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Weight Loss After Diagnosis with Gestational Diabetes and Birth Weight Among Overweight and Obese Women

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Abstract

To determine if, among overweight or obese women with gestational diabetes (GDM), weight loss after GDM diagnosis is associated with lower infant birth weight within levels of overweight or obesity class. Overweight and obese women with singleton pregnancies managed for GDM at a large diabetes and pregnancy program located in Charlotte, NC between November 2000 and April 2010, were eligible for this retrospective cohort study. All were managed using a rigorous standardized clinical protocol. Clinical information including maternal pre-pregnancy body mass index, gestational weight gain, treatment, and medical and obstetric history was abstracted from medical records. The association of weight loss after GDM diagnosis and birth weight was analyzed using linear regression stratified by maternal pre-pregnancy overweight or obesity class (I, II/III). Of the 322 women in this study 19 % lost weight between diagnosis of GDM and delivery. After adjustment for maternal age, parity, race/ethnicity, gestational week at first hemoglobin A1c (A1C), A1C at diagnosis, weight gain prior to GDM, treatment with insulin or oral hypoglycemic agents, gestational age at delivery, and infant sex, weight loss was associated with 238.3 g lower mean infant birth weight among overweight women (95 % CI –393.72, –82.95

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g), but was not associated with lower mean infant birth weight among obese class II/III women (95 % CI -275.61, 315.38 g). Weight loss, after diagnosis of GDM, is associated with lower infant birth weight among overweight women, but not among obese class II/III women.

Keywords

Gestational weight gain; Weight loss; Gestational diabetes; Birth weight; Obesity

Introduction

Over the last several decades the prevalence of overweight and obesity among women of reproductive age in the United States dramatically increased [1]. Between 1979 and 2004 the prevalence of overweight increased by approximately 34 %, the prevalence of class I [body mass index (BMI) 30–34.9 kg/m²] and class II obesity (BMI 35–39.9 kg/m²) doubled and the prevalence of class III obesity (BMI ≥ 40 kg/m²) tripled [2]. Concerns about appropriate gestational weight gain among obese women prompted the Institute of Medicine (IOM) to revise their guidelines for gestational weight gain in 2009 [2]. Current recommendations are that overweight women gain 6.8–11.3 kg during pregnancy and that obese women (pre-pregnancy BMI ≥ 30) gain no more than 5.0–9.1 kg during pregnancy. Yet the debate continues over optimal gestational weight gain, particularly among obese women. Excess gestational weight gain, particularly among obese women, is associated with increased risk of delivery of a large for gestational age (LGA) infant [3, 4] and related sequelae, [5, 6] indicated preterm labor, [7] and increased risk of gestational diabetes, [8] preeclampsia, [9] and postpartum weight retention [10, 11]. Low gestational weight gain or weight loss are associated with increased risk of delivering a small for gestational age (SGA) infant among normal and overweight women (BMI < 25 kg/m²), but may have no adverse effect when the mother is obese [4, 12].

Currently, little is known regarding optimal gestational weight gain among women with gestational diabetes (GDM) and it is recommended that they adhere to IOM guidelines according to their pre-pregnancy BMI [13, 14]. Compared with women without GDM those with GDM have a greater than threefold increased odds of delivering a LGA infant [15]. Nutrition therapy and counseling, with the goal of euglycemia and prevention of LGA, are the cornerstones of GDM management [16]. Standard diets for women with GDM are not intended to cause weight loss, but may reduce the rate of weight gain during pregnancy [13]. There is continuing controversy regarding the potentially adverse impact of caloric restriction, weight loss, and associated ketonuria on fetal growth and development among obese pregnant women [17, 18]. Previously published studies provide evidence that caloric restriction among obese women with GDM improves glycemic profile without marked ketonuria [19, 20]. There is also evidence that among classes II and III obese women, gestational weight gain below the goals recommended by the IOM, decreases risk of LGA without increasing risk of SGA [4, 10, 12].

While multiple clinical trials have demonstrated the benefit of treating GDM for preventing LGA [21, 22] controversy remains concerning optimal gestational weight gain among

affected women. Specifically, it is not clear whether weight loss, among overweight or obese women with GDM, has an adverse impact on fetal growth and development. The objective of this study was to determine the extent to which weight loss after GDM diagnosis is associated with lower infant birth weight among overweight and obese women.

Methods

Study Setting

The study took place in a large diabetes and pregnancy program, which is a consortium of two clinics located in Charlotte, NC. Clinic A, housed within the main medical center, provides comprehensive education and care for women with type 1 diabetes, type 2 diabetes, and GDM and serves a primarily white, privately insured population. The second clinic, Clinic B, provides obstetric care for women with and without diabetes in pregnancy. The majority of women cared for at Clinic B are racial/ethnic minorities and enrolled in Medicaid or uninsured. These two clinics, located within a mile of each other, use a common GDM clinical management protocol developed by the Medical Director, a Board Certified Endocrinologist (EM). The program serves all of Mecklenburg County, the nine surrounding counties and manages the majority of women diagnosed with GDM within the greater Charlotte area.

