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Weight gain in pregnancy and application of the 2009 IOM guidelines: toward a uniform approach

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Abstract

Objective—There is an urgent need to adopt standardized nomenclature as it relates to GWG, a more uniform approach to calculate it, and hence quantifying adherence to the 2009 Institute of Medicine (IOM) guidelines.

Results—This perspective highlights the varying methods used to estimate GWG and discuss the advantages and limitations of each. While these calculations could be argued to have a minimal impact on data at the population level, on the patient level, incorrectly estimating weight at conception can result in misclassification of preconception body mass index (BMI) and assignment of the IOM guidelines which inherently affect the prospective management of weight gain (and potential outcomes) during the current pregnancy.

Conclusions—We recommend that preconception BMI and total GWG be determined objectively and total GWG be adjusted for length of gestation before assessing adherence to the IOM GWG guidelines.

Keywords

pregnancy; weight gain

Introduction

Obesity is a multifactorial widespread public and personal health concern. In Rodgers' (1) and Gilman's (2) call to action, they point to the impact the maternal environment has on a child's life long risk for obesity and diabetes. Fetal development and epigenetics are influenced by the metabolic and hormonal milieu of the intrauterine environment that is shaped by maternal weight status and driven by diet and physical activity. The intrauterine environment is believed to be formed well-before conception making maternal health prior to conception important in addition to prenatal health. These important points were elegantly illustrated by the work in Gambian women showing that DNA methylation established in the early embryo which is maintained in differentiated tissues was significantly affected by season of conception and maternal nutritional status (3).

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Maternal preconception obesity and gestational weight gain (GWG) both independently increase the risk for increased infant adiposity, childhood obesity, and glucose, insulin and cardiometabolic dysregulation in the offspring (4). Over the past 10 years, data from the U.S. suggests that 39% percent of normal weight, 59% percent of overweight and 56% of obese pregnant women gain more than what is recommended during pregnancy (5). Mothers retain the excess weight gained during pregnancy increasing their body mass index (BMI) as they enter into subsequent pregnancies. The likelihood for further excess weight gain is high in the subsequent pregnancy, perpetuating a vicious cycle of increasing BMI and negative health outcomes (6). The prenatal period is thought to be an opportune time to intervene as pregnant women are: willing to make lifestyle changes for the benefit of their growing child, they are closely connected to their health providers through routine medical visits, and the prenatal period is relatively short resulting in improved adherence to positive changes (7). Lifestyle interventions initiated during pregnancy that result in longer-term behavior changes have the ability to yield lasting positive benefits for mother, child, and future offspring attenuating the detrimental cycle and progression of obesity (1, 2). The National Institutes of Health has supported this endeavor through funding a multicenter research consortium (LifeMoms or Lifestyle Interventions in Expectant Moms) aimed to implement lifestyle interventions during pregnancy for overweight and obese women and examine maternal and infant outcomes throughout the first year of life.

The Institute of Medicine (IOM) convened a committee to examine nutrition during pregnancy, and recommendations for GWG were published the 1990 report (8). Due to changes in maternal characteristics including higher prevalence of overweight preconception BMI and increased reports of GWG being associated with adverse maternal and infant outcomes, the IOM reconvened a committee to reexamine the impact of weight gain in pregnancy and as a result published revised guidelines in 2009 (6). Postpartum weight retention, preterm birth, non-elective cesarean delivery, gestational diabetes mellitus and preeclampsia were the primary consequences of maternal pregnancy weight gain that were considered in the formulation of the 2009 guidelines.

The 2009 guidelines were revised to 1) include four classifications of preconception body mass index (BMI; World Health Organization definitions); underweight, normal weight, overweight and obese and 2) provide weight gain recommendations as both total GWG and rate of weight gain per week of gestation (Table 1). Excess weight gain, or weight gain above the 2009 recommendations, was also associated with small and large for gestational age infants and preterm birth. The report emphasized the need for research and urged funding agencies like the National Institutes of Health to support research that allows for a better understanding of preconception BMI, GWG, and their impact on maternal and fetal health outcomes. With this call to action, there has been an exponential increase in the number of studies on GWG. More than 2,362 peer-reviewed articles in this area have been published since 2009 (Figure 1). In the *Obesity* journal alone, we have published 373. With this influx of manuscripts we note that the research on GWG demonstrates clear inconsistencies in the interpretation and application of the 2009 IOM guidelines. Here we review the different methods applied to interpret the 2009 IOM GWG guidelines and the resultant outcome on estimates for the proportion of women who adhere to the recommendations. This brief analysis highlights a need to establish minimum standards for

