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The relationship between gestational weight gain and fetal growth: time to take stock?

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Abstract: The aim of this article is to review the current evidence on gestational weight gain (GWG). Maternal obesity has emerged as one of the great challenges in modern obstetrics as it is becoming increasingly common and is associated with increased maternal and fetal complications. There has been an upsurge of interest in GWG with an emphasis on the relationship between excessive GWG and increased fetal growth. Recent recommendations from the Institute of Medicine in the USA have revised downwards the weight gain recommendations in pregnancy for obese mothers. We believe that it is time to take stock again about the advice that pregnant women are given about GWG and their lifestyle before, during, and after pregnancy. The epidemiological links between excessive GWG and aberrant fetal growth are weak, particularly in obese women. There is little evidence that intervention studies decrease excessive GWG or improve intrauterine fetal growth. Indeed, there is a potential risk that inappropriate interventions during the course of pregnancy may lead to fetal malnutrition that may have adverse clinical consequences, both in the short- and long-term. It may be more appropriate to shift the focus of attention from monitoring maternal weight to increasing physical activity levels and improving nutritional intakes.

Keywords: Fetal growth; gestational weight gain; maternal obesity.

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Introduction

Maternal obesity, based on a body mass index (BMI) >29.9 kg/m^2, has emerged as one of the great challenges in modern obstetrics because it is associated with increased maternal and fetal complications and, as a result, an increase in pregnancy interventions [9, 27]. It is common, and thus, its complications are associated with a significant increase in obstetric and pediatric healthcare costs [5, 22]. In the USA, concerns about the impact of maternal obesity led the Institute of Medicine (IOM) to re-examine national guidelines on weight gain during pregnancy. In its 2009 report, the IOM revised the recommendations for weight gain according to BMI category and, based on evidence primarily from women with a BMI of 30.0–34.9 kg/m^2 (mild obesity), it reduced the recommended gestational weight gain (GWG) for all obese women to 5–9 kg [19].

The IOM recommendations were specifically for the American population and a recent review has found no international consensus about GWG recommendations [1]. In the UK, weighing the woman at the first antenatal visit is recommended but repeat weighing during pregnancy to determine GWG is not advised in the absence of clinical concerns [26]. There is currently an upsurge of interest in GWG with a five-fold increase in annual academic publications on the subject registered with the PubMed database from 1990 to 2012 (Figure 1).

Epidemiological studies have reported an association between maternal obesity and aberrant fetal growth [17]. However, these observations must be interpreted with caution because it has long been established that epidemiological associations, however strong, do not prove causation. As weight gain in pregnancy includes the weight of both the baby and the placenta, it is hardly surprising that positive epidemiological associations have been found between GWG and birthweight. Despite the increasing prevalence of obesity among pregnant women there has not been a concurrent increase in the prevalence of babies with a birthweight over 4.5kg [23]. Studies on GWG to date have been fraught with difficulties and high quality scientific evidence is lacking [39]. Professional recommendations need to be careful to balance the risks of excessive fetal growth against the potential for fetal macronutrient and micronutrient deficiency, particularly when causal factors for excessive fetal growth have not been well established [31, 39].

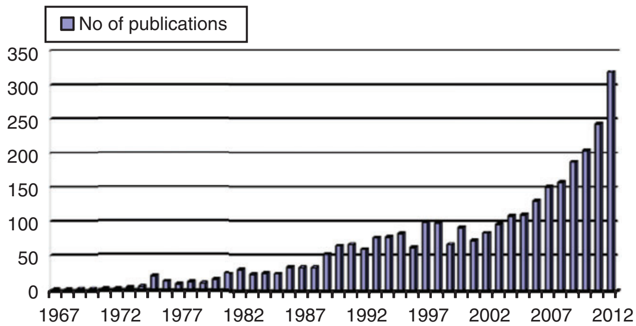

Figure 1 Gestational weight gain publications by year cited on the PubMed database.