Typically women are referred to one of the two diabetes and pregnancy program clinics at 24–28 weeks gestation following a positive 50 g oral glucose challenge test (GCT) and a positive 3 h 100 g oral glucose tolerance test (OGTT) [23]. Hemoglobin A_{1c} (A1C) and other laboratory tests are performed at or near the first appointment at Clinic A and at referral to the diabetes and pregnancy program at Clinic B. At both clinics women considered at particularly high risk for GDM may be referred to the diabetes and pregnancy program earlier in their pregnancy with or without GDM screening. Additionally, women may be diagnosed with GDM and referred to the diabetes and pregnancy program at any point in their pregnancy following an extremely elevated GCT or random blood glucose (RBG).

Upon referral patients are counseled by registered nurses and/or dietitians, who are all certified diabetes educators. Dietary guidelines include limiting carbohydrates to <27 g at breakfast, 45–60 g at lunch and dinner, and consuming up to 3 snacks consisting of 15–22 g of carbohydrates each. Patients are instructed in home glucose monitoring and told to check their glucose levels before breakfast and 1 h after meals. Patients are encouraged to exercise and to keep a diet and exercise diary.

Goals for treatment in both clinics are: fasting glucose <90 mg/dl, and 1 h postprandial glucose <120 mg/dl; once medication is prescribed, a fasting glucose target of 70–80 mg/dl is used. Insulin or oral hypoglycemic agents typically are initiated if after a week with diet and exercise, the glucose goals are not met. Follow-up is every 1–2 weeks for those maintained on a diet. Patients requiring insulin or oral hypoglycemic agents are followed on a weekly basis by a maternal fetal medicine specialist, nurse practitioner, or endocrinologist.

Study Participants

Women managed for GDM with a live singleton delivery between November 15, 2000, and April 15, 2010, were eligible for inclusion in the study. Additional inclusion criteria were: pre-pregnancy BMI ≥ 25 kg/m²; diagnosed with GDM at ≥ 24 weeks gestation by either a 3 h 100 g OGTT, a GCT ≥ 200 mg/dl, or a RBG ≥ 160 mg/dl; complete birth data; and recorded pre-pregnancy weight, weight at first A1C, and weight at final clinic visit before delivery. Study exclusion criteria were: established type 1 or type 2 diabetes; untreated endocrinopathies (hyperadrenalism, hypoadrenalism, hyperthyroidism, hypothyroidism, and acromegaly); hemoglobin variants (HbS, HbC, HbF, and HbE) or conditions (uremia, thalassemia) that impair interpretation of A1C; and first A1C measurement >4 weeks after initial visit to the diabetes and pregnancy program. The institutional review boards of the University of Washington and Carolinas HealthCare System approved the study protocol. Due to the retrospective nature of the study and limited risk to patients a waiver of consent was granted.

Study Variables

Three separate maternal weight measures were abstracted from the medical record: pre-pregnancy weight, weight at first A1C measurement, and weight at the final antepartum visit to the diabetes and pregnancy program. Pre-pregnancy weight was self-reported at the first antenatal visit to the diabetes and pregnancy program (median gestational week 30; interquartile range (IQR) 29–32) [24, 25]. Weight at the first A1C measurement (median gestational week: 30; IQR 29–32) and weight at final antepartum visit (median gestational week 37; IQR 36–38) were measured at the diabetes and pregnancy program. Pre-pregnancy BMI was calculated from measured height at the time of first clinic visit and self-reported pre-pregnancy weight (kg/m²). Women were categorized according to their pre-pregnancy BMI category as follows: overweight (25–29.9 kg/m²), obese class I (30–34.9 kg/m²), obese class II (35–39.9 kg/m²), and obese class III (≥ 40 kg/m²). In the final analysis obese class II and obese class III were combined into a single category.

The primary exposure was weight loss after diagnosis of GDM. Weight gain after GDM diagnosis was calculated as follows: weight (kg) at last clinic visit before delivery minus weight (kg) at first A1C measurement. Women were then classified as losing weight after diagnosis of GDM (weight gain after GDM diagnosis <0 kg) or maintaining or gaining weight after GDM diagnosis (weight gain after GDM diagnosis ≥ 0 kg).