weight data collection and reporting in pregnancy and to establish uniform definitions for: 1) preconception body mass index, 2) calculation of gestational weight gain and hence 3) adherence to the GWG guidelines. Lack of uniformity in reporting weight and associated metrics during pregnancy will dampen our ability to accurately quantify and then understand the consequences of GWG on maternal and infant outcomes and the effectiveness of interventions designed to attenuate them.

Determining GWG and adherence to the 2009 IOM GWG Guidelines

When put simply, there are generally two methods to assessing GWG and adherence to the 2009 IOM Guidelines, 1) total GWG and 2) incremental GWG. Identifying the best method for assessing GWG and interpreting adherence to the 2009 IOM Guidelines remains unclear. Assessing GWG may appear straight forward, however, it is plagued by challenges which limit accuracy.

Total GWG, as defined by the 1990 and 2009 guidelines, is the amount of weight a pregnant woman gains between the time of conception and the onset of labor (6, 8). Obtaining an objectively measured weight at both conception and at the onset of labor can be difficult and these measures are not often standardized in obstetric practice. However total GWG is most often defined as final weight minus preconception weight. Initial weight can be a preconception weight that is 1) derived from patient self-report, 2) measured in the clinic, 3) abstracted from medical charts at some date prior to conception or 4) measured at first prenatal/study visit. The final weight is met with similar problems since it can also be derived from a patient self-report or a weight measured at delivery, but it is more often a weight measured during the third trimester at the last prenatal/study visit. The assumptions associated with each variable make this seemingly simple measurement much more complex causing comparisons across research studies to become much more difficult or even impossible.

Determining preconception weight is a critical first step in determining GWG and ensuring proper classification of preconception BMI. Fifty-one percent of pregnancies are unplanned in the United States (9) making objective measurements of body weight at the time of conception mostly unavailable. Women also significantly underreport body weight which inherently increases the risk for misclassification of preconception BMI and thereby inappropriate adoption of the GWG recommendations, and later, assessment of total GWG (10). Groups have attempted to validate self-reported preconception weights from objective preconception weights extracted from the medical chart. While the timing of the preconception weight is likely to vary up to 1 year from the index pregnancy for most individuals, Phelan et al. (11) showed a high level of agreement between self-reported preconception weight gathered during the 13th week of pregnancy and clinical record of preconception weight gathered in the last year ($r = 0.95$; $p < 0.0001$). Bland-Altman analysis, a true measure of agreement, challenges the accuracy of estimating preconception weight based on self-reported preconception weight gathered in the first trimester by suggesting a potential negative bias (-0.62 kg; confidence intervals $[-4.4, 3.1$ kg]), indicating increased under-reporting of preconception weight with higher BMI (12).

Using a first trimester weight

Due to the difficulty obtaining an accurate preconception weight, many researchers default to using the first measured weight in the first trimester as the preconception weight. This is probably based on the assumption that weight gain in the first trimester is believed to be minimal (0.5 – 2 kg) (6). Using an elegant dataset compiled by Dr. Nancy Butte (13), where weight prior to conception and during the first trimester were measured under the same conditions (weight in gown following an overnight fast and using the same calibrated scale), we learn that on an individual basis, using the first trimester weight to determine preconception BMI is problematic. Using this dataset, the mean trimester 1 weight, measured at 63 ± 11 days of gestation (9 weeks), is 1.3 ± 3.0 kg higher (range: -5.2 to 13.5 kg; $p < 0.002$) than the mean weight measured prior to pregnancy. Hence assuming that a first trimester weight is equal to preconception weight is inaccurate. BMI was reclassified in almost 1 in 10 cases leading to inaccurate preconception BMI, incorrect GWG recommendations and adherence assessment.