Measurement of weight and BMI categorization

Epidemiological studies on GWG face numerous challenges. The first challenge is the accurate assessment of the woman's weight. In most studies on GWG, the woman's weight is based on self-reporting and not on actual measurement [38]. The accuracy of self-reported weight was reviewed in 32 studies involving 57,172 women [6]. In every study, women underestimated their weight. There is also evidence that underestimation of weight is more likely in women who are overweight or obese than in those with a normal BMI. A study of 2667 adults found that women who were morbidly obese (>39.9 kg/m^2) underestimated their BMI by an average of 5.0 kg/m^2 [33, 34]. This results in women being placed in the wrong BMI category when self-reported weight and height are used. The use of self-reporting of weight in epidemiological obesity research results in a miscategorization of BMI in 16% of women outside pregnancy and 22% of women during pregnancy [3, 13].

If self-reporting of early pregnancy weight is used as the baseline weight this leads to the overestimation of weight gain, and thus, to errors in calculating the velocity of GWG as pregnancy advances [12]. Self-reporting also introduces recall bias, particularly in obese subjects [19]. BMI miscategorization as a result of self-reporting is not uniform and so standard corrective formulae cannot be applied at a study population level to correct errors [30]. Furthermore, BMI categorization based on self-reporting has been shown to lead to epidemiological exaggeration of clinical risks because subjects with mild obesity are often categorized wrongly as "overweight" and not analyzed in the "obese" category and those categorized as "obese" are over-represented by those with moderate to severe obesity [38]. Therefore, evidence on GWG and obstetric risk based on self-reported weight must be interpreted with caution.

Timing of baseline weight measurement

A second challenge in the measurement of GWG is the timing of the baseline weight measurement. Some studies use pre-pregnancy weight, which may be either measured or self-reported. However, the time interval between this weight recording and conception is highly variable, and thus, may not reflect early pregnancy weight.

Women may try actively to gain or lose weight before becoming pregnant. In fact, often a change in weight can be the trigger for conception because anovulatory infertility can be treated by weight loss in obese women and women with polycystic ovarian syndrome and by weight gain in underweight women. Furthermore, about half of all pregnancies are unintended, therefore, measured pre-pregnancy weights are often unavailable [14]. Unintended pregnancies due to failure of hormonal contraception may also be commoner in obese women [8]. Thus, the availability or non-availability of a pre-pregnancy weight measurement in itself is a potential source of epidemiological bias in studies of GWG.

For baseline weight measurement during pregnancy, the gestational age at the time of measurement is important. Although previous reports suggest that women gain 0.5–2.0 kg in the first trimester, our research group has shown that there is no increase in average maternal weight and no changes in maternal body composition in the first trimester [12, 19]. Indeed, results indicate that maternal weight only starts to increase, on average, around 18 weeks of gestation (Figure 2 [12]). Thus, measurements of weight taken before 18 weeks of gestation can be used as accurate baseline measurements. Some epidemiological studies include women whose weight is measured after 18 weeks of gestation or where gestational age is uncertain, as it has not been confirmed by ultrasound.

Timing of repeat measurement

Weight gain implies the measurement of weight at two separate points in time. The timing of repeat weight measurements must be well-defined in order to compare outcomes of GWG studies. While serial weight measurements during pregnancy are common in the USA, they are not standard practice in other maternity services [20, 26]. As a result, there is a paucity of longitudinal studies of GWG based on accurate serial weight measurements.

Some studies report total GWG based on subtracting the first weight measurement (either pre-pregnancy

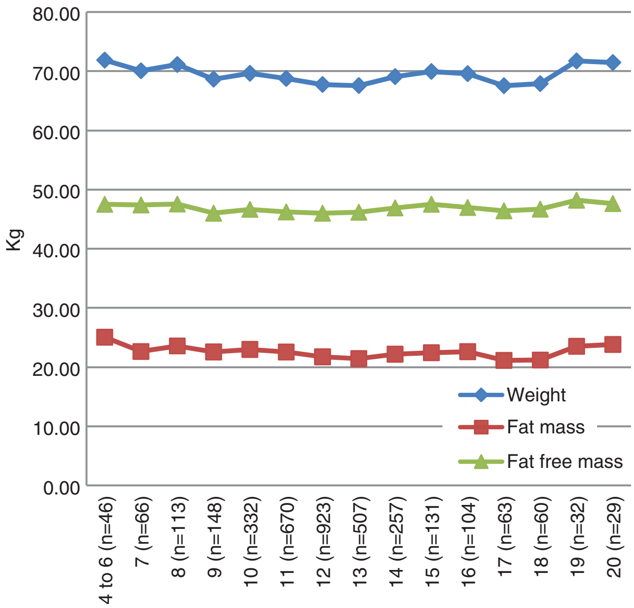

Figure 2 Body composition parameters by gestation (n=3476).

or early pregnancy) from the last measurement recorded during the pregnancy. However, the timing of last measurement is highly variable and makes no allowance for the important influence of gestational age. Other studies use maternal weight immediately after delivery or at various times in the puerperium. Some studies subtract the weight of the baby, however, other studies do not. This also raises questions about the weight of the liquor and the placenta, about pre-delivery water retention and edema, as well as post-delivery diuresis.

