Original Research:

The association between pre-pregnancy body mass index and gestational weight gain (GWG) among women in rural NSW, Australia

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160 character summary of article: Evaluation of the proportion of pregnant women in a rural medical practice not meeting the current guidelines for gestational weight gain with a secondary analysis of delivery methods.

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Abstract

Background: Pre-pregnancy body mass index (BMI) and excessive gestational weight gain (GWG) are associated with adverse outcomes of pregnancy. The Institute of Medicine (IOM) provides recommendations for weight gain during pregnancy based on pre-pregnancy BMI.

Objectives: To evaluate the proportion of pregnant women in a rural medical practice not meeting the IOM guidelines and to assess a link between pre-pregnancy BMI or excessive GWG and delivery method in this population.

Methods: A clinical audit of 168 patients in a rural NSW Medical Centre with a search criterion of 'pregnancy' was performed. Relevant patient details were collected and linked to patient files; pre-pregnancy weight, height, weights recorded during pregnancy, and delivery method.

Results: Among the 87% of gestating women who did not meet the current GWG recommendations, 57% gained weight excessively and 30% inadequately. There was a statistically significant association between pre-pregnancy BMI and excessive GWG with overweight women more likely to gain excessively (Fisher's exact test 29.04, $p<0.001$). Pre-pregnancy BMI was also associated with delivery method, with normal weight women more likely to have a normal vaginal delivery and obese women more likely to have an instrumental delivery or planned Caesarean-section (Fisher's exact test 20.89; $p<0.001$). Gestational weight gain was not associated with delivery method, regardless of pre-pregnancy BMI.

Conclusion: Given that the majority of women in this rural medical practice showed gestational weight gains outside the recommended limits and that pre-pregnancy BMI was associated with delivery method, there is a role for pre-conception and antenatal programs educating women regarding healthy pre-pregnancy weight and GWG.

Introduction

Pre-pregnancy obesity and excessive gestational weight gain (GWG) are associated with a wide range of adverse maternal, perinatal, puerperal, neonatal, childhood, and adulthood complications. Women with a higher pre-conception body mass index (BMI) have an increased risk of excessive GWG and of experiencing a miscarriage or stillbirth [1-6]. They also have increased risk of pre-eclampsia, gestational diabetes mellitus (GDM), dysfunctional labours, post-partum haemorrhage, wound infection, congenital abnormalities, prematurity, neonatal death, macrosomia and lower Apgar scores [1,5,7-15,17]. High pre-pregnancy BMI is also associated with increased risk of caesarean section (CS) [5,9,16,17], with odds ratios of 1.53, 2.26 and 3.38 for overweight, obese and morbidly obese categories, respectively [16]. High GWG imposes a further CS risk, regardless of pre-pregnancy BMI [18].

In addition to the immediate maternal and perinatal outcomes outlined above, maternal obesity is negatively associated with breastfeeding initiation and maintaining breastfeeding for the recommended six month period [14,19]. Breastfeeding is associated with decreased risk of maternal post-partum depression, childhood obesity, neonatal infections, Type 2 diabetes (T2DM) and obesity in the offspring [20,21,22,23].

The long-term health impacts of excessive GWG also extend beyond the immediate pregnancy, with an increased risk of post-partum weight retention, which further increases the risk of pre-eclampsia in subsequent pregnancies [9,24,25]. GDM and increased fat deposition may also precipitate impaired glucose tolerance and T2DM [26]. Furthermore, several studies show a positive association between high GWG and both childhood and adult obesity in offspring [27-30]. This is of increasing concern since a large proportion of women gain weight excessively during pregnancy. One U.S. multi-centre GWG study showed 73% of women exceeded the weight gain recommended for their BMI [7]. Accounting for a previous, more stringent set of recommendations, an earlier US cohort study showed only 43.7% of women exceeded the guidelines [31]. This suggests that even with a relaxation of weight-gain targets, there is an increased incidence of excessive GWG. Another Australian study found 38% of women gained in excess of the guidelines; however, several exclusions may account for some of the variation observed [32]. Given that some of the study's exclusion criteria, including prematurity, neonatal death, language spoken and ethnicity have been linked with excessive GWG, the study may have underestimated the prevalence of women gaining above the guidelines [1,33,34].

