous variable, postpartum BMI, and the odds of maternal overweight or obesity in the postpartum period. Outcomes were measured objectively in the majority of studies however outcome assessment occurred at different time points. There was a high degree of heterogeneity in the meta-analyses.

10 Synthesis of Findings

A summary table of the relationships between GWG and health outcomes is provided in Appendix G.

Maternal Outcomes

For the mother, there is moderate evidence that excessive GWG is positively associated with caesarean birth and postpartum weight retention, and that low GWG is associated with failure to initiate breastfeeding. There is weak evidence that high GWG is associated with stretch marks, induction, and length of labour.

Caesarean Birth

There is moderate evidence of a positive association between high GWG and caesarean birth.(2) In the studies that specifically examined GWG categorized according to the 1990 IOM guidelines, the increased risk of caesarean birth among women with excessive GWG was observed in underweight or normal weight women but findings were inconsistent for obese women.(2) More than half of studies noted that entering pregnancy overweight or obese increased women's risk of caesarean birth

compared to women with a lower BMI.(2) One review focused on obese women who gained below recommendations found that obese women with inadequate GWG had lower odds of a caesarean birth (Adjusted Odds Ratio (AOR) 0.87; 95% CI 0.82 to 0.92) than obese women who gained within the guidelines.(19)

Postpartum weight retention (PPWR)

Excessive GWG is associated with weight retention in the intermediate postpartum period.(2,21) In one review, women with excessive GWG had a significantly greater postpartum weight (weighted mean difference (WMD) 3.15kg; 95% CI 2.47 to 3.82 kg) between two weeks and 21 years postpartum, compared to women with appropriate GWG.(21) These findings showed a U-shaped trend in PPWR over time among women who gained excessive GWG compared to appropriate GWG with a decline in weight in early postpartum period and then an increase in weight in the later follow up period (8.5 to 21 year postpartum).(21) Women who gained above GWG recommendations experienced an increase in their BMI (3.78kg/m^2 95%CI 3.14 to 4.41kg/m^2) and an increased odds of being classified as overweight/obese compared to women who gain within the recommendations.(21) Many of the analyses did not account for pre-pregnancy BMI or for potential confounders such as nutrition, physical activity and breastfeeding.(2,21) The evidence of an association between GWG and PPWR in the long-term is weaker.(2,21)

Breastfeeding

A few studies (graded moderate) suggest that inadequate GWG is associated with a lower likelihood of breastfeeding initiation.(2) The limited available evidence also points

to an association between pre-pregnancy BMI and breastfeeding, with obese women being less likely to initiate breastfeeding regardless of GWG.(2)

Other antepartum outcomes

There is weak evidence that high GWG is associated with stretch marks.(2)

Induction or length of labour

A small number of studies (graded weak) suggest that high GWG is associated with induction of labour, failure of labour induction, and/or with a longer duration of labour.(2)

Infant Outcomes

For the infant, there is strong evidence of a positive association between GWG and birth weight; moderate evidence that GWG is associated with preterm birth, neonatal death, and overweight or obesity in childhood; and weak evidence that GWG is linked to stillbirth.

Birth weight

Findings consistently demonstrate that higher GWG is associated with increased infant birth weight and that low GWG is associated with a greater risk of low birth weight (LBW) (<2,500g). The guideline concluded that the risk of having a low birth weight baby is half for women in the highest GWG category compared to women in the lowest GWG category.(2) Conversely, the risk of macrosomia (defined as birth weight >4,000 or 4,500g) is roughly two to three times greater for women in the highest GWG category compared to women in the lowest category.(2) Additionally, a meta-analyses of 13

cohort studies demonstrated that women with a low total GWG had an increased risk of delivering a LBW infant (unadjusted RR 1.85; 95%CI 1.72 to 2.00)[4] compared to women who gained appropriate weight during pregnancy.(18) The review also concluded that the lower the GWG the greater the risk of LBW.(18)

Weight for gestational age

There is strong evidence of a linear relationship between GWG and birth weight for gestational age.(2) A higher GWG reduces the risk of SGA[5] and increases the risk of LGA[6]. The guideline authors estimate that women with the lowest GWG have two to three times the risk of having an infant who is SGA when compared to the women in the highest GWG category.(2) This risk appears to be greater among women with a lower pre-pregnancy BMI.(2) For each 1kg increase in GWG the risk of LGA is increased by a factor of 1.1.(2)

One review found that obese women who gained below recommended during pregnancy had an increased odds of SGA (AOR 1.24; 95% CI 1.13 to 1.36).(19) They also found that these women experienced a decreased odds of LGA (AOR 0.77; 95% CI 0.73 to 0.81) and of having a macrosomic infant (AOR 0.64; 95% CI 0.54 to 0.77).(19)

Preterm birth (PTB) (<37 weeks gestation)

There is a u-shaped association between GWG and PTB. (2) Guideline authors estimate that both low GWG and high GWG increase a woman's risk of PTB by about

[4] Adjusted data were available for one cohort study with consistent findings. See data extraction table in Appendix F.
[5] SGA is defined as birth weight less than the 10th percentile gestational age based on a given reference population.
[6] LGA is defined as birth weight above the 90th percentile for gestational age, based on a given reference population.(2)

1.5 to 2.5 times.(2) Pre-pregnancy BMI is an effect modifier of this relationship in that there is a stronger association between low GWG and PTB among underweight women and some evidence that women with a high pre-pregnancy BMI are at greater risk of PTB associated with a high GWG.(2)

One review found that women had an increased risk of PTB with low total GWG (unadjusted RR 1.64; 95%CI 1.62 to 1.65)[7] or low weekly GWG (adjusted/matched RR 1.91; 95% CI 1.45 to 2.52) compared to women who gained appropriate weight during pregnancy.(18) For obese women, gaining below recommendations during pregnancy was associated with higher odds of PTB (AOR 1.46; 95% CI 1.07 to 2.00) compared to obese women who gained within the guidelines.(19)

Infant mortality

There is evidence of an association between both high and low GWG and infant mortality based on one good quality study.(2)

Childhood obesity

There is a positive association between higher GWG and childhood obesity.(2) The evidence is insufficient to determine the effect of maternal BMI on this relationship.(2,20) One review found a significant positive association between total GWG and a child's body weight (in seven of eight studies).(20) Findings were summarized narratively, but overall an additional 1kg in GWG was found to increase a child's BMI z-score by 0.006-0.06 units and increased a child's risk of being overweight or obese by 1% to 23% after adjustment for confounders.(20) In addition, three out of

[7] Adjusted data were not available for this analysis. See data extraction table in Appendix F.

four studies found a significant positive association between net GWG (total GWG minus infant birth weight) and the child's body weight.(20) These studies found that an incremental increase in net GWG was associated with a 0.01 to 0.07 increase in a child's BMI z-score.(20) Four studies also indicated that a high rate of GWG in early and mid-pregnancy was associated with increased BMI z-scores and risk of overweight in the child.(20) Six out of eight studies that examined the relationship between GWG categorized according to IOM recommendations found that offspring of mothers who gained excessive GWG compared to appropriate GWG had a significant increase in BMI z-score ranging from 0.14-0.64 units and a 27% to 73% greater risk of overweight or obesity.(20)

Stillbirth

Based on a small number of methodologically flawed studies, there is weak evidence of an association between low GWG and stillbirth. The guideline authors note that more recent studies do not support this association but additional detail is not provided.

Based on the limited evidence available, there is no association between GWG and general discomforts of pregnancy, fatigue, heartburn or gallstones prenatally; **birth defects; or the duration of exclusive or any breastfeeding**.(2)

For obese women there was no association between GWG below recommended and the following outcomes: induction of labour, foetal distress, operative vaginal delivery, postpartum haemorrhage, infant death, shoulder dystocia, Apgar score (<7 at 5 minutes), or neonatal intensive care unit admission, when compared to women who experienced GWG within the guidelines.(19)

There is inconclusive evidence regarding the association between GWG and pregnancy complications such as gestational diabetes and maternal hypertensive disorders.

Gestational diabetes mellitus (GDM)

There is weak evidence of an association between GWG and impaired glucose tolerance or GDM due to mixed study results and methodological limitations.(2) Guideline authors noted that history of diabetes, maternal age, parity and BMI are stronger predictors of abnormal glucose metabolism than GWG.(2) In one review, excessive GWG compared to non-excessive GWG (combining both recommended and inadequate GWG) prior to GDM screening, demonstrated that women who gained excessive GWG had an increased odds of being diagnosed with GDM (unadjusted OR 1.40; 95% CI 1.21 to 1.61).(17) These results were consistent in the sensitivity analysis of the four studies with adjusted data which compared excessive to non-excessive GWG.(17) However a sensitivity analysis comparing women who gained excessive GWG prior to screening for GDM with women who gained the recommended amount of weight found that there was no significant difference in the odds of developing GDM (unadjusted OR 1.18; 95% CI 0.89 to 1.55)[8].(17)

Hypertensive disorders during pregnancy

Studies investigating the relationship between GWG and hypertensive disorders during pregnancy have mixed results.(2) The link between high pre-pregnancy BMI and hypertensive disorders in pregnancy is well established, however the influence of GWG

[8] Adjusted data were not available for this analysis.

on pregnancy-induced hypertension, preeclampsia and eclampsia could not be determined from the available evidence.(2) In a more recent meta-analysis of secondary outcomes for obese pregnant women with inadequate gestational weight gain, results indicated that obese women who gained below recommended weight during pregnancy had lower odds of gestational hypertension (AOR 0.70; 95% CI 0.53 to 0.93) and of preeclampsia (AOR 0.90; 95% CI 0.82 to 0.99) than obese women who gained within the guidelines.(19)

The evidence is inconclusive regarding an association between GWG and instrumental delivery or infant's Apgar score.

Findings on the relationship between GWG and instrumental delivery are mixed, with some research demonstrating that high GWG is associated with increased risk of instrumental delivery and other studies showing no association.(2) There is also weak evidence that excessive GWG is associated with low Apgar score.(2)

Currently, there is insufficient evidence to determine whether maternal mortality, perinatal mental health, or long term maternal outcomes such as Type 2 diabetes, cardiovascular disorders or cancer are consequences of GWG.(2)

For the infant, there is insufficient evidence to determine if GWG is associated with neonatal body composition, infant weight gain or long term outcomes such as neurodevelopment, allergies, asthma, cancer, or attention deficit hyperactivity disorder (ADHD).(2)

Specifically for obese women, there was no evidence available regarding the association between low GWG and secondary outcomes such as: placenta previa

or abruption, chorioamniotis, premature rupture of membranes, cephalopelvic disproportion, perinatal mortality, very LBW or extreme LBW, breastfeeding initiation, severe neonatal morbidity or postpartum increase in obesity class for the mother. (19)

In summary, excessive or inadequate GWG can influence the health of both a mother and her infant. Maternal outcomes associated with high gestational weight gain include caesarean birth and weight retention in the intermediate postpartum period. Low GWG is associated with failure to initiate breastfeeding. For the infant, there is a positive association between GWG and birth weight; as well as moderate evidence that GWG is associated with preterm birth, neonatal death, and overweight or obesity in childhood. The evidence is inconclusive regarding the relationship between GWG and key outcomes of interest to PPH such as GDM or pregnancy induced hypertension however the IOM guideline states that pre-pregnancy BMI is an important risk factor for both these complications during pregnancy.(2) The available evidence does not use appropriate GWG as the main exposures of interest and therefore we cannot determine whether GWG within the recommended range would prevent or reduce the risk of adverse pregnancy outcomes.

11 Applicability and Transferability

A tool for assessing the applicability and transferability (A&T) of research evidence (22) was adapted to consider the findings and recommendations from this report with our local context. A summary of key points from facilitated discussions[9] with internal and

[9] There were two meetings to discuss the applicability (feasibility) and transferability (generalizability) of the recommendations with: 1) Peel Public Health staff involved in reproductive health and healthy eating for adults on November 24, 2016; 2) Internal and external partners including a midwife, obstetrician, family physician and hospital manager on November 29, 2016.

external stakeholders is provided below:

- **Political acceptability**: The issues of pre-pregnancy BMI and GWG fall within the scope of Nurturing the Next Generation (NTNG) and Supportive Environments for Healthy Living (SEHL), two strategic program priorities at Peel Public Health (PPH). Regional Council has been informed that both preconception obesity and GWG are problems in Peel and there is support to address these issues. Health practitioners (e.g., physicians, midwives, etc.) were enthusiastic about public health's attention to these issues given the prevalence of obesity and excessive GWG observed in their practice.

- **Social acceptability**: Weight is a sensitive topic for women and concerns were raised about the unintended consequences of messaging about healthy weight gain in pregnancy (e.g., preoccupation with weight, body image). Internal and external health care providers felt it was an issue to discuss at an individual level. We also need to consider the influence of ethno cultural background on GWG. There are many misconceptions about diet and exercise during pregnancy and there is value in providing a credible and consistent source of information. Women and their partners may be more motivated to make lifestyle changes during pregnancy; however, they attend prenatal education classes too late to influence GWG. Messaging about healthy weights before and during pregnancy should be delivered in the preconception and early prenatal periods.

- **Organizational expertise and capacity**: Weight gain during pregnancy is addressed in PPH's reproductive health programming (e.g., adult prenatal

classes, Healthy Start, Teen Prenatal Supper Club, prenatal e-learning) but it is not a primary focus. Prenatal and postpartum messages could be further incorporated into these curricula, the ParentinginPeel website, just in time text messaging intervention, and/or the Family Health Nursing Practice Standards.

Collaboration with the Chronic Disease and Injury Prevention (CDIP) Division at PPH is essential to promote healthy BMI in the preconception and postpartum periods. CDIP is focused on creating environments that support healthy living rather than individual behaviour change. Language about weight before, during and after pregnancy would need to be considered given that CDIP does not use the terms BMI or healthy weights. However, pregnant women are a distinct population and may need more focused messaging. In addition, collaboration with the Healthy Sexuality program at PPH regarding preconception health could be explored. Provincially, the implementation of the new Ontario Perinatal Record may create an opportunity to raise awareness about pre-pregnancy BMI and GWG among health professionals and could lead to enhanced data quality.

- **Resources**: A review of reproductive health programming at PPH is underway and this could create opportunities to expand work to address pre-pregnancy BMI and GWG. Internal and external stakeholders indicated that Canada's Food Guide is a commonly referred to resource for pregnant women. This resource is currently under review by Health Canada and PPH could advocate for the development of supplementary resources tailored for prenatal nutrition. Participants agreed that access to nutritional support in the community is limited

and online resources for nutrition and physical activity during and after pregnancy would be beneficial.

- **Target population characteristics:** Approximately 31% of live births in Peel were to South-Asian-born mothers (23). Data on pre-pregnancy BMI and GWG by ethnicity is not available. The research evidence provided limited information about the ethno cultural background of study participants and findings may not be generalizable to our diverse community. Many women are getting pregnant later in life therefore age may be a factor associated with both pre-pregnancy BMI and GWG. Additional factors to consider include poverty (socioeconomic status) and parity. Health care providers cautioned against grouping together overweight and obesity prior to pregnancy since obesity has different health risks, and healthy women can be classified as overweight.