Gestational age is an important determinant not only of GWG itself but also of the clinical outcomes of GWG. Understanding optimal GWG requires comparing clinical outcomes at different weight gains at the same gestation. These clinical outcomes can only be compared when there is accurate knowledge of gestational age. This is particularly important when examining outcomes such as birthweight, or babies classed as small-for-gestational-age or large-for-gestational-age [18, 19]. Therefore, early pregnancy confirmation of gestational age by ultrasound should be a prerequisite for any study of GWG.

Calculation of gestational weight gain

There are differences in the literature as to how GWG is expressed. In most studies, it is expressed as the absolute difference in maternal weight between two points in time. However, this is of limited scientific value because of the wide range of timing of baseline and repeat measurements used in different studies. Other studies have expressed GWG as the average gain per week of pregnancy [18]. However, these calculations make many assumptions. They assume that gestational age is known accurately, that the normal weight gain at different gestational ages is known, that accurate weight measurements have occurred throughout pregnancy, and that weight gain is linear. They also assume that maternal body composition evolves uniformly throughout pregnancy, and make no allowance for the extracellular fluid increase that is common in the third trimester.

It may be more meaningful if GWG is expressed as a percentage of the baseline measurement. This makes more sense as a 10 kg GWG may have more clinical implications in a short woman than a taller woman in the same BMI category [28].

The limitations of current methods for measuring GWG have also been highlighted by other researchers [24]. Not only is gestational age at measurement important, but current methodology falsely assumes a linear increase in weight as pregnancy advances, the pattern of GWG is ignored. They suggest the use of the area under the GWG curve. This measures the relationship between the woman's weight trend plotted over time and her pre-pregnancy weight. This study has limitations; the measurements were self-reported and the subjects were older, wealthier and better educated than the general population, also, women who breastfed were excluded. Nonetheless, the authors proposed the development of novel methods to measure GWG.

Another study examined the bias in current measures of GWG [18]. The study quantified the extent to which currently used measures may bias the relationship between GWG and the risk of preterm delivery using a provincial Canadian database for the years 2000–2009. Simulated GWGs were classified using these approaches: total GWG (kg), average rate of GWG (kg/week) or adequacy of GWG in relationship to the IOM recommendations. All these measures of GWG induced an apparent association between GWG and preterm delivery <33 weeks even when, by design, none existed. The authors concluded that contemporary GWG measures are a potential source of bias in epidemiological studies and called for the use of serial antenatal GWG measurements as an alternative approach. They acknowledged that difficulties in conducting such studies meant that studies using serial GWG were few to date. They also called for the development of new methods for measuring GWG.

Understanding gestational weight gain and clinical outcomes

BMI is only a surrogate marker of adiposity and BMI categorization in itself is fraught with difficulties [38]. There are also uncertainties as to what level of BMI obstetric risk starts to increase [11, 38]. The level of increased risk may differ depending on a woman's parity, age, ethnicity, or comorbidities [16]. The level of clinical risk may also be different for the woman than for the baby. Linking GWG recommendations only to BMI categorization may make it more difficult to tease out the optimum GWG or normal range of GWG for individual women.

The new IOM guidelines have revised downwards the recommendation for GWG for obese women (Table 1). This change in recommendation was driven by concerns about rising population levels of obesity rather than by fetal considerations [19]. The new recommendations again assume that the BMI categorization is accurate at the onset of pregnancy.

Numerous studies report on the high number of obese women with excessive GWG. The high levels of "excessive" GWG in obese women may be simply explained by the stricter IOM recommendations for obese women. However, even without interventions, obese women already gain less weight on average during pregnancy than women with a normal BMI [19].