GWG in rural areas

While there is a paucity of literature focusing on GWG in rural Australia, studies elsewhere comparing urban and rural populations show mixed results. In comparison to women in urban areas, an Iranian study found rural women more likely to be underweight, while a U.S. study found rural women were more likely to be overweight or obese. Both studies found rural women had a lower GWG than their urban counterparts [35,36]. Differences in infrastructure and food availability may contribute to rural/urban differences in BMI and GWG. Across different BMI categories, the aforementioned study suggested that pre-pregnancy obesity might actually protect against excess GWG [36]. In contrast, another urban U.S. study reported that the single most predictive factor for ideal GWG was normal pre-pregnancy BMI [37] and an urban

Australian study, which identified 56% of overweight women compared to 30% of normal weight women gaining in excess of IOM recommendations ($p<0.001$) [32]. Post-pregnancy weight retention is another issue facing rural populations. In Australia, between 42.5% and 58.1% of women of child-bearing age, and 63% of women living rurally and remotely are overweight or obese [38]. One rural U.S. study assessed the long-term effects of excess GWG and limited postpartum weight-loss [24]. The study, by Rooney and Schauberger, found no relationship between weight gain ten years postpartum and pre-pregnancy BMI, in contrast to other studies describing a positive correlation between these two factors [1-3,36]. More importantly, Rooney and Schauberger's results revealed a positive correlation between excess GWG and weight retention at five years post-partum [24]. With higher rates of obesity and obesity-related diseases, together with reduced access to medical care, these findings pertinent for the health of rural Australian women [38,39,40].

The U.S. Institute of Medicine (IOM) has recommendations for GWG based on pre-pregnancy body BMI [41] and in the absence of Australian-specific guidelines, recommendations are generally based on this guidelines [1]. Overall, while increased risks associated with GWG and obesity in pregnancy are well documented, compliance in current Australian rural environments is less well known.

This study addresses this gap in knowledge by evaluating the proportion of pregnant women in a rural medical practice not meeting the IOM guidelines using three different methods to calculate GWG. With the local hospital being low-risk, a secondary analysis assessed the link between pre-pregnancy BMI or GWG and delivery method. This study was conducted to quantify the number of women who may benefit from the newly implemented *Expecting Changes* program in the area, a program targeting weight control in women planning to conceive or newly pregnant.

Material and Methods

Ethical approval was granted by the Human Research Ethics Committee (UOW, ethics number GSM16/015).

An audit of quarterly snapshot data (2016) from a rural NSW medical centre (Modified Monash Model classification 4) was conducted using the PenCS Audit Tool™ (Pen CS Pty Ltd, Leichardt, Australia). Patients with an active search criterion of 'pregnancy' were isolated (n=385) and cross-referenced to their Best Practice (Best Practice Software Pty Ltd, Bundaberg, Australia) file. Height, pre-pregnancy and pregnancy weight data and delivery details were extracted by the Practice Manager and patient information was de-identified. Patients with missing height information were excluded (n=136). A further 81 were excluded based on inadequate weight recordings, missing data or improbable values (Figure 1). This left 168 women in the study population.

Pre-pregnancy BMI was calculated using the woman's height and the record of either 1) their earliest pregnancy weight or 2) most recent pre-pregnancy weight (weight (kg) / height (m^2)). Weight status was categorized according to the WHO BMI cut-off points (Table 1).

Weight-gain during pregnancy was calculated via three methods (employed by other studies) allowing an assessment of whether method of calculation changed the outcome [7,15,32,36]. Calculations used were

1. Total weight-gain: last weight minus first weight.
2. Average weight-gain by week: total weight-gain divided by the number of gestational weeks.
3. Average weight-gain by week: weight-gains at each measurement divided by the number of weeks between weight measurements.