- **Reach:** Cooperation between primary health care, obstetricians and midwives would be required to reach women with messaging and/or resources about healthy weights during and after pregnancy.

In summary, both primary care and public health agree that pre-pregnancy BMI and GWG are problems in Peel that require action. There was consensus that population health approaches should focus on women entering pregnancy at a healthy weight. Next steps will require collaboration between primary care and PPH.

12 Recommendations

Given that excessive or inadequate GWG can influence specific maternal or infant health outcomes, it is recommended that Peel Public Health:

1. Continue to monitor provincial and local data on maternal pre-pregnancy BMI and GWG and associated health outcomes to observe and report on trends.

2. Advocate at the provincial and local levels for:

    a. BORN Ontario to include demographic information (e.g., ethnicity) in the public health unit BORN data cube.

    b. Health care professionals, hospital partners and midwifery practice groups to report on pre-pregnancy BMI and GWG collected at uniform time points using objective measurements of height and weight.

3. Identify effective interventions to influence:

    a. Pre-pregnancy BMI for women of childbearing age.

    b. Healthy weight gain during pregnancy.

4. Identify opportunities for partnerships and collaborate with relevant internal and external stakeholders.

5. Review and modify (where appropriate) messaging about healthy weight gain during pregnancy.

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12) Distribution of gestational age at birth in completed weeks, by public health unit and province (Standard Report), BORN Information System (BIS), BORN Ontario. Information accessed on July 6, 2016.

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Appendices

Appendix A: Recommended Weight Gain During pregnancy

Appendix B: Maternal weight and Gestational Weight Gain in Peel

Appendix C: Concept Model

Appendix D: Search Strategy

Appendix E: Literature Search Flowchart

Appendix F: Data Extraction Tables

Appendix G: Synthesis Table

Appendix H: Applicability & Transferability Worksheet

Appendix A:

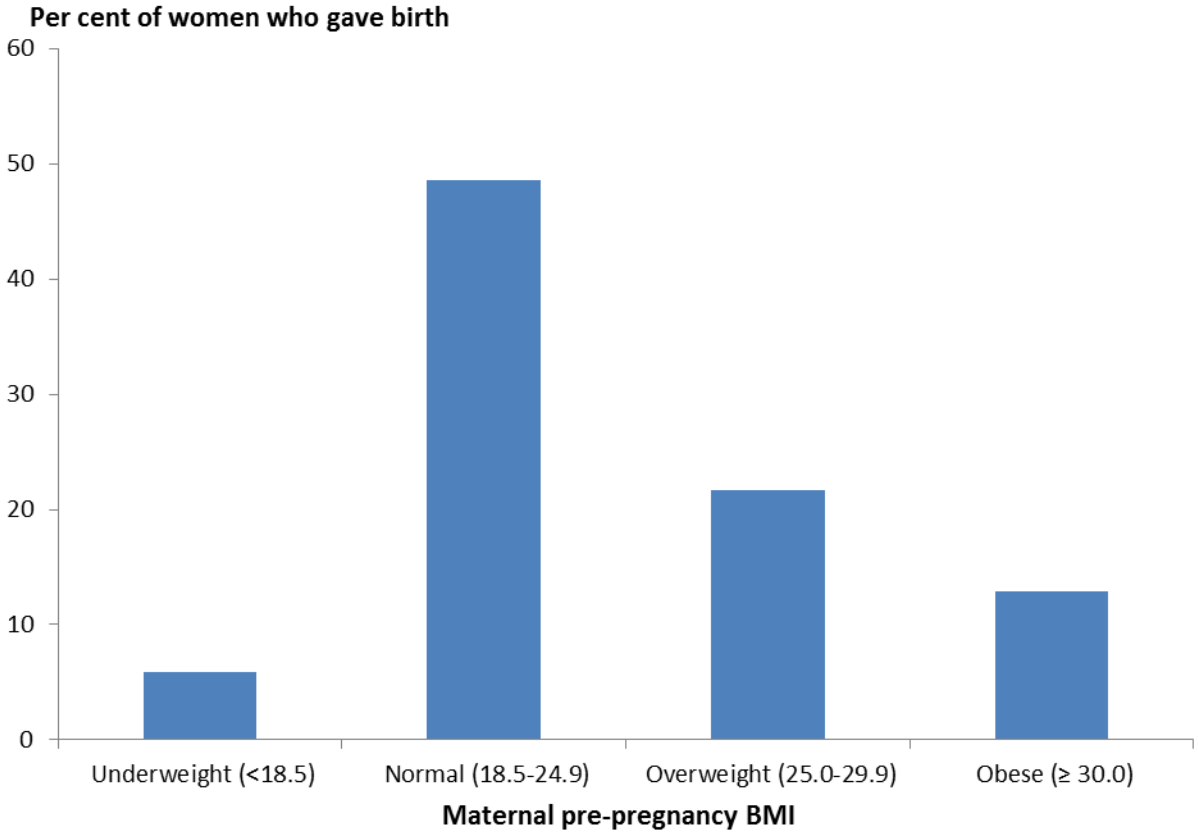
Table 1
Institute of Medicine (IOM) Guideline (2) on Total and Rate of Weight Gain During Pregnancy, by Pre-Pregnancy BMI

Pre-pregnancy BMI	Recommended total weight gain		Rate of weight gain 2nd & 3rd trimesters	
	Range in Kg	Range in lbs	Mean (range) kg/week	Mean (range) lbs/week
Underweight (<18.5)	12.5-18	28-40	0.51 (0.44-0.58)	1 (1-1.3)
Normal (18.5-24.9)	11.5-16	25-35	0.42 (0.35-0.50)	1 (0.8-1)
Overweight (25.0-29.9)	7-11.5	15-25	0.28 (0.23-0.33)	0.6 (0.5-0.7)
Obese (≥30.0)	5-9	11-20	0.22 (0.17-0.27)	0.5 (0.4-0.6)

Source: Institute of Medicine. Weight Gain During Pregnancy: Reexamining the Guidelines. United States of America; 2009. Available from: https://iom.nationalacademies.org/Reports/2009/Weight-Gain-During-Pregnancy-Reexamining-the-Guidelines.aspx

Appendix B:

Figure 1
Distribution of Maternal Pre-Pregnancy Body Mass Index (BMI), Peel, 2014



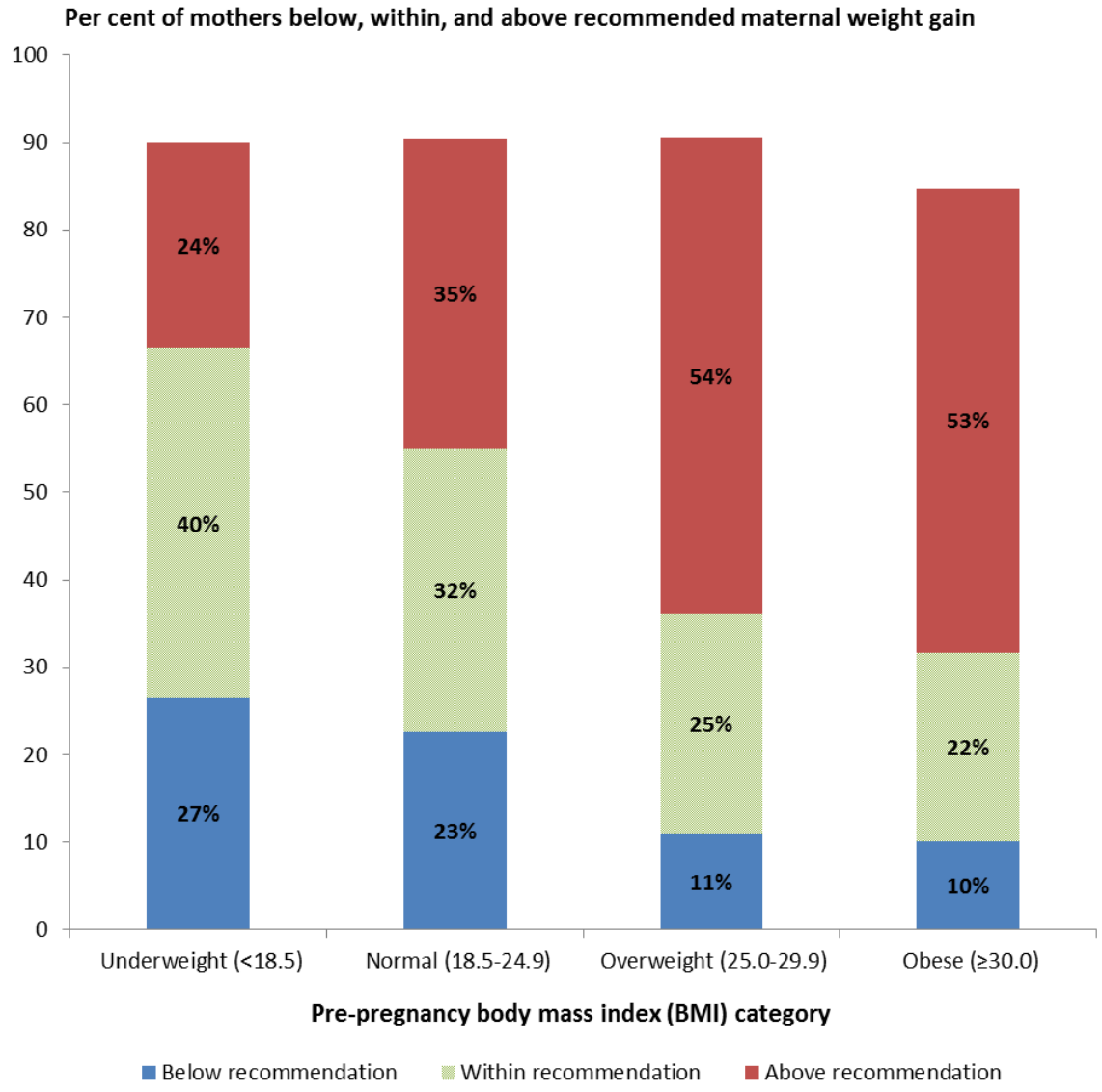
Notes: Use estimates with caution. Maternal Pre-pregnancy BMI category was missing for 10.8% of records in Peel in 2014.
In this region, we are able to report on 51% of women who have a pre-pregnancy BMI or gestational weight gain recorded in the BORN Information System for 2014.
Source: Public Health Unit Analytic Reporting Tool (Cube), BORN Information System (BIS), BORN Ontario. Information accessed on January 25, 2016.

Table 2
Maternal Pre-Pregnancy Body Mass Index (BMI) and Maternal Weight Gain by Institute of Medicine (IOM) Guideline Recommendations for Singleton Live Births, Peel, 2014

Total weight gain by IOM Guideline (2009)	Women by maternal pre-pregnancy BMI category (kg/m^2)								Total number of women
	Underweight (<18.5)		Normal (18.5-24.9)		Overweight (25.0-29.9)		Obese (≥30.0)		
	Number	%	Number	%	Number	%	Number	%	
Below recommendation	117	26.5	819	22.6	176	10.9	98	10.2	1,210
Within recommendation	176	39.9	1,173	32.4	405	25.3	208	21.6	1,962
Above recommendation	104	23.6	1,278	35.3	870	54.3	512	53.1	2,764
Missing weight gain data	44	10.0	346	9.6	152	9.5	147	15.2	689
Total number of women	441		3,616		1,603		965		6,625

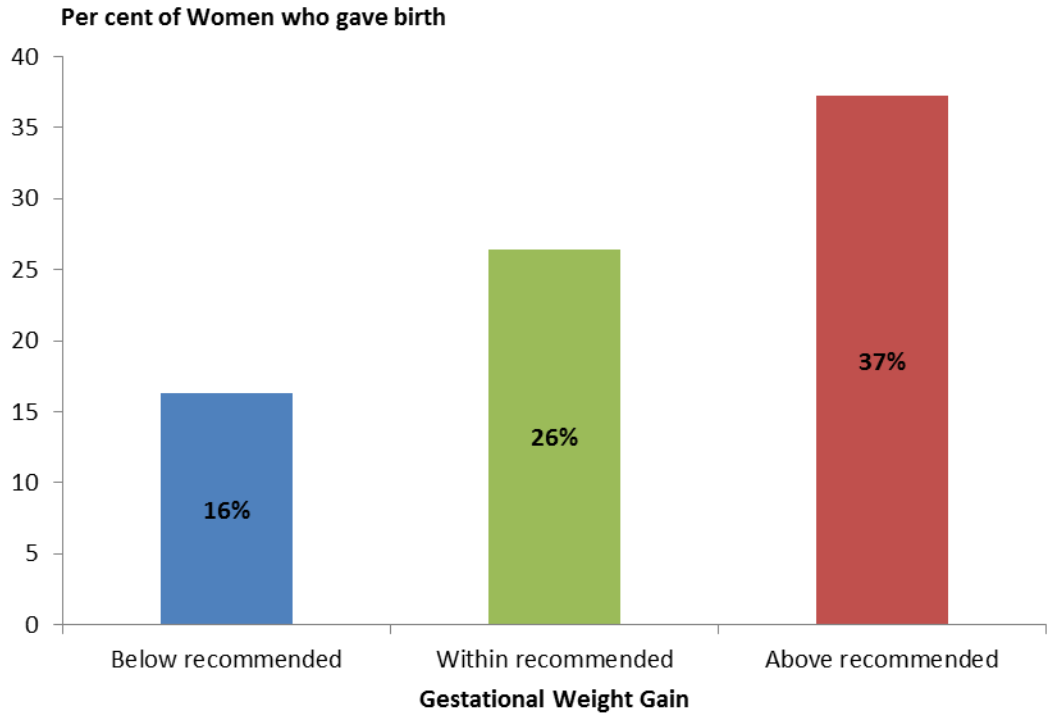
*Caution should be taken when interpreting data in the figure above. Missing responses are included for the main indicator presented. Maternal BMI Category was missing for 10.7% of singleton live birth records in Peel in 2014.
Note: In this region, we are able to report on 51% of women who have a pre-pregnancy BMI or gestational weight gain recorded in the BORN Information System for 2014.
BORN's Maternal Weight Gain Recommended Group variable best aligns with the recommended weight gain ranges outlined within the Institute of Medicine's (IOM) guideline. (4) Mothers who lost weight during their pregnancy were not included in the analysis.
Source: Public Health Unit Analytic Reporting Tool (Cube), BORN Information System (BIS), BORN Ontario. Information accessed on February 29, 2016

Figure 2
Distribution of Maternal Pre-Pregnancy Body Mass Index (BMI) and Maternal Weight Gain by Institute of Medicine (IOM) Guideline (2) Recommendations for Singleton Live Births,
Peel, 2014