Normal, excessive and insufficient GWG are not well defined. The range of normal GWG is wide and the relationship between abnormal GWG and adverse clinical outcomes for the baby is uncertain. Indeed, the optimum GWG for the baby may be different to that for the woman, and it is acknowledged explicitly in the revised IOM guidelines that there is a trade-off in outcomes between the woman and her offspring [19]. High GWG, for example, was found to be associated with a decreased risk of a small-for-gestational-age baby but with an increased risk of excessive maternal weight retention. There is also a lack of data on how best to balance the severity of the competing short-term and long-term outcomes for the woman and child across the range of GWG [21, 31].

Table 1 Institute of Medicine gestational weight gain (GWG) recommendations by body mass index (BMI) category [17].

BMI category	BMI (kg/m^2)	GWG recommendation (kg)
Underweight	<18.5	12.7–18.1
Normal	18.5–24.9	11.3–15.9
Overweight	25.0–24.9	6.8–11.3
Obese	≥30.0	5.0–9.1

An evidence-based review on outcomes of GWG considered 35 studies of variable quality that addressed GWG and birthweight as a continuous measure [35]. Every study found an association between greater GWG and greater birthweight. A review of 13 studies found that the risk of low birthweight diminished as GWG increased. Although varying definitions of fetal macrosomia were used, the review considered 12 studies and found a consistent trend for increased risk of macrosomia with increasing GWG.

There is also evidence that birthweight distribution is shifted upwards with increased GWG, reducing the risk of small-for-gestational-age babies and increasing the risk of large-for-gestational-age babies [41]. There was also evidence that the higher the GWG, the higher the newborn fat mass, which raises the possibility that higher GWG may lead to long-term adiposity in the offspring [32]. However, as measurement of weight during pregnancy includes the weight of the baby and placenta, it is to be expected that an association between birthweight and GWG has been found.

One observational study measured GWG between the first trimester and 38 weeks' gestation in 604 women attending for routine antenatal care in a large maternity hospital [28]. In the obese category (n=153), 46.5% of women put on excessive weight as recommended by the IOM guidelines compared with 17.5% in the overweight category (n=164) and with only 3.45% in the normal BMI category (n=280). However, the mean GWG was 10.4 kg (standard deviation 7.5) in the obese category, which was lower than the mean GWG of 12.6 kg (standard deviation 5.7) in women with a normal BMI ($P<0.001$). No relationship was found between percentage GWG and birthweight.

The relationship between GWG and clinical outcomes for the woman and her offspring needs to be evaluated more closely, and attention paid to confounding variables such as age, parity, ethnicity, smoking and diabetes mellitus. For example, increasing parity is associated with increasing maternal weight, but only in women who are socially and economically disadvantaged [40].

Considering absolute GWG only makes no allowance for the distribution of the weight gain. Distribution of adiposity, for example, has been shown to be an important predictor of adverse clinical outcomes in adults outside the setting of the pregnancy with visceral adiposity more strongly correlated with metabolic abnormalities than peripheral adiposity.

There is also evidence that the timing of weight gain during pregnancy may be important in influencing clinical outcomes [10, 31]. In particular, weight increases in early pregnancy may be more clinically important than weight gain during the third trimester. Understanding the influence of the timing of GWG on pregnancy outcomes requires repeat weight measurement at clearly defined gestational ages. A striking feature of GWG research to date is the absence of standardization in its measurements, and thus, there are major information gaps about maternal weight trajectories during pregnancy [39].

Gestational weight gain interventions

Even if excessive GWG is linked epidemiologically to excessive fetal growth, is there evidence that pregnancy interventions will lead to improvements that are clinically beneficial to the fetus? A recent meta-analysis of nine intervention trials involving 1656 subjects showed that promotion of healthy diet and physical activity was effective in minimizing GWG [15]. There was considerable heterogenicity in outcomes and while significant statistically, the reduction of GWG was on average only 1.19 kg. The meta-analysis did not address whether the interventions were associated with a decrease in either "excessive" GWG or fetal growth.

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Six systematic reviews were published in English on interventions to optimize GWG [29]. All the reviews commented on the poor to low quality literature, the heterogenicity of interventions and the inconsistency of results. In particular, interventions have not been shown to be effective in decreasing GWG in obese women, which may be explained in part by the fact that even without interventions obese women gain less weight than non-obese women.