Based on these three calculation methods, GWG was classified as below, within, or above the IOM recommendations. A secondary analysis of delivery method was matched to each category pre-pregnancy BMI and GWG.

Statistical analysis

Cross-tabulations using chi-square and exact tests were used to determine the association between 1) pre-pregnancy BMI and GWG, based on the IOM recommendations, and 2) GWG and delivery method. Fisher's exact test was used when the minimum expected cell frequency assumption was violated. Data were analysed using Excel (Microsoft® Corporation, Redmond, USA) and SPSS software (IBM, New York City, USA).

Results

Subjects

Of the 168 women in the final study population, 4% were underweight, 32% were normal weight, 23% were overweight and 42% were obese. Indigenous status was collected, but not considered due to the small sample size (n=11). Age ranged from 18.9 to 46.2 years (mean: 30.6 years).

GWG across all pregnancies

The three methods used to evaluate GWG revealed slightly different proportions of women below, within and above the IOM recommendations (Figure 2). Using total weight gained, 36% of participants gained above and 33% less than the guidelines. Almost a third of women (31%) gained weight within the recommendations. With regard to the methods of GWG classification, more women were found to have gained above the recommendations when total weight-gain was broken down by week (57%, n=95), with only 13% (n=22) of women gaining within the recommendations. When assessing weight-gain using the interval between weights, even fewer women had met the recommended guidelines (9%, n=15).

GWG based on pre-pregnancy BMI

On average, underweight, normal weight, overweight and obese women gained a total of 11.25 kg, 12.62 kg, 12.08 kg and 7.38 kg, respectively. Using the weight-gain by week calculation, underweight women gained an average of 0.354 kg per week; normal weight women, 0.478 kg; overweight women, 0.480 kg; and obese women, 0.311 kg (Table 2). A χ^2 test of this weekly weight-gain calculation revealed a statistically significant association between pre-pregnancy BMI and weight-gain based on IOM recommendations (Fisher's Exact test 29.01; $p<0.001$), with 76% (n=29) of overweight women (Table 3) gaining above the recommendations. Obese women were more likely gain less gestational weight than recommended by the IOM (Table 3). Women with normal pre-pregnancy BMIs were significantly more likely ($p<0.001$) to gain within the IOM recommendations. This significance was not observed when using the total weight-gain and interval weight-gain calculations; however, using each respective calculation, 50% (n=26) and 61% (n=23) of overweight, and 37% (n=26) and 55% (n=39) of obese women still gained above the recommendations. Using the interval calculation, 51% (n=27) of women within a normal pre-pregnancy weight range gained above the recommendation compared to 47% (n=25) using the average gain by week calculation. Despite the small sample size (n=6), the majority of women (67-83%) with an underweight pre-pregnancy BMI gained less than the IOM recommendations regardless of calculation method (Table 3).

Pre-pregnancy BMI, excessive GWG and delivery method

The association between pre-pregnancy BMI and delivery method was statistically significant, (Fisher's Exact test 20.89; $p<0.001$), with obese women significantly more likely to have an instrumental delivery (n=8) or planned-CS (n=16) and less likely than expected to have normal vaginal delivery (NVD). Normal weight women were more likely to have a NVD and although the numbers were small, underweight women were significantly more likely to undergo emergency-CS (Table 4). There was no statistically significant association between GWG and delivery method ($\chi^2=8.8$; $p=0.358$) (Figure 3).