Using an adjusted first measured pregnancy weight

To account for an unknown amount of weight gain between conception and the first measured weight in pregnancy and the fact that many women do not present for prenatal care in the first trimester, some researchers assume weight gain in the first trimester as a constant (i.e. 0.5–1 kg). This nominal value is then subtracted from the first measured weight in pregnancy to derive an estimated preconception weight. As shown in the example below, this assumption can also be incorrect as weight gain between conception and the first measured weight can be highly variable in magnitude and also timing.

Predicted preconception weight

To more accurately and objectively assess preconception weight when a reliable measured weight is not available, validated mathematical models have been proposed (12, 14). These models predict preconception weight based on maternal age, race, height and gestational age and measured weight at the first trimester visit and more closely estimate preconception weight than self-report (12). More data are needed to validate these models before they can be deployed in clinical practice and research.

Total weight gain: adjusting IOM GWG Guidelines for length of gestation

Total GWG computed as, final weight in pregnancy minus initial weight in pregnancy, will be highly variable simply on the basis of differences in length of gestation. It is unclear how to compare gestational weight gain between women who deliver at term (37 weeks) but prior to 40 weeks, during the 40th week or at 42 weeks. The pressing question here is, if a woman delivers either before or after 40 weeks or if a weight is not collected at delivery, but a weight during trimester 3 is available, how should the IOM guidelines be applied to calculate total GWG? Should total GWG be adjusted for length of gestation at the time the final weight was collected even if this weight was several weeks prior to delivery? Each method will obviously impact the classification of adherence to the IOM guidelines.

The hypothetical case study (Figure 2) shows a woman who has a preconception weight of 62 kg and preconception BMI of 22.8 kg/m² (normal weight), and therefore a target GWG of 11.5–16 kg according to the 2009 IOM definitions. The woman delivers at 33 weeks and weighed 76.7 kg. Computing total GWG as final weight minus initial weight gives 14.7 kg, which falls within the 2009 IOM recommendation, and a decision of appropriate GWG would be recorded. However, if we compute the total expected GWG for the actual length of gestation at delivery (33,0 weeks), the appropriate weight gain should be no more than 12.1 kg and therefore her weight gain of 14.7 kg through to 33,0 weeks exceeds the 2009 IOM recommendations.

Incremental weight gain does not rely heavily on gestational age, however is tracked as pregnancy progresses, and can therefore determine the rate of gain between two objective weight measurements. For example, incremental weight gain can be expressed as weight gain per week, month, or trimester. Incremental weight gain is often used to assess adherence to the IOM Guidelines in research and clinical practice. Incremental weight gain has an important role in studies of pregnancy and maternal outcomes that ensue throughout the course of pregnancy or throughout the duration of an intervention. Preliminary research shows that excessive weight gained in the first trimester predicts excessive weight gain throughout pregnancy (15). Incremental weight gain is then a valuable tracking and counseling tool to potentially correct early excess GWG and positively impact the maternal and fetal health for the remainder of the pregnancy. Incremental weight gain, however, does not always give an accurate picture of total weight gain and the rate in this defined period of time really cannot be extrapolated to the entire pregnancy as rate of gain can vary drastically.

Putting the methods into practice

To examine the effect of the various assumptions and calculations of GWG (Table 2) on the categorization of subject as adherent or not to the 2009 IOM GWG recommendations, we applied the different approaches to an albeit small but remarkably well-controlled cohort of pregnant women (13). In this study all measurements of weight were obtained under the same standardized conditions (following an overnight fast), on the same calibrated research scale and height was measured using a stadiometer, resulting in an accurate determination of preconception BMI. Using this dataset comprised of 52 individuals with complete data, we computed GWG using 4 commonly used approaches:

Method 1: Total weight gain = Final weight in pregnancy - Preconception weight

Method 2: Total weight gain = Final weight in pregnancy (corrected for length of gestation) - Preconception weight

Method 3: Total weight gain = Final weight in pregnancy - Initial weight in pregnancy

Method 4: Incremental weight gain = Weight₂ - Weight₁ / # weeks (or days) between weights