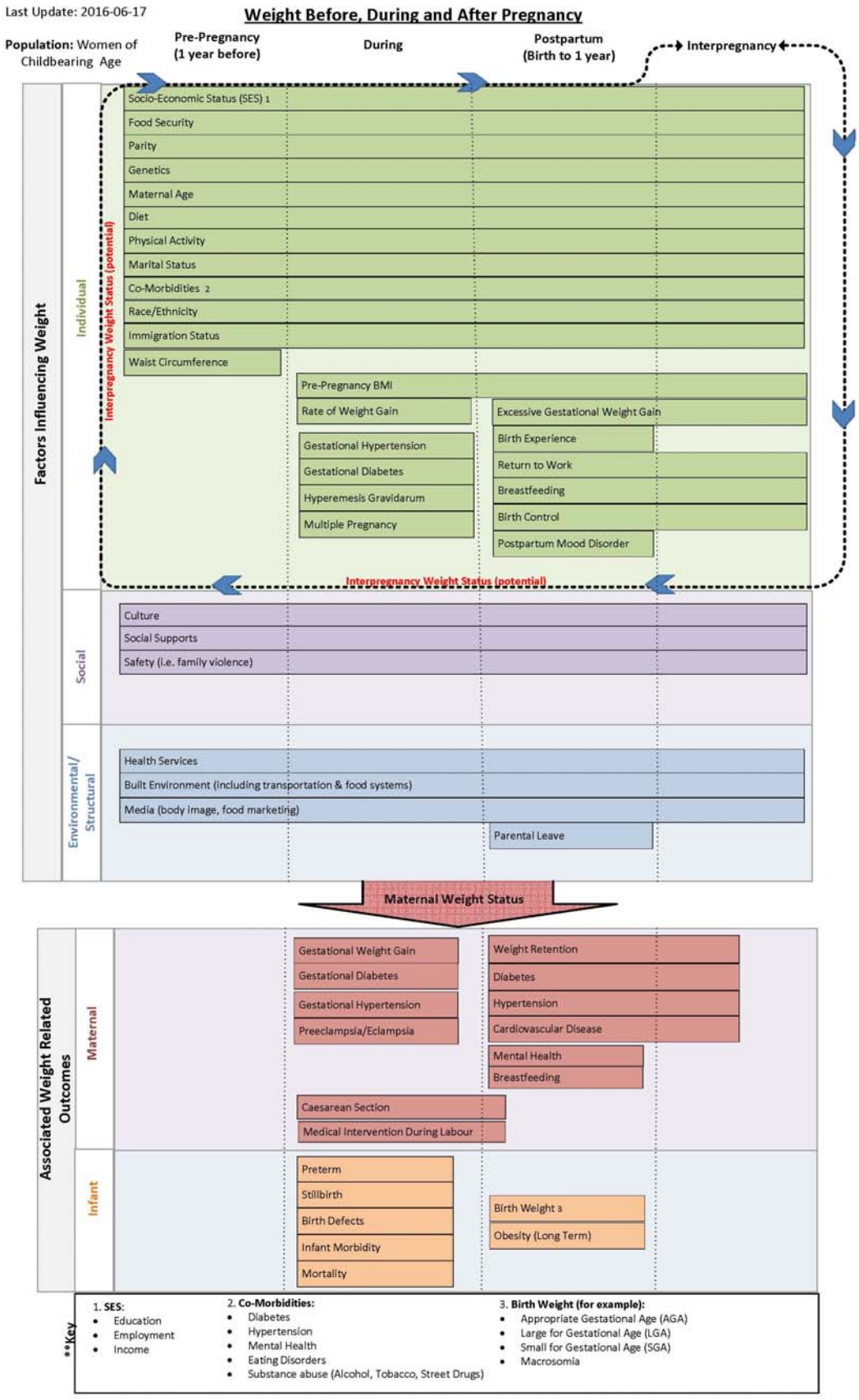
Notes: Maternal Pre-pregnancy BMI category was missing for 10.7% of singleton live birth records in Peel in 2014.
Where column totals do not sum to 100%, this reflects missing maternal gestational weight gain status data.
In this region, we are able to report on 51% of women who have a pre-pregnancy BMI or gestational weight gain recorded in the BORN Information System for 2014.
BORN's Maternal Weight Gain Recommended Group variable best aligns with the recommended weight gain ranges outlined within the Institute of Medicine's (IOM) guideline. (2) Mothers who lost weight during their pregnancy were not included in the analysis.
Source: Public Health Unit Analytic Reporting Tool (Cube), BORN Information System (BIS), BORN Ontario. Information accessed on February 29, 2016.

Figure 3
Distribution of Maternal Weight Gain by Institute of Medicine (IOM) Guideline Recommendations for Singleton Live Births,
Peel, 2014



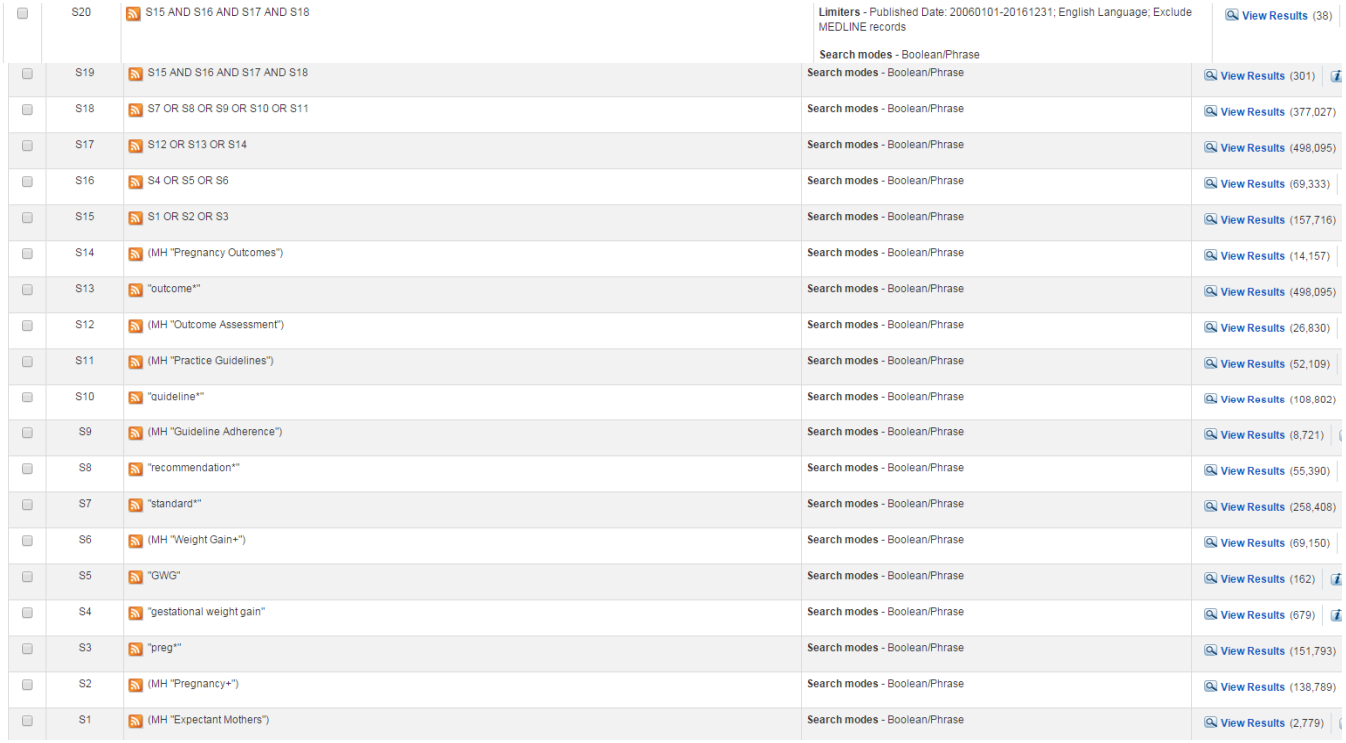
Caution should be taken when interpreting data in the figure above. Missing responses are included for the main indicator presented. Maternal gestational weight gain was missing for 20.0% of records in Peel in 2014.
Note: In this region, we are able to report on 51% of women who have a pre-pregnancy BMI or gestational weight gain recorded in the BORN Information System for 2014.
BORN's Maternal Weight Gain Recommended Group variable best aligns with the recommended weight gain ranges outlined within the Institute of Medicine's (IOM) guideline. (2) Mothers who lost weight during their pregnancy were not included in the analysis.
Source: Public Health Unit Analytic Reporting Tool (Cube), BORN Information System (BIS), BORN Ontario. Information accessed on March 3, 2016.

Appendix C: Concept Model



Appendix D: Search Strategy

CINAHL – May 2, 2016



S20	S15 AND S16 AND S17 AND S18	**Limiters** - Published Date: 20060101-20161231; English Language; Exclude MEDLINE records **Search modes** - Boolean/Phrase	View Results (38)
S19	S15 AND S16 AND S17 AND S18	**Search modes** - Boolean/Phrase	View Results (301)
S18	S7 OR S8 OR S9 OR S10 OR S11	**Search modes** - Boolean/Phrase	View Results (377,027)
S17	S12 OR S13 OR S14	**Search modes** - Boolean/Phrase	View Results (498,095)
S16	S4 OR S5 OR S6	**Search modes** - Boolean/Phrase	View Results (69,333)
S15	S1 OR S2 OR S3	**Search modes** - Boolean/Phrase	View Results (157,716)
S14	(MH "Pregnancy Outcomes")	**Search modes** - Boolean/Phrase	View Results (14,157)
S13	"outcome*"	**Search modes** - Boolean/Phrase	View Results (498,095)
S12	(MH "Outcome Assessment")	**Search modes** - Boolean/Phrase	View Results (26,830)
S11	(MH "Practice Guidelines")	**Search modes** - Boolean/Phrase	View Results (52,109)
S10	"guideline*"	**Search modes** - Boolean/Phrase	View Results (108,802)
S9	(MH "Guideline Adherence")	**Search modes** - Boolean/Phrase	View Results (8,721)
S8	"recommendation*"	**Search modes** - Boolean/Phrase	View Results (55,390)
S7	"standard*"	**Search modes** - Boolean/Phrase	View Results (258,408)
S6	(MH "Weight Gain+")	**Search modes** - Boolean/Phrase	View Results (69,150)
S5	"GWG"	**Search modes** - Boolean/Phrase	View Results (162)
S4	"gestational weight gain"	**Search modes** - Boolean/Phrase	View Results (679)
S3	"preg*"	**Search modes** - Boolean/Phrase	View Results (151,793)
S2	(MH "Pregnancy+")	**Search modes** - Boolean/Phrase	View Results (138,789)
S1	(MH "Expectant Mothers")	**Search modes** - Boolean/Phrase	View Results (2,779)

Medline Suite – May 4, 2016

Database: EBM Reviews - Cochrane Database of Systematic Reviews <2005 to April 27, 2016>, Global Health <1973 to 2016 Week 16>, Ovid Healthstar <1966 to March 2016>, Ovid MEDLINE(R) <1946 to April Week 3 2016>, Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations <May 03, 2016>
Search Strategy:

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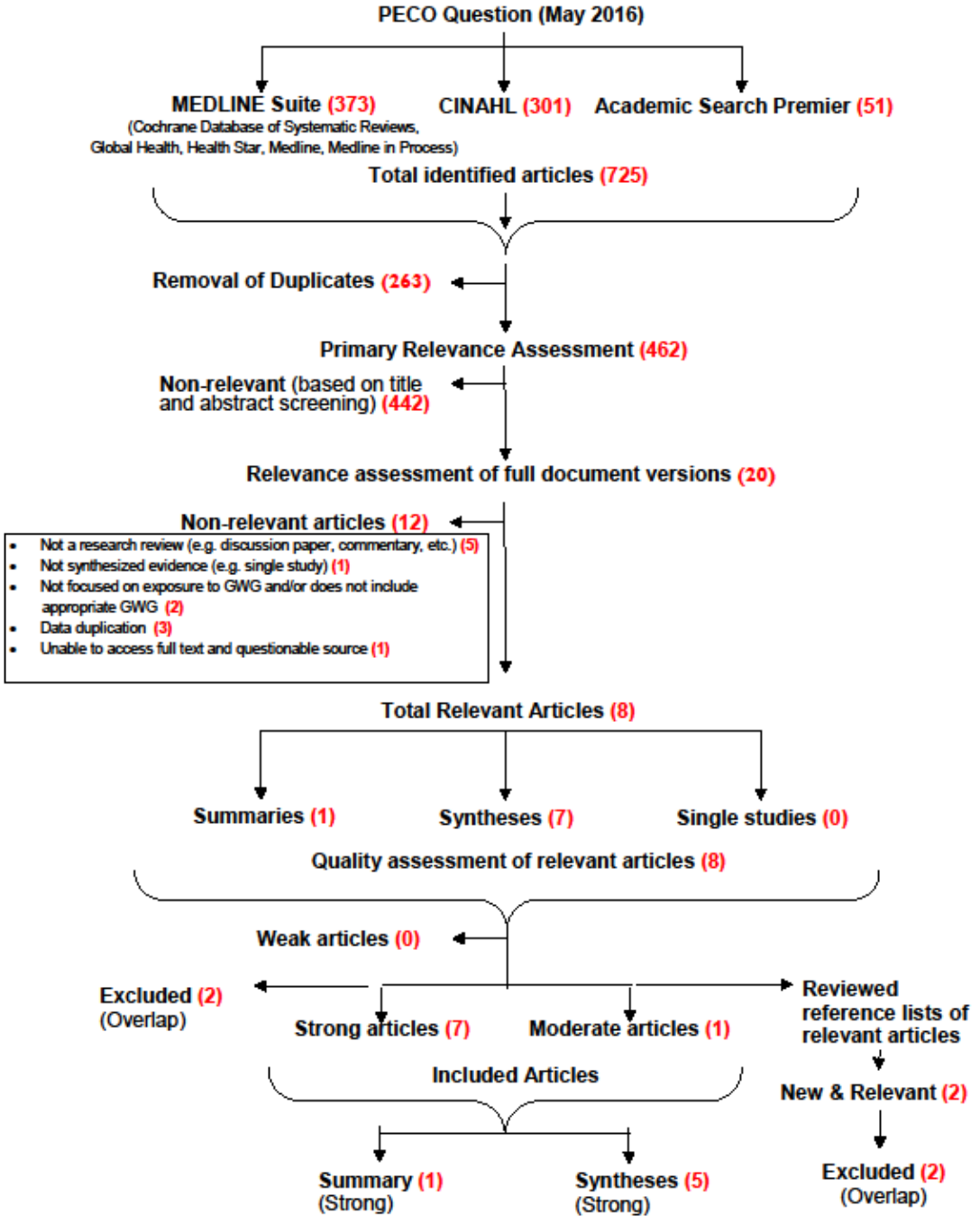
1 exp Pregnant Women/ (11936)
2 exp Pregnancy/ (1259910)
3 "preg*".ti,ab. (707473)
4 exp Weight Gain/ (48251)
5 "GWG".ti,ab. (1008)
6 "weight gain*".ti,ab. (92129)
7 exp Reference Standards/ (67725)
8 "standard*".ti,ab. (1724554)
9 "recommendation*".ti,ab. (364952)