Discussion

Regardless of pre-pregnancy BMI or calculation method, the majority of participants gained weight outside the IOM recommendations; only 9-31% of women gained within the recommended guidelines. Calculating GWG by week or interval rather than total weight-gain identified more women gaining outside the guidelines. Approximately one-third of women gained less weight than recommended, regardless of calculation method. Whether this is related to the environment, inadequate antenatal education or overly strict guidelines, these results are consistent with, or lower than, those reported previously. Johnson, *et al.* found 73% of participants gained above the guidelines using a total weight and weekly weight gain calculation; however, a Taiwanese study, however, found significantly fewer to have gained above (27.7%) and many more to have gained within (45%) the guidelines [7,15]. Ethnic differences in body morphology are more likely to have played a role than in the current study and provide grounds for variation in the IOM recommendations to also consider ethnicity rather than just BMI. Additionally, in a Swedish study of 163,352 women, the proportion of women gaining in excess of the guidelines was linked to education status and parity, with 37.1% of women gaining in excess of the guidelines in the first pregnancy and 32.9% in the second [3]. Being retrospective in nature, the current study did not collect data regarding parity or education. Irrespectively, with such a high proportion of women experiencing excessive GWG there is a clear need for intervention.

A common limitation for GWG studies is establishing pre-pregnancy weight. Various approaches have been used: many have used self-reported pre-pregnancy weight to determine BMI, while others have excluded women with incomplete BMI information [9,32,42,43]. In one study, where pre-pregnancy weight data were missing from participants' records, it was estimated post-delivery [44]. It is not clear whether this estimation was objective or subjective. In a later study using IOM guidelines, subjective pre-pregnancy weight provided by participants was used to calculate GWG [7]. Given that many women may neither be weighed prior to conceiving nor present within the first few weeks/months of pregnancy, it is difficult to assess true GWG based on pre-pregnancy weight. In an attempt to account for this limitation, Johnson, *et al.* assessed weekly weight-gain and provided an objective measure of weight upon study commencement [7]. This enabled a correlation between weekly weight-gain based on BMI and the IOM recommendations rather than a total weight-gain figure and formed the basis of the calculations used in this study. Another approach is using only the first prenatal visit weight to calculate GWG, with the justification that early pregnancy weight-gain should be relatively minor [24].

Using average weekly weight-gain, pre-pregnancy BMI was not associated with GWG outside the recommendations with more overweight and obese women gaining above the recommended weekly amounts. These findings are comparable with de Jersey *et al.*, where their methods included only a total weight-gain calculated by weights performed at 16 and 36 weeks' gestation [32]. The results do conflict with those of Gallagher *et al.* who found that rural overweight and obese women were less likely to have excessive GWG [36]. However, their finding that American rural women were more likely to have an overweight or obese pre-pregnancy BMI weight status is consistent with the demographic of the current study, with 64% of participants overweight or obese [36]. There was no statistically significant association between pre-pregnancy BMI and GWG when assessing total weight-gain and average weekly weight gained between measurements.

A secondary analysis of delivery method was included because the local hospital is classified as 'low-risk' (women with a BMI>40 must deliver at larger hospitals). An association between pre-pregnancy BMI and delivery method was observed with more obese women having instrumental deliveries or planned CS and more normal weight women having NVD. This finding is consistent with other large studies that found that compared to women with a normal pre-pregnancy BMI, overweight and obese women were more likely to undergo CS [5,7,16]. In a retrospective study (n=30,298), Scott-Pillai *et al.* further concluded the risk was greater for each increasing category of obesity; a breakdown of which was not included in the current study [5]. There was no statistically significant association between excessive GWG and delivery method which contrasts with previous studies; two in particular reported excessive GWG as an independent risk factor for CS delivery [16,4546,47]. The lack of association may have been related to the current study's use of categorical data to classify GWG, as opposed to quantifying the impact of increasing kilograms of GWG on delivery method. While reasons for planned-CS may not be related to maternal weight-gain or BMI, in the current study, it may indicate the need for the inclusion of pre-conception weight control planning in the *Expecting Changes* program.

Limitations

As discussed above, establishing pre-pregnancy weight can be difficult [7,9,24,32]. To overcome this, the calculation of weight-gain by week based on total GWG and interval between weight measurements was used. This is similar to the method adopted by Johnson, *et al.* [7]. Although the result was not significant, calculation based on the interval between weights allowed for a more accurate assessment of weight-gain as it factored in a potential change in rate of weight-gain occurring at different stages of pregnancy and allowed for consideration of lower weight gain targets in the first trimester.