Even if interventions were shown to decrease excessive GWG in obese women, they may not prevent excessive fetal growth. Large epidemiological studies have found that, despite a continued increase in the prevalence of maternal obesity, there has been an associated decrease, not an increase, in babies with excessive fetal growth [24]. In a meta-analysis of randomized evidence on the effects of interventions in pregnancy on maternal weight and obstetric outcomes, 44 trials involving 7278 women were studied [37]. In 34 trials, the meta-analysis found that interventions significantly reduced maternal weight gain but that there was no difference made to the adherence to the IOM GWG recommendations. In 31 trials, no significant reduction in birthweight was found.

A study of 63 women measured maternal body composition during pregnancy using a multicomponent model [4]. Birthweight was correlated positively with an increase in maternal fat-free mass ($P<0.01$), but not fat mass. Other studies have also found that maternal water gain, but not fat gain, is predictive of birthweight [36]. We have recently reported on the correlation between birthweight and maternal body composition in 2618 women studied prospectively in a large maternity hospital [24]. Maternal body composition was measured directly in the first trimester using advanced bioelectrical impedance analysis. In univariate analysis, birthweight correlated significantly with maternal age, BMI, parity, gestational age at delivery, smoking, fat mass, and fat-free mass. In multivariate regression analysis, however, birthweight correlated significantly with fat-free mass but not fat mass. Therefore, attempts to reduce maternal fat mass during the course of pregnancy are unlikely to decrease birthweight [26].

Women who are obese may already be on a poor-quality diet that is high in cheap calories but low in more expensive nutrients. Morbidly obese patients have been shown to have a high prevalence of micronutrient deficiencies [7]. Obese women have been shown to have lower folic acid levels and to have an increased risk of neural tube defects [8]. Micronutrient and macronutrient deficiencies in pregnancy are associated with poorer outcomes for both the mother and her baby [2]. A dietary intervention focused in losing weight during pregnancy by restricting dietary intake may inadvertently deprive the growing fetus of essential nutrients. It may be preferable to focus on pregnant women having a healthy diet rather than on hitting weight targets. Thus, during pregnancy, weight management programs based on increasing physical activity in obese women, may be safer than those based on dietary restriction. Overzealous hectoring of the obese woman by healthcare professionals during pregnancy may increase risks to the baby if a reduced dietary intake lacks essential nutrients.

The timing of any interventions may be important. BMI at the start of pregnancy may be more important in determining clinical outcomes than GWG. Therefore, pre-pregnancy interventions are likely to be more effective at reducing morbidity, as well as being safer for the fetus than dietary restriction during pregnancy. Likewise, if postpartum weight retention is the major concern following excessive GWG, then post-pregnancy interventions should be considered. There is also uncertainty about what interventions not only optimize GWG but improve clinical outcomes and whether successful interventions will work for different cohorts of women.

The IOM review team acknowledged that there are large research gaps in our knowledge of best practices for weight management during pregnancy. Specifically, they recommend that researchers needed to use consistent definitions of GWG, improve standardization of methods and timing of GWG measurement, analyze confounding variables better, improve study design, and increase follow up, if we are to fully understand the impact of GWG on short- and long-term outcomes for women and their offspring. We believe that there is an urgency about closing these research gaps.

Closing these research gaps is a priority in circumstances where compliance with the IOM recommendations in the USA, for whatever reasons, have been shown to be poor [41]. There is no international consensus about the best guidance, the effectiveness of interventions is unknown, the fetal risks of dietary restrictions are uncertain and a "one size fits all" approach to GWG may be inappropriate for the individual women and their offspring.

Conclusions

We believe that it is time to take stock again about the advice that pregnant women are given about GWG and their lifestyle before, during, and after pregnancy. The epidemiological links between excessive GWG and aberrant fetal growth are weak, particularly in obese women. Adherence to GWG recommendations is poor, which may be related to incoherent healthcare communication strategies. There is little evidence that intervention studies decrease excessive GWG or improve intrauterine fetal growth. Indeed, there is a potential risk that inappropriate interventions during the course of pregnancy may lead to fetal malnutrition that may have adverse clinical consequences, both in the short- and long-term. It may be more appropriate to shift the focus of attention from monitoring maternal weight to increasing physical activity levels and improving nutritional intakes.

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