10 "guideline*".ti,ab. (465515)
11 exp Guideline Adherence/ (49559)
12 exp Guideline/ (81854)
13 exp Practice Guideline/ (43269)
14 exp Practice Guidelines as Topic/ (186517)
15 1 or 2 or 3 (1414578)
16 4 or 5 or 6 (108831)
17 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 (2532543)
18 exp Patient Outcome Assessment/ (4128)
19 exp "Outcome Assessment (Health Care)"/ (1528629)
20 exp "Outcome and Process Assessment (Health Care)"/ (1577286)
21 "outcome*".ti,ab. (2172215)
22 exp Pregnancy Outcome/ (82524)
23 exp Odds Ratio/ (140052)
24 exp Logistics Models/ (0)
25 exp Multivariate Analysis/ (198026)
26 exp Retrospective Studies/ (1087417)
27 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 (4042241)
28 15 and 16 and 17 and 27 (1584)
29 limit 28 to (english language and yr="2006 -Current") [Limit not valid in CDSR; records were retained] (1254)
30 ("review*" or "meta analys*" or "synthes*" or "guideline*").af. (7345118)
31 29 and 30 (800)
32 remove duplicates from 31 (373)
****

Academic Search Premiere – May 5, 2016

#	Query	Limiters/Expanders	Last Run Via	Results
S9	S1 AND S7 AND S8	Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Premier	51
S8	S4 OR S5 OR S6	Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Premier	2,006,409
S7	S2 OR S3	Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Premier	667,948
S6	AB "narrative"	Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Premier	84,029
S5	SU "review*" OR "meta*"	Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Premier	1,072,119
S4	TI "review*" OR "meta*"	Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Premier	1,101,035
S3	"preg* outcome*"	Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Premier	8,827
S2	"outcome*"	Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Premier	667,948
S1	"gestational weight gain"	Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Premier	811

Appendix E: Literature Search Flowchart



Adapted from: healthevidence.org *Keeping Track of Search Results: A Flowchart.* [Retrieved January 13, 2010]

Appendix F: Data Extraction Tables

Data Extraction	
Last revised: October 28, 2016	
Guideline #1 Weight Gain During Pregnancy: Reexamining the Guidelines http://iom.nationalacademies.org/en/Reports/2009/Weight-Gain-During-Pregnancy-Reexamining-the-Guidelines.aspx	
General Information and Quality Rating	
Author(s) and Date	Institute of Medicine, 2009
Country	United States of America
Quality Rating using AGREE II Tool	Rated 6/7 (strong) and recommended for use by two independent appraisers (JM & SL) using AGREE II tool. The critical appraisal revealed that the editorial independence of the guideline developers is not discussed and a schedule for updating the guideline is not provided.
Generalizability to local population	These guidelines are intended for use among women in the United States. They may be applicable to women in other developed countries however they are not intended for use in areas of the world where women are substantially shorter or thinner than American women or where adequate obstetric services are unavailable. (p. 242)
Details of Guideline	
Objective	To review evidence on the relationship between weight gain patterns before, during and after pregnancy and maternal and child health outcomes; consider factors within a life-stage framework associated with outcomes; and recommend revisions to existing guidelines where necessary.
Target Audience	Health care providers, those who provide prenatal care, federal, state and local agencies, private voluntary organizations, medical and public health organizations.
Evidence used to develop this guideline	• Systematic review of outcomes of gestational weight gain (6) • Literature review (of studies published before or after the date limits used for the systematic review). • Consultation with experts • Four additional data analyses commissioned by the guideline developers: i. Analyses from the Danish National Birth Cohort on low and very high categories of gestational weight gain (GWG), as well as data for obese class I, II and III women and subgroups pregnant women, such as primiparous, short and young women, and smokers. ii. Analysis of data from the 1988 National Maternal and Infant Health Survey (NMIHS) on the association between GWG and pregnancy outcomes by race and on the association between GWG and postpartum weight retention. iii. Data on adverse outcomes associated with GWG stratified by

	racial/ethnic group using births data from 1995-2003 in New York City. iv. Quantitative analysis of risk trade-offs between maternal and child health outcomes associated with GWG.
Focus of the systematic review and literature review that informed this guideline	1. Systematic review • Outcomes of gestational weight gain with specific attention to: o Weight gain during pregnancy and association with i) birth outcomes, ii) infant health outcomes, and iii) maternal health outcome and their confounders and effect modifiers. o Gestational weight gain within or outside the 1990 Institute of Medicine (IOM) guidelines for weight gain during pregnancy. o Risks and benefits of weight gain recommendations for pregnant women. o Anthropometric measure of weight gain in pregnancy. 2. Literature review • Consequences of gestational weight gain for the mother and infant described in literature published before and after the date limits used for the systematic review.
Date of Search	1. 1990-October 2007 2. Before 1990, after October 2007 until 2009
Databases Searched	1. Systematic review • MEDLINE, Cochrane Collaboration, CINAHL, EMBASE. • Hand-searched reference lists of relevant articles and consulted with experts to identify any additional studies or any research underway and not yet published. 2. Medline, Science Direct, WorldCat/First Search
Inclusion and Exclusion Criteria	Systematic review & literature review: Inclusion: women of any age with singleton pregnancies, pre-pregnancy body mass index (BMI) or weight must be accounted for in relationship between maternal weight gain and outcome, studies conducted in developed nations: United States, Canada, Western Europe, Japan, Australia, New Zealand, publication after 1990 (when last guidelines for GWG were released),English language, Study designs: Systematic reviews, meta-analyses, Controlled trials (n≥40), nonrandomized controlled trials (n≥40), prospective trials with historical controls (n≥40), prospective or retrospective observational cohort studies (n≥40), and medium to large case series (n≥100) Exclusion: studies with a small sample size (case series <100 and cohorts <40), studies that failed to control for pregravid weight, studies limited to women with pre-existing health conditions
Number of Studies	1. Systematic review • 150 studies 2. Literature review • 33 additional studies not included in the systematic review
Types of Studies included	Systematic review & literature review • RCTs, Prospective cohort, retrospective cohort and case-control studies
Quality of included	• A quality assessment tool for observational studies was adapted from

studies	Downs & Black, 1998 and Deeks et al., 2003. The quality assessment form included nine key domains: background, sample selection, specification of exposure, specification of outcome, soundness of information, follow up, analysis comparability, analysis of outcome and interpretation. • Studies were rated for each domain as good, fair or poor and then overall as: o Good – 5 or more good ratings and no poor ratings on subdomains o Fair - < 5 good ratings and <3 poor ratings on subdomains; 5 or more good ratings and any poor ratings. o Poor – 3 or more poor ratings on subdomains • Strength of Available Evidence was determined based on quality of the research, quantity of studies (including # of studies and adequacy of the sample) and consistency of the findings. I. **Strong**: The evidence is from studies of sound design (good quality); results are both clinically important and consistent with minor exceptions at most; results are free from serious doubts of generalizability, bias or flaws in research design. Studies with negative results have sufficiently large samples to have adequate statistical power. II. **Moderate**: The evidence is from studies of sound design (good quality), but some uncertainty remains because of inconsistencies or concern about generalizability, bias research design flaws, or adequate sample size. Alternatively, the evidence is consistent but derives from studies of weaker design (fair quality). III. **Weak**: The evidence is from a limited number of studies of weaker design (fair or poor quality). Studies with strong design (good quality) either have not been done or are inconclusive. IV. No evidence: No published literature.
Consequences of Gestational Weight Gain for the Mother and Child included in the Guideline	
Relevant recommendations	Action recommendation 5-1: The committee recommends that appropriate federal, state and local agencies as well as health care providers inform women of the importance of conceiving at a normal BMI and that all those who provide health care or related services to women of childbearing age include preconceptual counselling in their care.
Main results	**Note:** For many of the outcomes discussed in this guideline, summary effect sizes were not calculated and are not reported. For some specific infant outcomes, a range of the effect sizes were noted in the guideline in which case they were included in this table. Results of individual studies included in the systematic review that informed the guideline are appended to the guideline. <u>Consequences of gestational weight gain for the mother</u> *Prenatal Period* **Gestational Diabetes Mellitus (GDM) and impaired glucose tolerance**

	• There is **weak** evidence in support of association between gestational weight gain and development of either GDM or impaired glucose intolerance. (11 studies) o GWG above the recommended range (based on IOM, 1990) was positively associated with abnormal glucose tolerance in four studies (1 good, 2 fair, and 1 poor quality). o GWG below the recommended range was associated with increased likelihood of GDM in three studies (1 good, 1 fair, and 1 poor quality) o Four studies concluded was no significant association between GWG and glucose tolerance (2 fair, 2 poor) o Authors note that all but one of these studies had the major limitation that total GWG was used as the exposure rather than weight gain until the time of diagnosis with abnormal glucose metabolism. o The guideline authors note that based on the evidence systematically reviewed to inform this guideline, history of diabetes, maternal age, parity and pre-pregnancy BMI were stronger predictors of abnormal glucose metabolism than GWG. **Hypertensive Disorders during Pregnancy** (pregnancy induced hypertension, preeclampsia, and eclampsia) • Fourteen studies examined the association between GWG and hypertensive disorders with mixed results. o Five studies examined the relationship between GWG and **pregnancy-induced hypertension** (2 fair and 3 poor quality). All five studies differed in their control of confounders. Two of these five studies reported an association between higher GWG and pregnancy-induced hypertension o Ten studies explored the association between weight gain during pregnancy and **preeclampsia** (7 fair and 3 poor quality). Six of these ten studies found an association between higher total GWG and increased risk of preeclampsia. The remaining four studies found that lower total weight gains were protective for preeclampsia but did not find an association with higher total GWG. o Two additional studies found that GWG above recommended was associated with increased risk of preeclampsia among overweight women (quality not described). **Maternal mental health during pregnancy** • There was no data available on the relationship between GWG and maternal mental health. **Other antepartum outcomes** (8 studies - 3 fair and five poor quality) • There is a weak association between higher GWG and stretch marks (2 studies) • There is an increased likelihood of antenatal admissions for hyperemesis among women who gained <7kg total (1 study) • There was no association between higher GWG and general

	discomforts, physical energy and fatigue, stretch marks, heartburn or gall stones. *Delivery* **Induction of labour** • There is **weak** evidence of an association between high gestational weight gain and induction or failure of labour induction. (5 studies – 2 fair and 3 poor quality) **Length of labour** • There is **weak** evidence of an association between high gestational weight gain and longer duration of labour (3 studies – 2 fair and 1 poor quality) **Mode of delivery** • There is **moderate** evidence of an association between high gestational weight gain (as a continuous or categorical variable) and **caesarean delivery** (21 studies – 14 fair and 7 poor quality). o Only 10/21 studies controlled for mode of previous delivery among multiparous women, and only 5 out of these 10 studies controlled for comorbidities. o Of these 21 studies, only four did not demonstrate a relationship between GWG and caesarean delivery. o In those studies that also examined instrumental delivery as an outcome, higher GWG was associated with **instrumental delivery** in three of these studies, but there was no association in two studies. o There was **moderate** evidence that among normal and underweight women, that excessive GWG (categorized according to IOM (1990) recommendations) was associated with caesarean delivery. There was **weak** evidence that excessive GWG (categorized according to IOM (1990) recommendations) was associated with caesarean delivery among obese women (8 studies) **Maternal Mortality** • There was no evidence available on the relationship between GWG and maternal mortality. *Postpartum period* **Lactation** • There is **moderate** evidence that low GWG is associated with decreased initiation of breastfeeding. • There is **weak** evidence of an association between GWG and duration of exclusive or any breastfeeding (4 studies – all fair quality). o Three of these studies found that obese women had a shorter duration breastfeeding regardless of GWG. • One additional cross-sectional study found that women with a high pre-pregnancy BMI were less likely to initiate breastfeeding but that GWG was not associated with initiation or duration of breastfeeding (quality not provided).

	Postpartum weight retention (PPWR) Short term (≤11 weeks) • In the short term, there is **weak** evidence of a relationship between GWG as a continuous variable and postpartum weight (1 study – fair quality). However there was **moderate** evidence that GWG exceeding the IOM (1990) recommendations is associated with postpartum weight retention irrespective of a woman's age (4 studies – 4 fair quality). Intermediate term (3 months to 3 years) • In the intermediate term, there is **moderate** evidence that high GWG is associated with an increase in postpartum weight retention (5 studies – 1 good, 3 fair and 1 poor quality). There is also **moderate** evidence that women who gained above the IOM (1990) guidelines retained more weight postpartum compared to women who gained within the recommended range (6 studies – 5 fair and 1 poor quality). o Covariates such as nutrition, exercise and breastfeeding were not adjusted for consistently in this body of evidence. In addition, only one study included various racial/ethnic groups. Long term (>3 years) • The evidence is less conclusive regarding a relationship between GWG and postpartum weight retention in the long term. o Two studies (1 good, 1 fair quality) found **weak** evidence of an association between high GWG and postpartum weight retention long term. o There was **moderate** evidence from three studies (all fair quality) that GWG above recommended was associated with greater postpartum weight retention the magnitude of the weight increase was small. • Four additional studies (quality not provided) strengthen the evidence regarding an association between GWG and postpartum weight retention in the intermediate period. Maternal fat gain • There is **weak** evidence that GWG exceeding IOM (1990) recommendations is associated with increased maternal fat gain (2 studies– 2 fair quality) **Postpartum depression** • There was no evidence available on the relationship between GWG and postpartum depression. *Long-term consequences* • There is insufficient evidence available to determine if there is an association between GWG and long-term health consequences for the mother such as type 2 diabetes (no studies), cardiovascular disorders (no studies), mental health issues (2 studies), or cancer (1 study). o There is **weak** evidence of an association between

	postpartum weight retention up to 1 year after delivery and self-esteem/depression (2 studies – quality not provided but it is noted these studies did not control for pre-pregnancy BMI). • There is **weak** evidence and inconsistent findings regarding an association between GWG and risk of **breast cancer** (2 studies – 1 fair quality, 1 quality not provided). o One study found that after adjustment for pre-pregnancy BMI, the risk of postmenopausal breast cancer was 1.62 (95% CI: 1.02 to 2.53) among women with GWG >15 kg. o Another study found that among premenopausal women, risk of premenopausal breast cancer were reduced for women with GWG >16kg and an increase in BMI >7kg/m^2 after age 20.
	<u>Consequences of gestational weight gain for the infant</u> **Stillbirth** (pregnancy loss after 20 weeks gestation) • There is **weak** evidence of an association between low GWG and stillbirth (3 studies – 2 fair, 1 poor). The literature on which these findings were based was methodologically flawed with poor control for confounding. • Recent, better quality research does not support an association between GWG and stillbirth. **Birth defects** • Limited evidence does not support an association between GWG and birth defects. **Infant mortality** • There is **moderate** evidence of an association between GWG and infant mortality based on results from one good quality study. o Among underweight and normal weight women, low GWG was associated with increased odds in infant mortality on the order of 3-4 compared to those with the highest GWG. The effect diminishes with increasing pre-pregnancy BMI (one study). o More specifically, low GWG was more strongly associated with neonatal death (in first 30 days of life) than post-neonatal deaths (after 1 month). In the lowest weight gain group, the odd of neonatal death were 3.6 among underweight women, 3.1 among normal weight women, 2.0 among overweight women and 1.2 among obese women demonstrating a diminishing effect of low GWG on neonatal death with increasing pre-pregnancy BMI (one study). o In contrast, the highest category of total GWG was more strongly associated with neonatal death with increasing pre-pregnancy BMI (OR for neonatal death among women who gained ≥18kg was 1,1.2, 1.4 and 1.8 for underweight, normal weight, overweight, and obese women respectively) (one study).