While this study reports a statistically significant difference in weight-gain by women based on pre-pregnancy BMIs, there are limitations to the accuracy of such data and the representative nature of the sample size to the broader population of gestating rural women. Since the National Institute for Health and Care Excellence (NICE) guidelines advised against it, there has been a shift away from weighing women at every antenatal appointment [48]. This was reflected in the number of women excluded from the study due to lack of weight data. It may also be that weights were recorded on 'yellow cards' rather than in GP patient records, which this study did not have ethical approval to access. Midwives report anecdotal bias in that women who appear overweight tend to be weighed more than those who look normal or underweight. While this is associated with the local hospital's low-risk status, it also potentially means that more normal or underweight women were excluded from the study. As such, the sample size of underweight women was too small to detect statistical significance. Other limitations leading to reduction in weight information include women opting-out of weighing and variation in doctor practice (including own biases and limitations in addressing the subject of weight with women).

Comorbidities were outside the scope of this research; however, the lack of consideration of possible confounding factors such as socioeconomic factors, education level, marital status, age, parity, smoking status, and indigenous status may have confounded our study results and reduced their generalisability. This information was not always available in the GP patient record and therefore would not have accurately reflected the participant characteristics. Additionally, inability to include information regarding hypertension or endocrine disorders would influence the results, although there does not seem to be a consistent approach regarding co-morbidities, with some studies excluding women based on comorbidities and others not [5,7,9,16,32,49].

Method of delivery was obtained from GP patient records, but given that in 11% of participants this parameter was unknown and many births in the area were excluded, the study sample was unlikely to have represented all delivery methods.

Implications for the 'Expecting Changes' program

Herein, we provide evidence of the need for pre- and/or post-conception support for overweight and obese women in this rural area; however, given the total number of women with excessive GWG, more targeted antenatal counselling may be prudent for all expectant mothers. Data from this study may be applied to other rural populations in Australia and suggests that with limited access to services in rural areas, specific programs for weight control may be an important way to address this issue.

Given increased rates of CS and instrumental deliveries related to high pre-pregnancy BMI the need for pre-conception planning is further emphasised [5,7,16]. Ongoing weight management in women of childbearing age is an important role for the GP, with recommendations of promoting moderate-intensity exercise and nutritional diets outlined in the current clinical guidelines [50].

Future research

The findings of the current study will allow an accurate assessment of the effectiveness of the *Expecting Changes* program.

Adverse outcomes of high pre-pregnancy BMI and excessive GWG extend beyond the immediate pregnancy to impact health outcomes for both mother and child. Regardless of pre-pregnancy BMI or method of GWG calculation, the majority of women in this small rural centre are gaining outside the recommended guidelines. Women with high pre-pregnancy BMIs are more likely to gain above the recommended amount and obese women are more likely to have a CS or instrumental delivery. Thus, there is a role for a program like the multi-disciplinary *Expecting Changes* program, targeting women with a pre-pregnancy BMI≥25 and further antenatal counselling on GWG is likely to benefit women both prior to and during pregnancy, regardless of BMI.

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Conflicts of interest

None declared.

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***Table 1. Institute of Medicine weight gain in pregnancy recommendation. Units, converted from pounds to kilograms* [1].**

Pre-pregnancy Weight Category	Body Mass Index	Recommended range of total weight (kg)	Recommended rate of weight in second and third trimester (kg/week)
Underweight	Less than 18.5	12.7 – 18.1	0.45 (0.45 – 0.58)
Normal weight	18.5 - 24.9	11.3 – 15.8	0.45 (0.36 - 0.45)
Overweight	25 - 29.9	6.8 – 11.3	0.27 (0.22 - 0.31)
Obese (includes all classes)	30 and greater	4.9 – 9.0	0.22 (0.18 - 0.27)