Following these computations for each subject, we classified individuals as either below IOM, within IOM or exceeded IOM guidelines. The adherence distributions between the methods can be seen in Table 3. The Bowker's Test and Kappa Coefficient assessed the

symmetry and agreement between each classification method. There was medium classification agreement and symmetry between GWG Methods 1 and 3 ($\kappa = 0.6$, 95% CI [0.42, 0.78], $p < 0.0001$; Bowker's Test: $p = 0.36$). Agreement was seen between other methods, but the level of agreement was low ($\kappa < 0.4$ and symmetry was significantly different). Indeed, methods 1 and 3 are most commonly used in the literature (11, 13, 16–19), but as we demonstrated, these methods wrongly assume total GWG because many weeks of gestation (and opportunity for weight gain) are not correctly accounted for when length of gestation is ignored. This was demonstrated by method 2 and the influx of women who exceed the 2009 GWG guidelines when total GWG is adjusted for length of gestation. Methods 2 and 4 have the potential to be interpreted and utilized differently. Method 2 takes into account the entire pregnancy and can be used to track progress throughout.

Method 4, however, is a snap shot of a particular period and may not tell the whole story (i.e. excess weight gain of 15 pounds in trimester 1). With medium agreement, at most, between the methods, the inability to compare results across studies and the need for a uniform approach becomes very clear. What is obvious from this analysis is that the classification of adherence to the IOM guidelines using Method 2, which we propose should be considered the gold standard, is not associated at all with the most commonly reported metric for GWG, Method 1. We demonstrated that by adjusting total GWG for the length of gestation, there was a 40% increase in the number of cases with defined excess GWG. While more research is needed to correlate each method with birth outcomes, it is clear that determination of adherence to the IOM GWG guidelines is greatly dependent on the method used to calculate GWG. Each method has its place in clinical practice, but assessing adherence to the IOM guidelines in research requires standardization in order to better evaluate the published literature and make reliable conclusions, recommendations and evidence-based changes in obstetrical care.

We suggest the most accurate approach to avoid wrongful classification is to calculate total GWG while taking into account the length of gestation. Ideally, preconception weight and height should be measured according to standard operating procedures. When a measured preconception weight is not available, researchers should consider using an estimated weight derived from mathematical models to objectively estimate preconception weight (12). Whether the final weight is measured in the third trimester or at delivery, total GWG should be corrected to length of gestation. When adjusting for length of gestation it is critical to remember the 2009 IOM trimester specific, incremental weight gain guidelines (Table 1). The IOM guidelines assume a gain of 0.5 to 2 kg in the first trimester for all preconception BMI categories, and provide weekly incremental weight gain guidelines for the second and third trimester specific to each preconception BMI category. With this uniform approach to estimating total GWG and adherence to IOM guidelines, consistency and alignment across research studies strengthening the body of evidence in the field. This would in turn lead to more valid and reliable evidence based GWG recommendations to improve maternal and child health throughout the world.

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What is already known?

- The IOM has provided GWG guidelines specific to preconception BMI
- Excess GWG is associated with negative maternal and fetal health outcomes
- GWG is assessed and tracked by many methods in the research and clinical setting

What this study adds

- Discussion of the challenges in the assessment of GWG including assessment of preconception weight
- Discussion of the four main methods used to calculate GWG
- Recommendation of a uniform approach to GWG assessment based on total GWG adjusted for the length of gestation