	<u>Fetal growth</u> • Overall, there is **strong** evidence that GWG is associated with birth weight for gestational age. The entire birth weight distribution is shifted upward. A higher GWG reduces the risk of SGA and increases the risk of LGA as the mean birth weight increases. o There is **moderate** evidence that this trend is more pronounced among women with a low pre-pregnancy BMI. o It is unclear whether other factors are impacting the relationship between GWG and birth weight for gestational age such as ethno cultural background, smoking status or maternal lifestyle. **Birth weight** • Higher GWG is associated with increased infant birth weight (25 studies – 4 good, 12 fair, 9 poor quality studies) • The risk of **low birth weight** (LBW, defined as <2,500g) is decreased as GWG increases (13 studies – 1 good, 9 fair, 3 poor quality studies) • The magnitude of the association varied across the studies but the guideline authors note that in general the highest GWG category had roughly half the risk of LBW compared to the lowest GWG category. • The risk of **macrosomia** (defined as birth weight >4,000g or >4,500g) increases as GWG increases. (12 studies – 1 good, 9 fair, 2 poor quality studies). o The risk of macrosomia was roughly 2-3 times greater in the highest GWG category compared to the lowest GWG category. **SGA** • Higher GWG is associated with decreased risk of SGA (20 studies – 1 good, 12 fair, 7 poor quality studies) o The guideline authors estimate that across studies the relative risk of SGA with low GWG is 2 to 3. o Of the six studies that stratified analyses by pre-pregnancy BMI, lower GWG was associated with an increased risk of SGA; however the results did not suggest that pre-pregnancy BMI modified the relationship. **LGA** • In general there were consistent findings of a positive association between increasing GWG and an increased risk of LGA (10 studies – 6 fair, 4 poor quality studies) o The guideline authors note that for each 1 kg increase in GWG, the risk of LGA may be increased a factor of 1.1. o The effect of GWG on LGA did not differ for pre-pregnancy BMI categories except for a modest increase in the strength of the association between high GWG and LGA among women with a low pre-pregnancy BMI. **Preterm birth** (<37 weeks gestation) (12 studies; 2 commissioned data analyses) • Overall, there is **strong** evidence of a u-shaped association between lower GWG and preterm birth among normal weight and underweight

	women and **moderate** evidence of an association between higher GWG and preterm birth. o The authors note that the magnitude of the association is fairly strong with relative risks on the order of two but difficult to summarize because of variability in the definitions of higher and lower rates of GWG. • Preterm birth is associated with both low and high rates of GWG (12 studies – 2 good, 7 fair and 3 poor). o 5 of 12 studies examined the effect modification of pre-pregnancy BMI on this relationship and results were consistent that a lower rate of GWG had a strong effect on preterm birth among underweight women. As pre-pregnancy BMI increases the risk of preterm birth associated with lower rate of GWG diminishes. ▪ There was some evidence that the increased risk of preterm birth associated with a high rate of GWG was greater with increasing pre-pregnancy BMI. ▪ 4/5 of these studies reported the greatest risk of preterm birth associated with inadequate GWG among underweight and normal weight women. o In those studies that compared higher and lower GWG to the middle range, the risk of preterm birth was in the range of 1.5 to 2.5 for both the higher and lower GWG groups with greater consistency of the influence of lower GWG on preterm birth. • Two additional data analyses commissioned by the guideline development committee indicate that pre-pregnancy BMI is predictive of both preterm birth (higher risk with lower BMI) and GWG (higher GWG with lower BMI). These analyses demonstrate a modest u-shaped relationship between rate of net weight gain and risk of preterm birth. **Neonatal body composition** • There is insufficient evidence regarding the relationship between GWG and infant body composition from birth onwards. o Among overweight/obese women, higher GWG was correlated with more newborn fat mass when controlling for pregravid weight, however no correlation was found among underweight/normal weight women (one study – quality not provided). o Two other studies found a direct association between GWG and lean and fat mass at birth among diabetic and non-diabetic mothers when analyses were adjusted for pre-pregnancy weight, gestational age, smoking, and family history of diabetes. **Infant weight gain** • There is a lack of evidence on the relationship between GWG and infant weight gain.

	Apgar score • There is **weak** and inconsistent evidence that GWG is associated with the infant's Apgar score (5 studies – 4 fair, 1 poor). **Breastfeeding initiation and maintenance** • No evidence was identified regarding the relationship between GWG and breastfeeding related outcomes in the infant. **Childhood obesity** • The limited evidence available is suggestive (but not conclusive) that GWG outside of recommended is associated with a higher BMI in offspring. • Four studies had mixed findings with respect to an association between GWG and childhood weight status. (3 fair, 1 poor quality study) • A small number of large and more recent studies showed that childhood obesity (as measured by BMI) is associated with higher GWG. o There is a lack of evidence on the effect of maternal BMI, or whether the timing of weight gain during pregnancy impacts the BMI of the child. **Neurodevelopment** • Data are limited but raise the possibility that ketonemia among diabetic women could lead to suboptimal neurologic development • There are no studies that specifically examine the link between GWG and neurocognitive development in infants and children. **Allergies/asthma** • There is limited evidence available to determine if there is an association between low GWG and risk of childhood asthma (as a complication of preterm birth). **Cancer** • There is insufficient evidence to determine whether associations exist between GWG, birth weight and risk of childhood cancers**.** **Attention deficit hyperactivity disorder (ADHD)** • There is a lack of evidence to determine whether GWG is associated with ADHD.
Comments and limitations	• The guideline authors note that the literature related to GWG and maternal or child outcomes does not allow inference of causality since it is based solely on observational studies. • Some studies examined GWG without stratifying for pre-pregnancy BMI and these results can be affected by confounders. • The guideline committee note that it was difficult to summarize the quantitative impact of GWG on each outcome of interest because of differences between study designs or variation in the definitions of high or low weight gain or in the way the outcome was defined.

	Overall conclusions: <u>Mother</u> • There is a strong association between higher GWG and increased risk of caesarean delivery. • There is a strong association between higher GWG and postpartum weight retention in the intermediate postpartum period (3 months to 3 years). • Low GWG is moderately associated with failure to initiate breastfeeding. • The association between GWG and pregnancy complications such as glucose abnormalities and gestational hypertension is inconclusive due to methodological limitations of the research. • There is a lack of research on the relationship between GWG and mental health during pregnancy or in the postpartum period. • There is insufficient evidence to draw conclusions about the effect of GWG on maternal mortality or long term health consequences for the mother. • Maternal pre-pregnancy weight status is an important independent predictor of maternal short and long term outcomes. <u>Infant</u> • There is a linear, direct relationship between GWG and birth weight for gestational age. Lower GWG predicts SGA (and this risk appears to be greatest among women who are underweight prior pregnancy) and high GWG predicts LGA. • Most studies show associations between lower GWG and preterm birth among underweight, and to a lesser extent, normal weight women. Higher GWG among all BMI categories may also be associated with preterm birth. Evidence is insufficient regarding associations between GWG and spontaneous versus induced preterm birth. • A small number of more recent studies indicate that higher GWG is associated with childhood obesity. There is insufficient evidence to determine the effect modification by maternal BMI. • The evidence of an association between GWG and stillbirth is weak given that there are few methodologically sound studies. • There is insufficient evidence that GWG is associated with adiposity in the infant however a small number of studies show that GWG is directly associated with fat mass in the newborn period.

Data Extraction for Systematic reviews	
Last revised: September 15, 2016	
Systematic Review #1 Brunner, S. et al. (2015). Excessive gestational weight gain prior to glucose screening and the risk of gestational diabetes: meta-analyses. http://link.springer.com/article/10.1007%2Fs00125-015-3686-5	
General Information and Quality Rating	
Country (of authorship)	United States. Individual studies (total=8) were conducted in the USA (4), Canada (1), Norway (1), South Korea (1), Turkey (1). • Majority of studies from high income countries
Health Evidence Quality Tool	9/10 (strong) by two independent appraisers (JM & SL)
Details of the Review	
Objective	To study the association between excessive gestational weight gain (GWG) (defined according to Institute of Medicine recommendations) prior to screening for gestational diabetes mellitus (GDM) and risk of GDM.
Number of primary studies included	8 individual studies (n=13,748 pregnant women)
Included studies	• Secondary analysis of data from a randomized controlled trial – 1/8 (13%) • Prospective cohort study - 4/8 (50%) • Case-control study - 3/8 (38%)
Search period	• Searched for studies published from 1990 – September 2014. • Relevant studies were published between 2009-2014
Number of databases searched	• 4 databases: MEDLINE, EMBASE, Web of Science, Cochrane Library. • Hand search of reference lists of relevant articles.
Inclusion/exclusion criteria	Inclusion criteria: • Observational studies • Publication from 1990 onward • German or English language • Singleton pregnancies • Reporting an association between GWG and the outcome of GDM • GWG measured up to the time of GDM screening or an earlier period • GWG classified according to IOM recommendations as excessive or non-excessive. Exclusion criteria: • Data published in conference abstracts only • Review articles
Quality of included studies	• Two authors independently assessed study quality using the Graphic Appraisal Tool for Epidemiological studies (GATE) • Internal and external validity of the included studies was rated as low, medium, good: o Good internal and external validity (3 studies) o Medium internal validity (5 studies), and of these: ▪ medium external validity (3 studies)

	▪ low external validity (2 studies)
Populations, Exposures and Outcomes included in the Review	
Study population(s)	• Women with singleton pregnancy with no previous diagnosis of diabetes. • Five studies comprised of multiethnic populations • One study was of an Asian population • Two studies ethnic composition not explicitly stated
Description of exposure	• All but one study used self-reported pre-pregnancy weight • Measured or recorded weights were used to calculate GWG • Five studies provided GWG data up until the time of GDM screening between 24-28 weeks gestation. • One study provided data for both first and second trimester weight gain. • One study evaluated weight for each trimester but classified GWG according to IOM recommendations for the first trimester only. • One study investigated early weight gain up to 15-18 weeks gestation
Outcome measures	• Six studies used a two-step screen for GDM o 50g non-fasting screening glucose challenge test o followed by a 3h/100g or 2h/75g diagnostic oral glucose tolerance test (OGTT) if the previous test was abnormal. • One study used a universal 2h/75g OGTT • Several diagnostic criteria were used for GDM: o Carpenter & Coustan criteria (4 studies) o International Association of Diabetes and Pregnancy Study Group criteria (1 study) o National Diabetes Data Group 1998 criteria (1 study) o Canadian Diabetes Association criteria (1 study) • One study did not describe the method of diagnosis of GDM
Results of the Review	
Main results	**Gestational Diabetes Mellitus (GDM)** (8 studies) • Women who gained **excessive** weight during pregnancy had higher odds of being diagnosed with GDM (unadjusted OR 1.40; 95% CI 1.21 to1.61; p<0.001; I^2 = 16.7%*) when compared with **non-excessive GWG** (weight gain within or below recommended). o Four studies adjusted for maternal age, ethnicity, smoking status, pre-gravid BMI, BP at first prenatal visit, parity and history of GDM, and found that women who gained **excessive** weight during pregnancy had higher odds of being diagnosed with GDM (Adjusted Odds Ratio (AOR) 1.42; 95% CI 1.20 to1.68; p<0.001; I^2 = 0%) when compared with **non-excessive** GWG (weight gain within or below recommended). (4 studies – 3 good qualities, 1 medium/low quality). o Four studies found there was no difference in the odds of developing GDM between women who gained **excessive** weight during pregnancy and those that gain recommended weight (unadjusted OR 1.18; 95% CI 0.89 to1.55; p= 0.253; I^2 = 44.5%*) (4 studies – 2 good quality, 1 medium quality, 1 medium/low quality). o An analysis of stratified data found there is no effect

	modification by maternal pre-pregnancy BMI category on the association between excessive weight gain and odds of GDM when normal weight women were compared to overweight/obese women (4 studies – 2 good quality, 1 medium quality, and 1 medium/low quality). *Note: p values not provided in this review for the tests of heterogeneity
Comments and limitations	• The funnel plot did not indicate substantial publication bias • The authors note that most studies compared excessive vs. non-excessive weight gain however non-excessive weight gain includes both adequate and inadequate weight gain. This could lead to an overestimation of GDM risk if there is a reduced GDM risk among women with inadequate weight gain. Inadequate weight gain would not be recommended due to potential negative risks for the infant. • Most of the included studies were of medium quality mainly because of failure to adjust for confounders. • The criteria used for diagnosing GDM varied across studies. • Included studies relied on self-reported pre-pregnancy weight. • Most study authors did not explicitly report how IOM criteria were used for classifying excessive GWG. • There may be limited external validity of some of the included studies because they focused on a specific subpopulation however 5/8 studies focused on the general population. • The authors note that since the analysis is based on observational studies it is possible that excessive GWG may not be a risk factor for GDM but instead confounded by another factor representing a common cause for both high GWG and GDM. **Overall conclusions:** • **Excessive** GWG occurring before testing for GDM was associated with increased odds of developing GDM by a factor of 1.4 when compared to women who gain **non-excessive** weight gain (within or below GWG recommendations). o Results were similar when the analysis was restricted to studies that adjusted for confounders o Findings were of similar strength in normal weight and overweight/obese women. There was no evidence that the effect of GWG on GDM differs by pre-pregnancy BMI category • The odds of developing GDM are not significantly different when comparing women who gain **excessive** GWG prior to testing for GDM with those who gain the **recommended** amount of weight (from a sensitivity analysis of four studies).