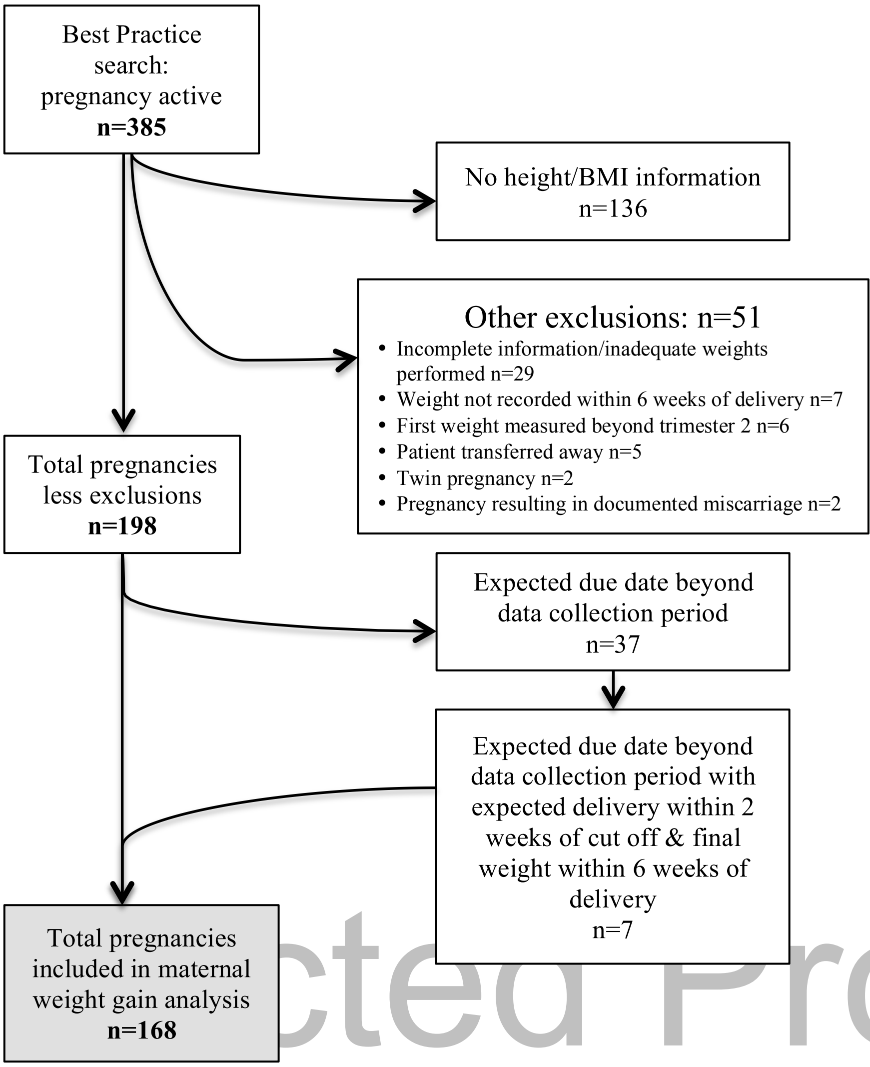

Figure 1. Participant inclusion and exclusion protocol.