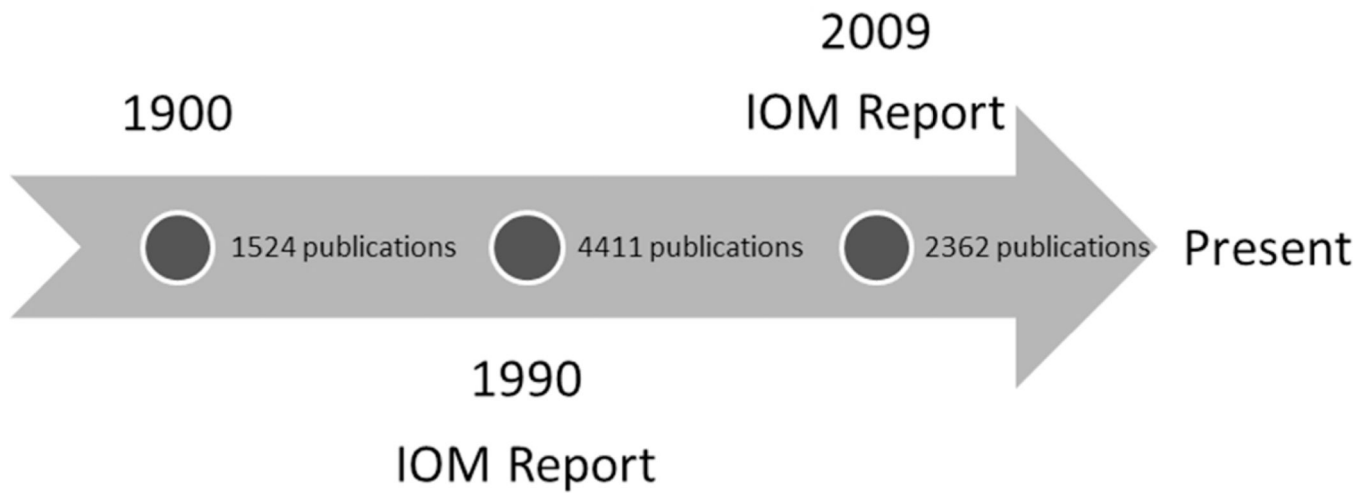


Figure 1.

Pregnancy and GWG publication timeline. A Pubmed search using the terms pregnancy weight gain” and “gestational weight gain” resulted in 1,524 publications between 1900 and 1990. In 1990, the first IOM GWG report was released. Between 1990 and 2009 4,411 papers were published. In 2009 the IOM released a report reexamining the GWG guidelines. Since the release of 2009 IOM report, 2,362 papers have been published relating to gestational weight gain.