Data Extraction	
Last revised: November 2, 2016	
Systematic Review #2 Han, Z., et al. (2011). Low gestational weight gain and the risk of preterm birth and low birthweight: a systematic review and meta-analyses. http://onlinelibrary.wiley.com/doi/10.1111/j.1600-0412.2011.01185.x/abstract;jsessionid=7D800CF99D82E0CB28C959A2C9E0E1B2.f04t04	
General Information and Quality Rating	
Country (of authorship)	China & Canada Individual studies (total=55) were conducted in the USA (28), Canada (2), Denmark (2), Portugal (1), Bangladesh (1), Thailand (3), Rasht (1), Iran (1), India (3), Japan (1), England (1), Taiwan (2), China (2), Australia (1), Spain (2), Nigeria (1), Saudi Arabia (1), Israel (1), Not Reported (1)
Health Evidence Quality Tool	9/10 (strong) by two independent appraisers (JM & LG)
Details of the Review	
Objective	To determine the relationship between low gestational weight gain and preterm birth or low birth weight in singletons in developing and developed countries.
Number of primary studies included	55 individual studies (n=3,467,683 pregnant women)
Included studies	• Cohort studies - 37/55 (67%) • Case-control studies – 18/55 (33%) • Studies originated predominately from developed countries
Search period	• Searched databases from date of inception – January 2, 2009. • Included studies were published from 1969-2008.
Number of databases searched	• 2 electronic databases: MEDLINE, EMBASE • Screened reference lists of included studies for additional articles.
Inclusion/exclusion criteria	Inclusion: • Case-control or cohort studies • Low total gestational weight gain or low weekly gestational weight gain according to IOM guidelines. • Preterm birth (PTB) (birth before 37 weeks gestation) or low birth weight (LBW) Exclusion: • Studies with duplicate publication of data • Studies with fewer than 10 participants • Studies published only as abstracts • Analyses that included multiples unless stratification was done for singleton versus twin outcomes
Quality of included studies	• Two reviewers completed critical appraisal independently using predetermined criteria to assess for six types of biases: 1) selection, 2) exposure, 3) outcome, 4) confounding, 5) analytic, 6) attrition. o 43/55 (78%) studies had a low risk of bias o 12/55 (22%) studies had a moderate risk of bias • Some key limitations of the included studies were: o Most studies assessed some confounding factors but no single study addressed all of them. o Many of the included studies did not perform a power calculation. o

Populations, Exposures and Outcomes included in the review	
Study population(s)	Women who delivered singletons **Note**: The characteristics of the populations are not synthesized in this review. Details of each individual study are provided in the "Characteristics of included studies" tables which are a supplement to the review.
Description of exposure	• Self-reported weight gain or objective assessments of GWG were included. • Low GWG was defined according to IOM 2009 GWG guidelines. o <12.5kg for underweight women o <11.5kg for normal weight women o <7kg for overweight women o <5kg* for obese women ***Note**: The review states that <9 kg was considered low GWG for obese women, however this is most likely an error since 9kg is the upper limit of the appropriate GWG for obese women. According to IOM 2009, <5kg would be considered low GWG for obese women. An email was sent to the corresponding author to clarify but no response was received. • For studies that did not report maternal BMI, 11-16kg was used as the reference group as this is appropriate GWG for women with a normal BMI, and then did a second analysis with 7-11kg which is the amount recommended for women who are overweight. • Low weekly GWG ranged from <0.23kg/week to less than 0.4kg/week. Normal rate of GWG was 0.23kg-0.68kg/week. The authors note this spans the IOM 2009 recommendations for normal weekly weight increases of 0.42kg on average and range from 0.35-0.52kg/week during the second and third trimesters.
Outcome measures	Primary outcomes • PTB(<37 weeks) – spontaneous or induced • LBW (<2 500 g) Secondary outcomes: • PTB from 32-36 weeks gestation, or <32 weeks • Very LBW <1 500g or extremely LBW <1 000g In addition, the following information was included if available: • Intrauterine growth restriction (IUGR) (birth weight <10% for gestational age) • Birth weight (in grams) • Gestational age at birth (in weeks)
Results of the Review (Note number of studies in brackets)	
Main results	**Total GWG and Preterm Birth (PTB)** Women with a low total GWG had an increased risk of PTB (<37 weeks) (unadjusted RR 1.64; 95%CI 1.62 to 1.65, I^2=0%, p = 0.76) compared to women who gained appropriate weight during pregnancy. (3 cohort studies – all low risk of bias) o Low GWG was associated with increased risk of PTB at 32-36 weeks (unadjusted RR 1.39; 95%CI 1.38 to 1.40) (1 cohort study) and PTB <32 weeks (unadjusted RR 3.80; 95%CI 3.72

	to 3.88) (1 cohort study) o The lower the GWG, the greater the risk of PTB. Risk of PTB was greater among women with very low GWG (unadjusted RR 2.27; 95% CI 2.25 to 2.39) compared to moderately low weight gain (unadjusted RR 1.37; 95% CI 1.36 to1.38). o The finding that low total GWG increases the risk of PTB was consistent with the results from 2/3 cohort studies which were not included in the meta-analyses (inability to pool these data due to format). • The results of three cohort studies indicate the risk of PTB (<37 weeks) was significantly increased in women who gained <10 kg compared to those gaining >10 kg total GWG in both the crude and adjusted data. • Pooled analyses from three case-control studies are consistent. Low total GWG is associated with increased odds of PTB (<37 weeks) (adjusted/matched OR 2.41; 95% CI 1.92 to 3.03, I^2=24%) when compared to women who experienced appropriate GWG. • Of the five case-control studies with total GWG as a continuous variable, 4/5 found that women who delivered at term had a similar GWG to women who experienced PTB (WMD -1.14; 95% CI -4.14 to 1.86kg, I^2=97%). The one study with matched data found that women who experienced PTB had a lower GWG (WMD -3.40; 95% CI -5.12 to -1.68kg) • For those studies that did not stratify by pre-pregnancy BMI overall results were similar in a secondary analysis using weight gain ranges for normal weight or overweight women as a reference group. Relative risks of PTB (<37 weeks) in women with low total GWG were 1.87 (95% CI: 1.46 to 2.39) using 7-11 kg as the reference and 1.64 (95% CI: 1.62 to 1.65) using 11.5-16 kg as the reference. **Low weekly GWG and Preterm Birth (PTB)** • Women with low weekly GWG weekly are at increased risk of PTB (<37 weeks) compared to women who had appropriate GWG weekly (adjusted/matched RR 1.91; 95% CI 1.45 to 2.52, I^2=68%) (3 cohort studies). • In three case-control studies weekly GWG was significantly different in women who experienced preterm birth than those that did not (crude WMD -33kg; 95% CI -44 to -21kg, I^2=29%) but the one study with matched data did not find a significant difference (matched WMD -30kg; 95% CI -81 to 21). **Total GWG and Low birth weight (LBW)** • Women with a low total GWG had an increased risk of delivering a LBW infant (<2,500g) (unadjusted RR 1.85; 95%CI 1.72 to 2.00, I^2=81%, p < 0.00001) compared to women who gained appropriate weight during pregnancy. (13 cohort studies – 10 low risk of bias and 3 moderate risk of bias). Adjusted/matched data was only available from one cohort study (adjusted/matched RR 2.62; 95% CI 1.38 to 4.98) o Low GWG was associated with increased risk of LBW (1,500-

	2,500 g) (unadjusted RR 2.02; 95%CI 1.88 to 2.17) (1 cohort study) and LBW <1,500g (unadjusted RR 2.00; 95%CI 1.67 to 2.40) (1 cohort study) o The lower the GWG the greater the risk of LBW. Risk of LBW was greater among women with very low GWG (unadjusted RR 2.50; 95% CI 2.07 to 3.01) compared to moderately low weight gain (unadjusted RR 1.48; 95% CI 1.23 to 1.77). o The finding that low total GWG increases the risk of LBW was consistent in the two cohort studies not included in the meta-analyses (inability to pool these data due to format) particularly for women who were underweight or normal weight prior to pregnancy. • The risk of LBW was significantly increased in women who gained <10 kg compared to those gaining >10 kg total GWG in the crude analysis (unadjusted RR 2.16; 95% CI 1.59 to 2.93) (4 cohort studies) but not in the analysis of adjusted/matched data (adjusted RR 1.45; 95% CI 0.87 to 2.42) (2 cohort studies) • Pooled analyses from the case-control studies also found that women with low total GWG at a increased risk of LBW (unadjusted OR 2.37; 95% CI 1.82 to 3.07, I^2=30%) (2 case control studies). • Five case-control studies examined GWG as a continuous variable and pooled results indicate that women with LBW infants had a significantly lower GWG (unadjusted WMD -1.93kg; 95% CI -3.34 to -0.51kg) compared to women without a LBW infant. • For those studies that did not stratify by pre-pregnancy BMI overall results were similar in a secondary analysis using weight gain ranges for normal weight or overweight women as a reference group. Relative risks of LBW (<2,500g) in women with low total GWG were 1.73 (95% CI: 1.67 to 1.78) using 7-11 kg as the reference and 1.85 (95% CI: 1.72 to 2.00) using 11.5-16 kg as the reference. **Low weekly GWG and Low birth weight (LBW)** • Overall, women with low weekly GWG did not experience an increased risk of delivering a LBW infant compared to women who had appropriate weekly GWG (unadjusted RR 1.64; 95% CI 0.89 to 3.02, I^2=90%) (2 cohort studies) • Weekly GWG was significantly different in one case-control study that compared women who delivered a LBW infant to those without a LBW infant (unadjusted WMD -40kg; 95% CI -58 to -22kg) and for the one study comparing women whose infants experienced IUGR compared to those that didn't (unadjusted WMD -30kg; 95% CI -58 to -2kg). **Note**: When both crude and adjusted data were reported, preference was given to extracting the adjusted analyses. Crude or unadjusted results are only presented above when adjusted data were not available.
Comments and limitations	• There was no publication bias detected in the trim and fill analysis performed for the outcomes with >10 studies. • Some studies did not adjust for confounders that could explain the relationship with PTB or LBW such as smoking. • Very few studies provided adjusted analyses or examined the

	combined impact of maternal pre-pregnancy BMI and gestational weight gain on the outcomes of interest • Most studies used self-reported weight and if there is a mild underreporting of weight and weight gain particularly in women who have above average weight gain it could underestimate the magnitude of the associations. • Few studies examined the impact of weekly GWG which limits the ability to draw firm conclusions. **Overall conclusions**: • Singletons born to women with low total GWG are at an increased risk of PTB and LBW. • There is a graded relationship between GWG and PTB as well as GWG and LBW, given that women with the lowest GWG have the highest risk of PTB or LBW.

Data Extraction for Systematic Reviews	
Last revised: October 18, 2016	
Systematic Review #3 Kapadia, M. Z., et al. (2015). Can we safely recommend gestational weight gain below the 2009 guidelines in obese women? A systematic review and meta-analysis. http://onlinelibrary.wiley.com/doi/10.1111/obr.12238/pdf	
General Information and Quality Rating	
Country (of authorship)	Canada. Individual studies (total=18) were conducted in the USA (13), Canada (1), Sweden (1), Norway (1), Denmark (1), Malta (1) Majority of studies conducted in developed countries
Health Evidence Quality Tool	9/10 (strong) by two independent appraisers (JM & LG)
Details of the Review	
Objective	To determine the risk of adverse pregnancy outcomes of gestational weight gain (GWG) below the 2009 IOM guidelines compared to within the guidelines among obese pregnant women.
Number of primary studies included	• 18 individual studies (n= 99,723 obese pregnant women)
Included studies	• Retrospective cohort studies – 16/18 (89%) • Prospective cohort studies – 2/18 (11%)
Search period	• January 1, 2009 – July 31, 2014. • Included studies published from 2009 – 2014
Number of databases searched	• 5 electronic databases: MEDLINE, EMBASE, Cochrane, Register, CINAHL and Web of Science • Reference lists of included studies were screened for additional articles
Inclusion/exclusion criteria	Inclusion: • Randomized controlled trials, cohort studies, case control studies and cross-sectional studies. • English-language articles. • Studies of obese women overall (BMI ≥ 30 kg m^2) and/or in any of the obesity classes with singleton pregnancies. • Weight below the recommendation of the 2009 IOM guidelines (0-4.9 kg) compared with within the 2009 guidelines (5-9 kg) • Reported on at least one of the primary outcomes: small for gestational age (SGA); large for gestational age (LGA); preterm birth (PTB). Exclusion: • Duplicate or secondary publications • Reviews, editorials, opinion articles and conference proceedings that were published abstracts only. • Studies that fail to stratify women by pre-pregnancy BMI.
Quality of included studies	• Study quality assessed using a modified Newcastle-Ottawa scale (tool modified so a max score = 7) for cohort studies. This tool was used to assess: o **Selection** (max 3 points) referring to the representativeness of the exposed cohort, selection of the non-exposed cohort

	and ascertainment of the exposure; o **Comparability** (max 2 points) if the two most important confounders for each outcome are controlled for; and o **Outcome** assessment and adequacy of follow-up • Half (9/18 – 50%) of the included studies had a score of ≤ 4 (low quality) • Three studies did not adjust for confounders. • All but three studies had a loss to follow-up > 10% (range 11-45%). • Five studies were deemed underpowered.
Populations, Exposures and Outcomes included in the Review	
Study population(s)	• 13/18 studies were representative of an average pregnant population in the community • Five studies focused on specific populations such as: low income populations (two studies), adolescents (one study), high-risk pregnant women (one study) and subscribers to a popular ethnic magazine (one study). • The non-exposed cohort was always drawn from the same population as the exposed cohort.
Description of exposure	• Ten studies extracted GWG from medical records. • Seven studies used self-reported GWG. • One study did not specify how GWG was ascertained.
Outcome measures	Primary outcomes: small for gestational age (SGA) < 10th percentile of birth weight for sex and gestational age; large for gestational age (LGA) > 90th percentile of birth weight for sex and gestational age; preterm birth (PTB) (<37, <32 or 32-36 weeks). Secondary infant outcomes included: low birth weight (<2,500 g), very low birth weight (<1,500 g), extremely low birth weight (<1,000 g), SGA (defined as birth weight less than third and less than fifth percentile for sex and gestational age), LGA (defined as birth weight>95th and >97th percentile for sex and gestational age), macrosomia (birth weight > 4000 or >4,500g), shoulder dystocia, and severe neonatal morbidity (such as respiratory distress syndrome, intraventricular haemorrhage, necrotizing enterocolitis, retinopathy of prematurity, transient tachypnea of the newborn, congenital malformation, Apgar score, arterial cord blood pH, neonatal hypoglycaemia, neonatal resuscitation, perinatal mortality or admission to the neonatal intensive care unit. Secondary maternal outcomes included: caesarean birth, pre-eclampsia or pregnancy-induced hypertension, gestational diabetes mellitus (GDM), placenta Previa, abruption placenta, chorioamnionitis, premature rupture of membranes (<37 weeks gestation in the absence of labour), cephalopelvic disproportion, operative vaginal delivery (such as forceps or vacuum), induction of labour, antepartum haemorrhage, postpartum haemorrhage, breastfeeding initiation postpartum weight retention (PPWR) up to one year after birth, and postpartum increase in obesity class. • In 13 studies, outcomes were extracted from medical records. • Four studies used self-reported outcomes. • One study did not describe the method of outcome assessment.