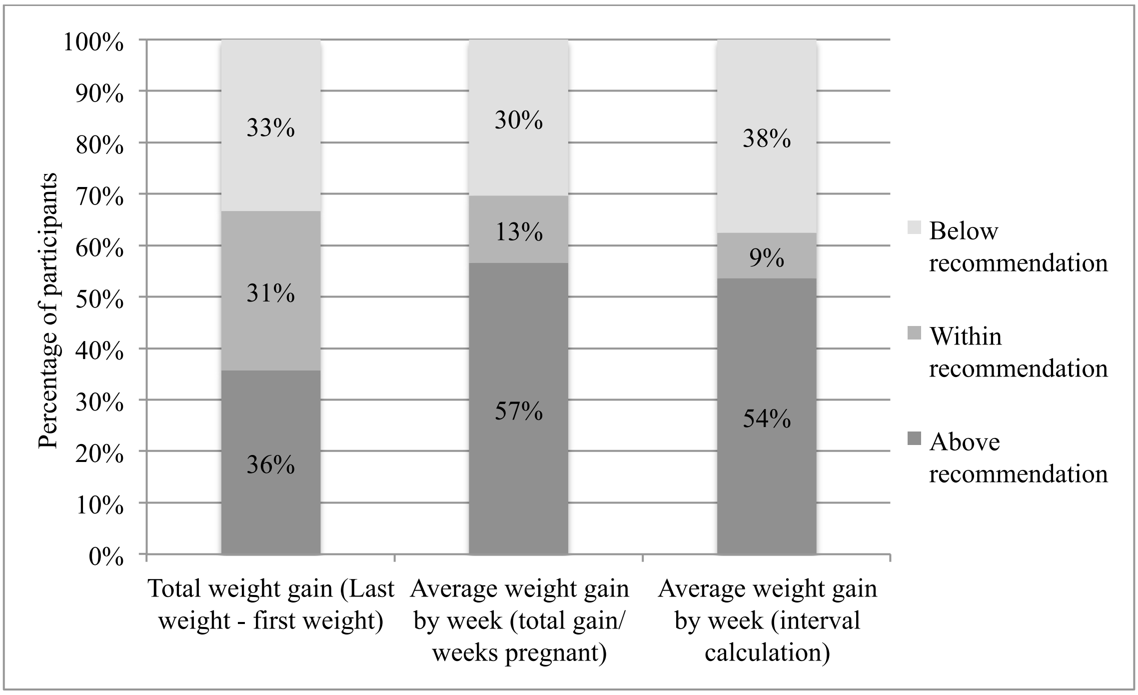

Figure 2. All pregnancy GWG relative to IOM recommendations showing proportion of women in each category across the three methods of calculation.

Table 2. Average total and weekly weight gain (with standard deviation) across BMI categories with IOM recommendations per BMI category.

Pre-pregnancy Weight Category	**Participant average total weight gain (kg) (±SD)**	**IOM Recommended range of total weight (kg)**	**Participant average weekly weight gain (total weight/weeks pregnant) (±SD)**	**Participant average weekly weight gain (weight gain over interval between measurements) (±SD)**	**IOM Recommended rate of weight in second and third trimester (kg/week)**
Underweight	11.25 (±4.27)	12.7 – 18.1	0.354 (±0.31)	0.381 (±0.11)	0.45 (0.45 – 0.58)
Normal weight	12.62 (±5.13)	11.3 – 15.8	0.478 (±0.28)	0.481 (±0.21)	0.45 (0.36 - 0.45)
Overweight	12.08 (±6.26)	6.8 – 11.3	0.480 (±0.29)	0.456 (±0.25)	0.27 (0.22 - 0.31)
Obese (includes all classes)	7.83 (±6.07)	4.9 – 9.0	0.311 (±0.36)	0.355 (±0.27)	0.22 (0.18 - 0.27)

Table 3. Assessment of weight gain by pre-pregnancy BMI relative to IOM GWG recommendations using three methods of calculation, Fisher's Exact statistic 29.04, p<0.001.

	IOM Recommendation			
	Above (n, %)	Within (n, %)	Below (n, %)	Total
Underweight	0(0)	1 (5)	5 (10)	6 (4)
Normal weight	25 (26)	13 (59)	15 (29)	53 (35)
Overweight	29(31)	5 (23)	4 (8)	38 (24)
Obese	41 (43)	3(14)	27 (53)	71 (42)
TOTAL	95	22	51	168

Table 4. Delivery methods of women classified by pre-pregnancy BMI p<0.001 using Fisher's exact test.