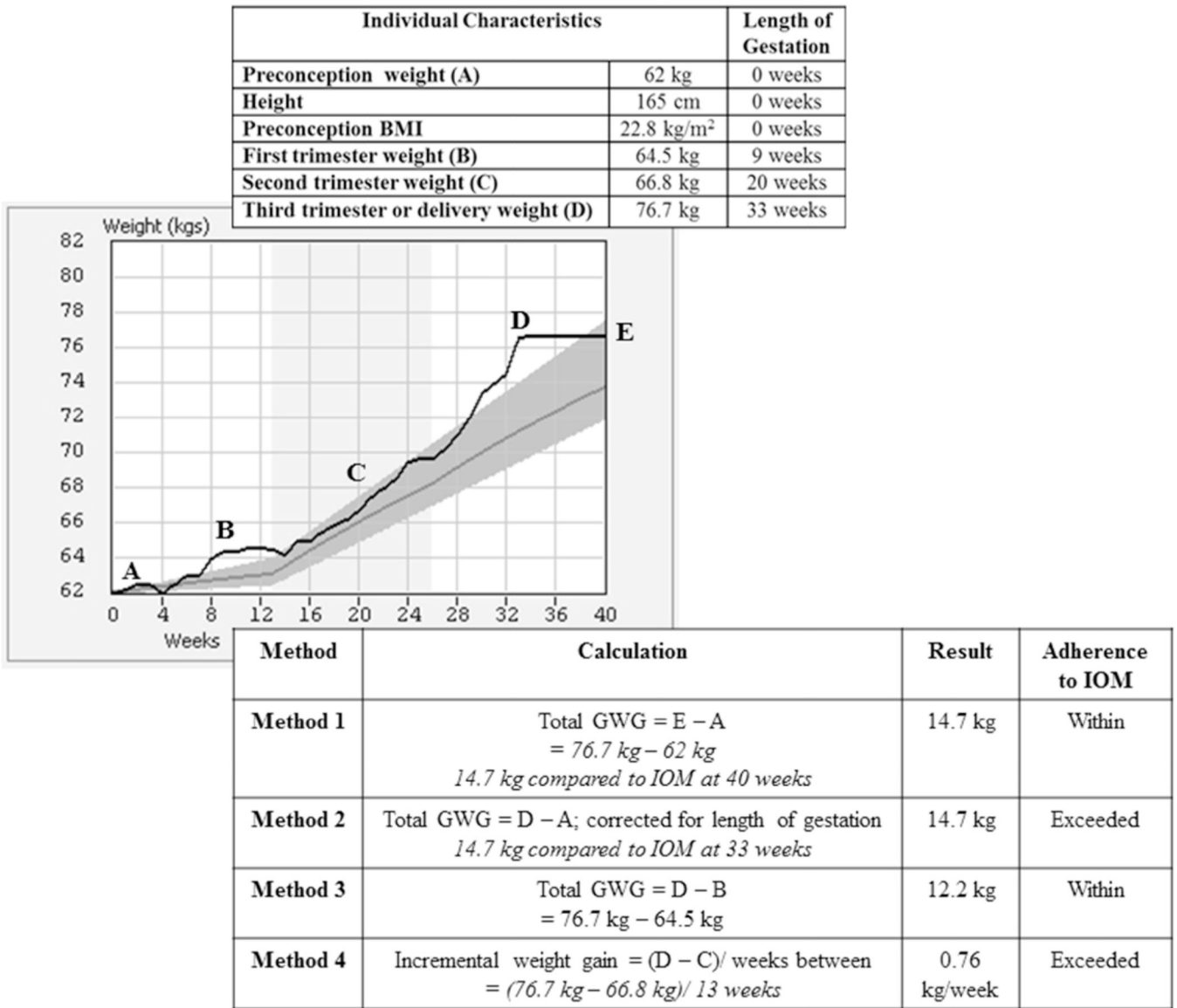


Figure 2. GWG case study showcasing the four methods used to estimate GWG and adherence to the 2009 IOM GWG guidelines. Point A is the individual’s weight measured prior to conception. Preconception height was also measured to calculate preconception BMI, and to determine the GWG range recommended. Point B is a weight measured in the first trimester (initial weight). Point C is a weight measured within the second trimester. Point D represents either a weight measured within the third trimester or a weight measured at delivery. In this example, the individual delivered at 33 weeks. Point E represents a delivery at 40 weeks.

Table 1Institute of Medicine 2009 Gestational Weight Gain Guidelines¹

Preconception BMI	Total Weight Gain		Incremental weight gain during the 2 nd and 3 rd Trimester	
	Range in kg	Range in lbs	Mean (range) in kg/wk	Mean (range) in lbs/wk
Underweight (<18.5 kg/m ²)	12.5 – 18	28 – 40	0.51 (0.44 – 0.58)	1 (1 – 1.3)
Normal weight (18.5 – 24.9 kg/m ²)	11.5 – 16	25 – 35	0.42 (0.35 – 0.50)	1 (0.8 – 1)
Overweight (25.0 – 29.9 kg/m ²)	7 – 11.5	15 – 25	0.28 (0.23 – 0.33)	0.6 (0.5 – 0.7)
Obese (≥ 30.0 kg/m ²)	5 – 9	11 – 20	0.22 (0.17 – 0.27)	0.5 (0.4 – 0.6)

¹ Recreated from IOM 2009 GWG Report (6).

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Table 2

Methods used to assess adherence to the 2009 IOM GWG Guidelines: Pro's and Con's

	Pros	Cons
Total GWG	<ul style="list-style-type: none"> • Recommendations are specific to preconception BMI (see note on preconception weight) • Gives overall picture of gestational weight gain • Less sensitive to rounding errors 	<ul style="list-style-type: none"> • Accurate preconception weight may not be known or is difficult to obtain • Relies on gestational age • Delivery weight not routinely collected • Not able to assess until delivery
Incremental weight gain	<ul style="list-style-type: none"> • Recommendations are specific to preconception BMI • Does not rely on gestational age • Able to assess between two objective weights • Able to assess weight gain during different periods of pregnancy 	<ul style="list-style-type: none"> • More sensitive to rounding errors • Assumes linear gain between weight measures

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Table 3

Calculations of GWG and effects on adherence to the 2009 IOM GWG Guidelines

Method of Assessing Adherence N=52	Below IOM Recommendations N (%)	Within IOM Recommendations N (%)	Exceeded IOM Recommendations N (%)
Method 1^a	17 (33%)	16 (31%)	19 (37%)
Method 2	7 (13%)	18 (35%)	27 (52%)
Method 3^a	17 (33%)	21 (40%)	14 (27%)
Method 4	6 (12%)	13 (25%)	33 (63%)

^aMethods showed medium agreement in classifying individuals based on adherence to 2009 IOM GWG guidelines ($\kappa = 0.6$, 95% CI [0.42, 0.78], $p < 0.0001$; Bowker's Test: $p = 0.36$).

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