Results of the Review	
Main results	**Note:** There were a number of different factors adjusted for in each of the included studies. Studies included in the adjusted analyses would have adjusted for one or more confounding factor such as parity, age, smoking, diabetes mellitus, GDM, race/ethnicity, socioeconomic status, pre-pregnancy BMI. The review authors do not provide a common list of all factors that were controlled for in the studies included in adjusted pooled results. Primary outcomes: **Preterm birth (PTB)** (<37 weeks) (2 studies – 1 strong and 1 low quality) • Obese women who gained below recommended weight during pregnancy had higher odds of preterm birth (<37 weeks) (Adjusted Odds Ratio (AOR) 1.46; 95% CI 1.07 to 2.00; I^2 = 0%, p=0.64) than obese woman who gained within the guidelines. • Association between specific obesity classes and PTB was not assessed in the included studies. • The unadjusted pooled odds ratio (OR) was non-significant for this outcome **SGA** (< 10th percentile of birth weight for sex and gestational age) (10 studies – 7 moderate and 3 low quality) • Obese women who gained below recommended weight during pregnancy had higher odds (AOR 1.24; 95% CI 1.13 to1.36; I^2 = 57%, p=0.010) of delivering an SGA infant than obese woman who gained within the guidelines. • Odds of SGA were increased for each of the three obesity classes without a notable gradient. • The unadjusted pooled OR was non-significant for this outcome **LGA (**> 90th percentile of birth weight for sex and gestational age) (10 studies – 7 moderate and 3 low quality) • Obese women who gained below recommended weight during pregnancy had lower odds (AOR 0.77; 95% CI 0.73 to 0.81; I^2 = 0%, p=0.52) of having an LGA baby than obese women who gained within the guidelines. • The odds of LGA were decreased for each of the three obesity classes. • The unadjusted pooled OR for LGA was similar to the pooled AOR. Secondary outcomes: **Macrosomia (>4000g or >4500g)** (3 studies – 1 moderate and 2 low quality) • Obese women who gained below recommended weight during pregnancy had lower odds (AOR 0.64; 95% CI 0.54 to 0.77; I^2 = 0%, p=0.70) of delivering a macrosomic infant than obese woman who gained within the guidelines. **Gestational hypertension** (2 studies – 1 moderate and 1 low quality) • Obese women who gained below recommended weight during

	pregnancy had lower odds (AOR 0.70; 95% CI 0.53 to 0.93; I^2 = 0%, p=1.00) of gestational hypertension than obese woman who gained within the guidelines. **Pre-eclampsia** (5 studies – 1 strong, 3 moderate and 1 low quality) • Obese women who gained below recommended weight during pregnancy had lower odds (AOR 0.90; 95% CI 0.82 to 0.99; I^2 = 0%, p=0.51) of developing preeclampsia than obese woman who gained within the guidelines. **Caesarean birth** (5 studies – 1 moderate, 4 low quality) • Obese women who gained below recommended weight during pregnancy had lower odds (AOR 0.87; 95% CI 0.82 to 0.92; I^2 = 0%, p=0.46) of having a caesarean birth than obese woman who gained within the guidelines. **No significant differences** were noted for obese women with lower than recommended GWG compared to appropriate GWG for the following secondary outcomes: • **SGA < 3rd percentile** AOR 1.31; 95% CI 0.90 to 1.91; I^2 = 88%, p=0.004 (2 studies – 1 moderate, 1 low quality) • **Apgar score** (<7 at 5 min) AOR 0.92; 95% CI 0.67 to 1.27; I^2 = 6%, p=not reported (3 studies – all low quality) • **NICU admission** AOR 0.95; 95% CI 0.77 to 0.1.18; I^2 = 0%, p=0.49 (2 studies – all low quality) • **Operative vaginal delivery** AOR 0.96; 95% CI 0.84 to 1.10; I^2 = 8%, p=0.34 (3 studies – all low quality) • **Postpartum haemorrhage** AOR 0.97; 95% CI 0.85 to 1.11; I^2 = 0%, p=0.66 (3 studies – all low quality) • **Infant death** AOR 1.22; 95% CI 0.75 to1.99; I^2 = 29%, p=0.24 (2 studies – 1 strong, 1 low quality) For each of the following secondary outcomes an adjusted analysis is only available from a **single study**: • **Postpartum weight retention (PPWR)** Obese women who gained below recommended weight during pregnancy experienced a decrease in weight after one year postpartum (adjusted mean difference = -5.3; 95% CI -9.0 to -1.7kg) compared to obese woman who gained within the guidelines however an adjusted analysis was only provided in one low quality study. • **LGA >97th percentile** – significant difference (AOR 0.81; 95% CI 0.72 to 0.91). (1 study – moderate quality) • **Foetal distress** – no significant difference (AOR 0.99; 95% CI 0.80 to 1.22) (1 study – moderate quality) • **Shoulder dystocia** – no significant difference (AOR 0.82; 95% CI 0.49 to1.37) (1 study – moderate quality) • **Gestational diabetes mellitus (GDM)** – no significant difference (AOR 1.15; 95% CI 0.91 to 1.45). (1 study – moderate quality)

	• **Induction of labour** – no significant difference (AOR 0.97; 95% CI 0.76 to 1.54). (1 study – moderate quality) • **Low birth weight (LBW)** (<2500g) – no significant difference (AOR 1.08; 95% CI 0.80 to 1.22). (1 study – low quality) The findings are similar even when considering the unadjusted results. None of the included studies addressed the following secondary outcomes: • Placenta previa • Abruption • Chorioamnionitis • Premature rupture of membranes • Cephalopelvic disproportion • Perinatal mortality • Very LBW or extremely LBW • Severe neonatal morbidity • Breastfeeding initiation • Postpartum increase in obesity class
Comments and limitations	• There was no evidence of publication of bias from the funnel plots of outcomes with five our more studies (e.g. for adjusted SGA, LGA, caesarean birth and pre-eclampsia). None of the other outcomes had five our more studies so publication bias could not be assessed. • For a number of secondary outcomes only a single study was included. • A number of studies were underpowered to assess the relationship between GWG and particular outcomes. • Some of the included studies did not control for important confounders (e.g. GDM is a potential confounder for LGA and macrosomia and not all studies assessing these outcomes controlled for GDM). • The authors note that the majority of the included studies originated from the United States which could limit generalizability of the findings. • A number of the included studies did not stratify analyses according to obesity classes **Overall conclusions**: • Obese pregnant women who gained below the recommended 5kg during pregnancy had increased odds for PTB (<37 weeks) and SGA (<10th percentile) and decreased odds of LGA (>90th percentile), macrosomia, gestational hypertension, pre-eclampsia and caesarean birth compared to obese women who gained within the recommendations. However many findings were based on moderate or low quality evidence from a small number of studies. • This review did not demonstrate a graded effect of GWG below the guidelines on adverse pregnancy outcomes with increasing obesity class, except for SGA (<10th percentile) and caesarean birth in which the highest odds were observed in obesity class I. However the

	limitations of sample size could not be ruled out. • The review authors conclude that weight gain below the IOM 2009 guidelines cannot be recommended based on available evidence.

Data Extraction	
Last revised: October 18, 2016	
Systematic Review #4 Lau, E., et al. (2014). Maternal Weight Gain in Pregnancy and Risk of Obesity among Offspring: A Systematic Review. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4202338/pdf/JOBE2014-524939.pdf	
General Information and Quality Rating	
Country (of authorship)	USA. Individual studies (total= 22) were conducted in the USA (15), UK (1), Sweden (1), Denmark (2), Germany (1), Finland (1), Norway (1)
Health Evidence Quality Tool	9/10 (strong) by two independent appraisers (JM & SL)
Details of the Review	
Objective	To summarize observational research of the association between GWG and offspring body weight in children aged 2 to 18.9 years.
Number of primary studies included	22 individual cohort studies (n=261,744)
Included studies	• Prospective cohort design - 13/22 (59%) • Mixed prospective cohort design - 6/22 (27%) • Retrospective cohort design – 3/22 (14%)
Search period	• Searched databases from date of inception – March 19, 2013. • Included studies were published from 2007-2013.
Number of databases searched	• 4 electronic databases: PubMed, Web of Science, CINAHL, Academic Search Premiere • Reference lists of included studies were screened for additional articles
Inclusion/exclusion criteria	Inclusion: • Cohort study design • Studies focusing on children aged 2 to 18.9 years • GWG as an exposure • Studies that include child age-and-gender specific BMI or overweight status as an outcome Exclusion: • Studies focusing on GWG in relation to child birth weight • Studies examining maternal pre-pregnancy overweight status rather than GWG in relation to offspring's body composition outcomes
Quality of included studies	• Used the quality assessment tool for observational studies adapted for the systematic review that informed the IOM (2009) GWG guidelines. The quality assessment form included nine key domains: background, sample selection, specification of exposure, specification of exposure, specification of outcome, soundness of information, follow up, analysis comparability, analysis of outcome and interpretation. • Studies were rated for each domain as good, fair or poor and then overall quality was rated as: o High (H) – ≥6 or more good ratings and no poor ratings on subdomains o Medium (M) - < 6 good ratings; ≤6 good ratings and ≤2 poor ratings on subdomains o Low (L) – ≥3 poor ratings on subdomains or any other score • Overall, the majority of included studies were of moderate quality: o 3/22 high quality studies (14%) o 19/22 medium quality studies (86%)
Populations, Exposures and Outcomes included in the review	
Study population(s)	• Studies in Europe and the USA mainly enrolled Caucasian women.

	• All studies except two enrolled both male and female offspring. • 12/22 studies focused on younger children (aged 3-5 yrs); 4/22 focused on older children (aged 6-12 years); 3/22 concentrated on adolescents (13-18 years); and 3/22 studies examined the association across age groups.
Description of exposure	• Methods used to assess GWG varied across the included studies o **Total GWG** was defined as difference between the mother's weight at delivery and mother's pre-pregnancy weight in most studies. o **Net GWG** was defined as the total GWG minus infant birth weight to account for variation in infant birth weight. o **Rate of GWG** was defined as the total GWG divided by the duration of the pregnancy. o 9/22 studies used the IOM guidelines (1990 or 2009) to categorize total GWG as inadequate, adequate or excessive. o There was variation in the proximity of the last weight taken during pregnancy and the time of delivery. o The majority of studies used self-reported pre-pregnancy weight or weight obtained from medical records to calculate GWG.
Outcome measures	• Child body weight outcomes were expressed as BMI z-scores (continuous) (10 studies) or overweight status (categorical) (13 studies). Child body weight cut off points were determined by: o CDC 2000 (All 16 US studies) o IOTF/WHO growth chart (5/7 European studies) o National growth chart (1 study) o BMI (weight kg/height m^2) (2 studies) • Child body weight was measured objectively (15 studies), self-reported (4 studies), parent reported (2 studies) or clinically recorded (1 study). • Only four studies measured child body weight at two or more measurement time points during the follow up period. The remaining studies measured it once.
Results of the Review	
Main results	**Total GWG (continuous) and offspring's body weight** (10 studies – all moderate quality) • 7/8 studies found a significant positive association between total GWG and the child's body weight. o An additional 1kg in total GWG increased a child's BMI z-score by 0.006 to 0.06 units and increased the risk of overweight/obesity status by 1%-23% after adjusting for potential confounders. o Of the five studies (all moderate quality) that stratified for pre-pregnancy BMI, only one found that the direct (crude) effect of GWG on offspring's BMI z-score was stronger than indirect (adjusted) effects in normal-weight and overweight mothers. This one study found that pre-pregnancy BMI is significantly associated with a child's BMI z-score. • Two studies used an arbitrary cut-off point to classify total GWG:

	o One study found that the odds of a child (aged 2-12) experiencing early-onset overweight was 1.7 times greater if their mother gained ≥20.43 kg during pregnancy compared to children whose mother gained between 11.35-15.88kg. However total GWG was not associated with late-onset overweight in offspring (being overweight > 8 years). o Another study found that compared to children whose mother gained 15-19lbs in pregnancy the odds of being overweight at age 18 increased in offspring whose mother gained <10lbs (adjusted odds ratio (AOR) 1.51; 95% CI: 1.00 to 2.30); 10-14 lbs (AOR 1.56; 95% CI 1.13 to 2.16) and >40lbs (AOR 1.68; 95% CI 1.13 to 2.52). **Net GWG and offspring's body weight** (4 studies – 2 moderate, 2 high quality) • 3/4 studies demonstrated a significant positive association between net GWG and the body weight of offspring o Increments in net GWG were associated with a 0.01 to 0.07 unit increase in a child's BMI z-score. o One of these studies (high quality) found that in a between-family analysis (participants from different families), the positive association between net GWG and offspring BMI at 18 years was stronger in normal weight mothers than overweight mothers. In the within-family model (siblings from the same family), the positive association between net GWG and offspring BMI at 18 years of age was found In overweight mothers but not in normal weight mothers. **Rate of GWG and offspring's body weight** (4 studies – 1 high, 3 moderate quality) • The results of four studies indicate that a high rate of GWG in early and mid-pregnancy was associated with increased BMI z score and risk of overweight in offspring whereas the rate of GWG in late pregnancy was not associated with a child's body weight outcomes. **IOM recommended GWG and offspring's body weight** (11 studies - 2 high, 9 moderate quality) • Eight studies had mixed results regarding the association between excessive or inadequate GWG and a child's body weight outcomes when compared with adequate GWG. o 6/8 studies found a significant increase in BMI z-scores (0.14 to 0.64 units) and elevated risk of overweight or obesity (27% to 73%) among offspring born to mothers who gained **excessive** weight during pregnancy compared to offspring whose mothers gained adequate weight. o 5/8 studies found no association between **inadequate** GWG and offspring's body weight outcomes; 3/8 found a negative association with a reduction of 0.06 to 0.21 units in child's BMI z-scores comparing children exposed to **inadequate** GWG versus appropriate GWG. o Two of these studies stratified analyses by prepregnancy BMI

	and found that the effects of excessive GWG on offspring's bodyweight did not vary by maternal BMI. • One study (moderate quality) compared **excessive** GWG to **non-excessive** GWG (adequate or inadequate) and found that the child's risk of being overweight between 5-8 years of age was 73% greater among those exposed to excessive GWG. • Another study (moderate quality) found no association between **excessive** GWG and risk of the child being overweight when compared to children whose mothers experienced **non-excessive** weight gain in pregnancy. • One study (moderate quality) found children exposed to **excessive** GWG had a higher BMI z-score (0.47 units) and four times the risk of being overweight when compared to children exposed to **inadequate** GWG. **GWG measures at specific time points and offspring body weight outcomes** (2 studies – moderate quality) • One study found that an additional 1kg increase in total GWG during the first 20 weeks of pregnancy increased offspring's odds of developing overweight by 3%. • Another study showed that total GWG at 30 weeks of gestation was associated with 0.02 unit increments in offspring's BMI at age 3.
Comments and limitations	• The authors note that the findings should be interpreted with caution due to several methodological concerns such as: o Failure to adjust for potential confounders such as shared familial characteristics between mother and child (e.g. genetics and/or maternal and child lifestyle factors). o None of the included studies reported whether the study was sufficiently powered to detect differences in the primary outcome and interactive effects by maternal pre-pregnancy BMI. • Findings may not be generalizable given that the included studies focused predominately on Caucasian, well-educated, non-obese women. • The included studies were heterogeneous and meta-analysis was not possible. The semi-quantitative reporting in this review focuses more on direction of association rather than magnitude of the effect. • Several of the included studies draw data from the same cohort which may over represent findings. • Publication bias is possible given that the search was limited to English language and studies published in peer reviewed journals. **Overall conclusions**: • Higher total GWG significantly increases BMI z-score (0.006 to 0.06) and risk of overweight or obesity (1% to 23%) in offspring. • Compared to offspring whose mothers gained adequate weight during pregnancy, children of mothers who experience excessive GWG had a significantly higher BMI z-score (0.74 to 1.73 units) and elevated risk of overweight or obesity (1% to 57%). • The small number of available studies on rate of weight gain

	consistently demonstrated that high rates of GWG in early or mid-pregnancy had strong adverse effects on offspring body weight outcomes.