	Method of Delivery					
	Total (n, %)	Unknown (n, %)	NVD (n, %)	Instrumental (n, %)	Planned LSCS (n, %)	E-LSCS (n, %)
Underweight	6 (4)	1 (25)	1 (25)	0 (0)	0 (0)	2 (50)
Normal weight	53 (35)	4 (8)	39 (74)	1 (2)	4 (8)	5 (9)
Overweight	38 (24)	6 (16)	24 (63)	1 (3)	4 (11)	3 (8)
Obese	71 (42)	7 (10)	34 (47)	8 (11)	16 (22)	8 (11)
TOTAL	168	18 (11)	98 (58)	10 (6)	24 (14)	18 (11)

NVD: normal vaginal delivery, LSCS: lower segment Caesarean-section, E-LSCS: emergency lower segment Caesarean-section

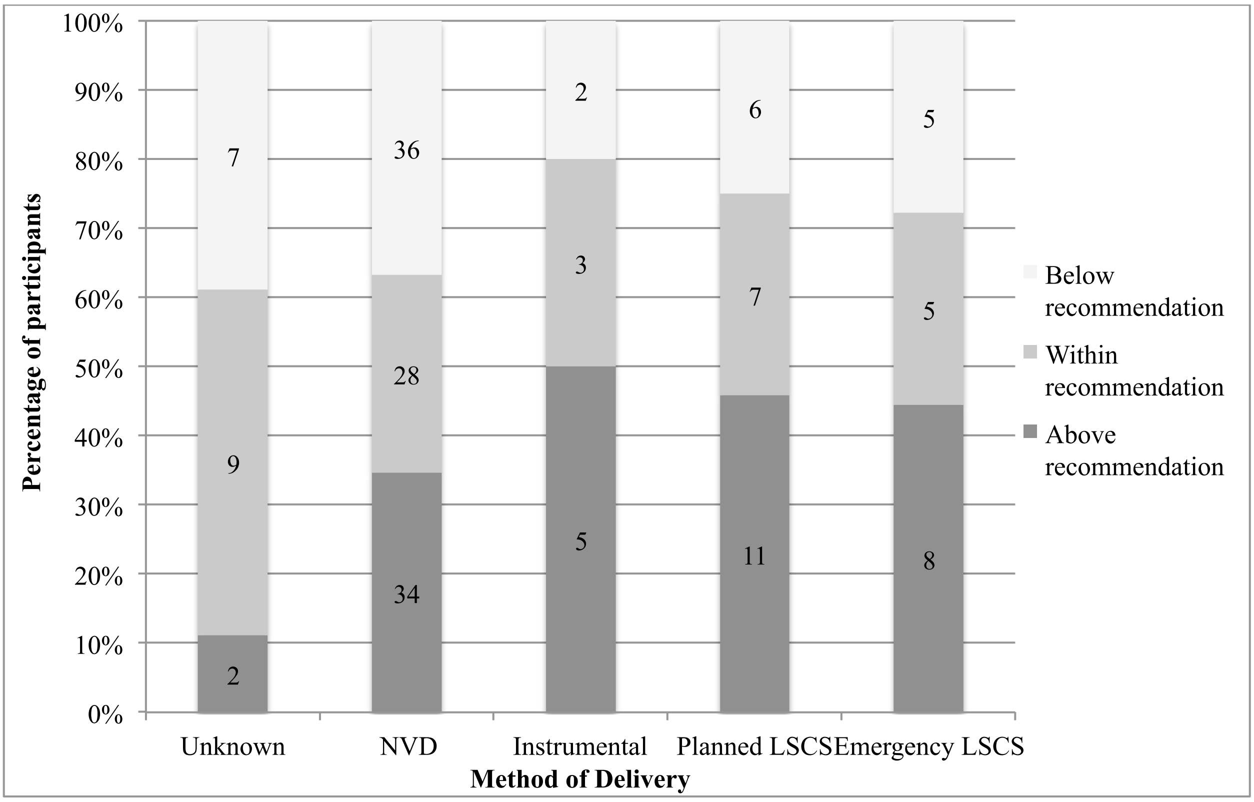

Figure 4. Delivery methods of women classified by GWG above, within and below the IOM recommendations (numbers within columns represent number of deliveries). NVD: normal vaginal delivery, LSCS: lower segment Caesarean-section. Instrumental: forceps or ventouse (vacuum extraction).