Data Extraction	
Last revised: October 18, 2016	
Systematic Review #5 Mannan, M., et al. (2013). Association between weight gain during pregnancy and postpartum weight retention and obesity: a bias-adjusted meta-analysis. http://search.ebscohost.com/login.aspx?direct=true&db=nyh&AN=87947795&site=ehost-live	
General Information and Quality Rating	
Country	Australia Individual studies (total=12) were conducted in North America (6), Europe (3), Brazil (1), Asia (1), Australia (1).
Health Evidence Quality Tool	9/10 (strong) by two independent appraisers (JM & EW)
Details of the Review	
Objective	To study the strength of the association between gestational weight gain and postpartum weight retention and maternal body mass index over time.
Number of primary studies included	12 individual studies (>68,000 women)
Included studies	• Prospective cohort studies - 9/12 (75%) • Retrospective cohort studies - 3/12 (25%)
Search period	• Searched databases from 1961-2011. • Included studies were published from 2002-2012.
Number of databases searched	• 5 databases: PubMed, CINAHL, Embase, BIOSIS Previews, Current Contents Connect • Reference lists of included studies were screened for additional articles
Inclusion/exclusion criteria	Inclusion: • English language • Singleton pregnancies • Studies reporting GWG as classified by IOM recommendations into 'inadequate', 'adequate', and 'excess' categories • Postpartum weight retention (PPWR) documented as a continuous variable and reported from 2 weeks postpartum onward
Quality of included studies	• Quality assessment conducted by 2 independent reviewers using a 5-item quality scoring instrument (max score = 20) o Criteria included: design-specific bias (1.0 point), selection bias (3.0 points), adjustment of potential confounding (10 points), information bias (4 points), and analytical methods (2 points). • Study quality was rated as low (1.0 – 6.0 points), moderate (7.0 – 15.5 points), or high (16.0 – 20.0 points). Study quality ranged from 6-16 points with the included studies being rated as: o Low quality - 1/12 studies (8%) o Moderate quality - 10/12 (84%) o High quality assessment score - 1/12 studies (8%) Review authors note that some key limitations were: o 3/9 prospective studies had loss to follow up >20% and 2/9 did not report follow-up status o Half of the studies (6/12) were designed with a short term

	follow-up (up to 1 year) o 7/12 studies used self-reported pre-pregnancy weight o 5/12 studies reported missing data. Postpartum weight was objectively measured in 10/12 studies.
Populations, Exposures and Outcomes included in the review	
Study population(s)	• Socioeconomic status was thought to be homogenous across all studies except one. • The majority of studies (9/12) had a high proportion of Caucasian participants, but review authors note that most studies included women from a mix of different ethnic backgrounds. • Mean age of study participants was 27 years (range from 22.2-31.2)
Description of exposure	• The IOM categories of "inadequate", "adequate" and "excess" were used to define GWG according to a woman's pre-pregnancy BMI. o 8/12 reported GWG as recommended by the IOM 1990 guidelines o 4/12 studies reported GWG according the IOM 2009 guidelines. • The mean GWG ranged between 10.6kg and 15.8kg across included studies.
Outcome measures	• 11/12 studies reported postpartum weight retention (PPWR) as a continuous variable (body weight after pregnancy minus pre-pregnancy weight). • 5/12 studies reported postpartum BMI and its categories as an outcome. • 2/12 reported the odds of overweight and obesity. • Outcomes of included studies were measured at different time points.
Results of the Review	
Main results*	**Postpartum weight retention (PPWR)** - weighted mean difference (WMD) **PPWR Overall** (11 studies – 10 moderate, 1 low quality) • Women with an **inadequate GWG** had a significantly lower postpartum weight (WMD -2.14kg; 95% CI –2.61to -1.66kg; I^2=88% p=0.00) between 2 weeks and 21 years postpartum, compared with women who had an adequate GWG • Women with an **excessive GWG** were significantly greater postpartum weight (WMD 3.15kg; 95% CI 2.47 to 3.82 kg; I^2=95% p=0.00) between 2 week and 21 years postpartum, compared with women who had an adequate GWG. **PPWR <1 year postpartum** (8 studies - 7 moderate, 1 low quality) • Women who experienced **inadequate GWG** had a significantly lower postpartum weight (WMD -2.25kg; 95%CI -3.08 to -1.42kg; I^2=91% p=0.00) at up to one year postpartum compared to women with an adequate GWG. • Women who experienced **excessive GWG** weighed more (WMD 2.98kg; 95%CI 1.77 to 4.18kg: I^2=96% p=0.00) at up to one year postpartum compared to women with an adequate GWG.

	PPWR 1 year to <9 years postpartum (3 studies – all moderate quality) • Women who experienced **inadequate GWG** had a significantly lower postpartum weight (WMD -2.23kg; 95%CI -2.56 to -1.90kg; I^2=43% p=0.17) between one and nine years postpartum compared to women with an adequate GWG. • Women who experienced **excessive GWG** weighed more (WMD 2.89; 95%CI 2.00 to 3.77kg; I^2=96% p=0.00) between one and nine years postpartum compared to women with an adequate GWG. **PPWR ≥15 years** (2 studies – all moderate quality) • Women who experienced **inadequate GWG** had a significantly lower postpartum weight (WMD -1.59kg; 95%CI -2.59 to -0.60; I^2=68% p=0.08) 15 or more years later compared to women with an adequate GWG. • Women who experienced **excessive** GWG weighed more (WMD 4.96kg; 95%CI 3.90 to 6.00; I^2=68% p=0.08) 15 or more years later compared to women with an adequate GWG. • Compared to women with adequate GWG, PPWR in women with excessive GWG showed a U-shaped trend with a decline in weight in the early postpartum years (6 months to 1.5 years) and then an increase weight in the later follow-up period (8.5-21 years). **Postpartum body mass index (BMI)** (5 studies – all moderate quality) • Women who experienced **inadequate** GWG had a decline in BMI of -2.42kg/m^2 (95%CI -3.03 to -1.80kg/m^2; I^2=98% p=0.00) compared to women with an adequate GWG over a postpartum period of up to 21years • Women who experienced **excessive** GWG increased their BMI by 3.78kg/m^2 (95%CI 3.14 to 4.41kg/m^2; I^2=98% p=0.00) compared to women with an adequate GWG over a postpartum period of up to 21years. **Maternal overweight or obesity** (2 studies – 1 moderate, 1 high quality) • A woman's odds of becoming overweight or obese increase with excessive GWG compared to adequate GWG. o One moderate quality study reported women who gained excessive weight during pregnancy had an increased odds of being overweight (OR 2.15; 95%CI 1.64 to 2.82) or obese (OR 4.49; 95% CI 3.42 to 5.89) 21 years after the index pregnancy. o One high quality study found that there was an increased odds of being overweight (OR 3.58; 95% CI, 2.61 to 4.93) at 16 years postpartum. **Note**: The meta-analyses presented in this review use a quality effects model (weighting by study quality). Results were similar using a random effects model.
Comments and limitations	• There was a high degree of heterogeneity among the studies meta-analyzed for this review. Publication bias was assessed and the

	heterogeneity of studies included in the analysis did not appear to be a consequence of publication bias. • The analyses were limited to those studies that measured GWG in relation to IOM categories. This approach resulted in GWG being analyzed without accounting for pre-pregnancy BMI. • The authors note that only a few of the included studies adjusted for potential confounders (not listed). • The authors note that most of the studies included in the review did not consider reliable sources of information on diet and physical activity which may influence the association between GWG and PPWR or BMI. • The authors note that more information is needed on women's SES, culture, lifestyle, breastfeeding and other related behaviours and the association with weight gain during pregnancy and PPWR or obesity later on. • The authors note the reliability of results for long-term outcomes is weak given that only a low number of long-term studies were identified. In addition data on BMI in the long-term was only available from five studies. **Overall conclusions:** • Weight gain in pregnancy outside of IOM recommendations is associated with both short and long-term weight imbalance. o **Inadequate** GWG was associated with a decreased postpartum weight and BMI in the long term compared to women who gain the recommended amount of weight during pregnancy and this association was independent of the postpartum time span. o Women who gained **excessive** weight during pregnancy had a higher postpartum weight and BMI compared to women who gained recommended weight and this association was dependent on postpartum follow-up time with a U-shaped trend observed.

Appendix G: Synthesis Table

Table 3: Synthesis of maternal and infant outcomes associated with gestational weight gain

Exposure Category	Outcomes	
	Maternal	**Infant**
High GWG	**Prenatal Period:** ➢ **+** Stretch marks (1 guideline [2 studies] graded weak) ➢ **Ø** General discomforts during pregnancy, physical energy, fatigue, heartburn or gallstone (1 guideline [8 studies] not graded)	**Prenatal Period:** ➢ **+** Preterm birth (>37 weeks gestation) (1 guideline [12 studies] graded moderate) o Effect of high rate of GWG on PTB may be greater with increasing pre-pregnancy BMI (1 guideline)
	Labour & Delivery: ➢ **+** Caesarean Birth (1 guideline [21 studies] graded moderate) o Moderate evidence in underweight or normal weight women (1 guideline [8 studies]) o Weak evidence for obese women (1 guideline, [8 studies]) ➢ **+** Induction of labour or failure of labour induction (1 guideline [5 studies] graded weak) ➢ **+** Length of labour (1 guideline [3 studies] graded weak)	**Neonatal Period:** <u>Birth weight</u> (1 guideline/graded strong) ➢ **+** Infant birth weight (1 guideline [25 studies]) ➢ **+** Macrosomia (>4,000g) or 4,500g) (1 guideline [12 studies]) ➢ **-** LBW (>2,500g) (1 guideline [13 studies]) <u>Birth weight for gestational age</u> (1 guideline/grade strong) ➢ **+** LGA (1 guideline [10 studies]) ➢ **-** SGA (1 guideline [20 studies]) o Moderate evidence of increased risk of SGA among women with low pre-pregnancy BMI ➢ **+** Neonatal death (1guideline [1 study] graded moderate) o Increased odds of neonatal death among women with highest pre-pregnancy BMI
	Postpartum Period: ➢ **+** Postpartum weight retention (PPWR) (1 guideline [19 studies] graded moderate; 1 SR [11 studies]) ➢ **+** Maternal fat gain (1 guideline [2 studies] graded weak) ➢ **+** Maternal overweight or obesity (1 SR [2 studies]) ➢ **+** Postpartum BMI (1 SR [5 studies])	**Childhood:** <u>Offspring's weight status</u> ➢ **+** Child's BMI z-score (1 SR [10 studies]) ➢ **+** Child overweight or obesity (1 guideline [4studies]); graded weak); 1 SR [13 studies])

Ø = There is no association between the exposure and the outcome
+ = the exposure is associated with an increase in the outcome
- = the exposure is associated with a decrease in the outcome
[# studies] = the number of studies included in the systematic review or guideline for that particular outcome
SR = systematic review

Exposure Category	Outcomes	
	Maternal	**Infant**
Low GWG	**Prenatal Period:** Specifically for obese pregnant women: ➢ **-** Gestational hypertension (1 SR [2 studies]) ➢ **-** Preeclampsia (1 SR [2 studies])	**Prenatal Period:** ➢ **+** Preterm birth (PTB) (>37 weeks gestation) (1 guideline [12 studies] graded strong; 1 SR [~29 studies]; 1 SR of obese women [2 studies]) o Highest risk of PTB among women with the lowest GWG (1 guideline) o Strongest effect of low rate of GWG on PTB among underweight women (1 guideline) ➢ **+** Stillbirth (1 guideline [3 studies] graded weak) ➢ **Ø** Birth defects (1 guideline [2 studies] grade of evidence not provided)
	Labour & Delivery: Specifically for obese pregnant women: ➢ **-** Caesarean Birth (1 SR [5 studies] ➢ **Ø** Induction of labour (1 SR [1 study]) ➢ **Ø** Operative vaginal delivery (1 SR [3 studies]) ➢ **Ø** Postpartum haemorrhage (1 SR [3 studies])	**Neonatal Period:** ➢ **+** Infant mortality (1 guideline [1 study] graded moderate) **o** Highest odds of neonatal death with low GWG for underweight & normal weight women (1 guideline) ➢ **+** LBW (<2,500g) (1 SR [~31 studies]) Specifically for obese pregnant women: ➢ **+** SGA (1 SR [10 studies]) ➢ **-** LGA (1 SR [10 studies]) ➢ **-** Macrosomia (1 SR [3 studies]) ➢ **Ø** LBW (1 SR [1 study]) ➢ **Ø** Infant death (1 SR [2 studies]) ➢ **Ø** Shoulder dystocia (1 SR [1 study]) ➢ **Ø** Apgar score (>7 at 5 min) (1 SR [3 studies]) ➢ **Ø** Foetal distress (1 SR [1 study]) ➢ **Ø** NICU admission (1 SR [2 studies])
	Postpartum Period: ➢ **-** Breastfeeding initiation (1 guideline [4 studies] graded moderate) ➢ **-** PPWR (1 SR [11 studies]; 1 SR of obese women [1 study]) ➢ **-** Postpartum BMI (1 SR [5 studies])	
Any GWG*	➢ **Ø** Duration of exclusive or any breastfeeding (1 guideline [4 studies] graded weak)	

*Analysis was not described according categories of GWG (e.g. high or low)

The evidence is <u>inconclusive</u> regarding the association between GWG and the following outcomes:

- Gestational Diabetes Mellitus (GDM) (1 guideline [11 studies] graded weak; 1 SR [8 studies]; 1 SR of obese women [1 study])
- Gestational Hypertension (1 guideline [14 studies] grade of evidence not provided for these mixed research findings)
- Instrumental Delivery (1 guideline [5 studies] grade of evidence not provided for these mixed research findings)
- Apgar score (1 guideline [5 studies] graded weak)
- Maternal breast cancer (1 guideline [2 studies] graded weak)

There is <u>insufficient</u> evidence to determine the association between GWG and the following outcomes:

- Maternal mortality (1 guideline)
- Perinatal mental health (1 guideline)
- Adiposity in the infant (1 guideline)
- Infant weight gain (1 guideline)
- Long-term maternal outcomes such as: Type 2 Diabetes, Cardiovascular disorders, or Cancer (1 guideline)
- Long- term child outcomes such as: Neurodevelopment, Allergies/asthma, Cancer, ADHD (1 guideline)

Specifically among obese pregnant women with inadequate GWG there was **<u>no</u> evidence** for:

- Placenta previa or abruption (1 SR)
- Chorioamniotis (1 SR)
- Premature rupture of membranes (1 SR)
- Cephalopelvic disproportion (1 SR)
- Perinatal mortality (1 SR)
- Very LBW or Extremely LBW (1 SR)
- Severe neonatal morbidity (1 SR)
- Breastfeeding initiation (1 SR)
- Postpartum increase in obesity class (1 SR)