Key covariates cover maternal demographics, medical and obstetric history, pregnancy, and delivery and infant characteristics. Demographic variables included: clinic (Clinic A, Clinic B), maternal age at GDM diagnosis (years), parity (0, 1), insurance (private, uninsured or Medicaid), and maternal race/ethnicity (white, non-white). Medical and obstetric history variables included: prior history of GDM, prior history of preeclampsia/eclampsia, history of polycystic ovarian syndrome (PCOS), history of spontaneous abortion, and history of intra-uterine fetal demise. Pregnancy variables included: gestational week at first A1C as recorded on the medical chart based either on ultrasound or on last menstrual period, GDM diagnostic method (3 h OGTT; or GCT or RBG), A1C at first clinic visit, treatment modality (diet only; or glyburide, insulin, metformin, or other combination), preeclampsia in the current

pregnancy, gestational week at final antenatal visit, weight gain prior to GDM diagnosis (kg), and total gestational weight gain. Weight gain prior to GDM diagnosis was calculated by subtracting the self-reported pre-pregnancy weight from maternal weight at first A1C as recorded in the medical record. The rate of weight gain (kg/week) following GDM diagnosis was calculated as the difference in last and first weight measured at the diabetes and pregnancy program divided by the weeks between the two measurements. Total gestational weight gain was calculated by subtracting the self-reported pre-pregnancy weight from maternal weight at the last antenatal clinic visit as recorded in the medical record. Delivery and infant variables included: infant sex, and gestational age at delivery (weeks). Gestational age at delivery was calculated from the date of the last visit to the diabetes and pregnancy program, the date of delivery, and the gestational week at the last clinic visit. If the gestational week at last clinic visit was unavailable ($n = 5$) then gestational age at delivery was calculated from the date of first clinic visit, the date of delivery, and the gestational week at first clinic visit.

Study Outcome

The primary outcome was infant birth weight (g) as recorded in the medical record. Secondary outcomes were SGA defined as <10th percentile for gestational age and sex based on US vital statistics, [26] and low birth weight defined as birth weight <2,500 g regardless of gestational age. Due to limited sample size only the prevalence of SGA and low birth weight are reported.

Statistical Analysis

The association of weight loss after GDM diagnosis and infant birth weight was analyzed by linear regression with robust standard errors stratified by maternal pre-pregnancy BMI: overweight (25–29.9 kg/m²), obese I (30–34.9 kg/m²), obese II/III (BMI ≥ 35 kg/m²). Unadjusted and adjusted coefficients and 95 % confidence intervals (CI) for differences in mean infant birth weight comparing women who lost weight with those who gained or maintained weight after GDM diagnosis are reported for each pre-pregnancy BMI category.

Additionally, the association of weight loss after GDM diagnosis and infant birth weight was analyzed by linear regression stratifying by whether weight gain prior to GDM diagnosis was below, met, or exceeded IOM guidelines for total gestational weight gain. Unadjusted and adjusted coefficients and 95 % CIs for differences in mean infant birth weight comparing women with weight loss with those who gained or maintained weight after GDM diagnosis are reported separately for women who met IOM guidelines for total gestational weight gain prior to GDM diagnosis, those with weight gain below IOM guidelines prior to diagnosis, and those with weight gain that exceeded IOM guidelines prior to GDM diagnosis.

Understanding that preeclampsia could impact weight gain due to edema, and independently influence birth weight, we conducted a sensitivity analysis excluding women with preeclampsia ($n = 22$). Additionally, we tested for heterogeneity of the association of weight loss after GDM diagnosis and infant birth weight between clinics by introducing an interaction term between weight loss after GDM diagnosis and clinic.

All analyses were completed using STATA 9 software [27]. Potential confounders were included in the final model if their inclusion resulted in a substantial change ([10 %] in the estimate or if they were a priori considered important. Statistical significance was defined at the two-sided alpha level of 0.05.

Results

Of the 1,345 charts that were reviewed 536 were determined to be eligible (Fig. 1). The final sample of 322 women excluded the following: 171 women with a pre-pregnancy BMI <25 kg/m², 16 who attended only one clinic visit and did not have a final pregnancy weight before delivery, 4 missing pre-pregnancy weight, 2 missing weight at first A1C, 5 missing a weight from their last clinic visit, and 16 with incomplete birth data. In our final study sample, 62 (19 %) women lost weight after diagnosis of GDM, 4 (1 %) women maintained their weight after GDM diagnosis, and 256 (80 %) gained weight after GDM diagnosis. Of those losing weight 32 % were overweight, 42 % had class I obesity, 16 % had class II obesity, and 10 % had class III obesity.

The demographic, prior medical and obstetric history, pregnancy, and delivery and infant characteristics of the overall study population are shown in Table 1. Overall, 29 % of women were >35 years old, 37 % were nulliparous, 49 % were enrolled in Medicaid or uninsured, 69 % were of non-white race/ethnicity, and 56 % were obese (classes I, II, or III). Pregnancy variables indicated that 73 % of women were diagnosed with a 3 h OGTT and only 20 % managed their GDM with diet alone. Before diagnosis of GDM 33 % of women met the IOM guidelines for total gestational weight gain, and 43 % already exceeded these guidelines.

Comparing demographic characteristics: Clinic A participants were more likely to be >35 years old, nulliparous, and of white race/ethnicity while the majority of Clinic B participants were uninsured or received Medicaid (Table 1).

Table 1 shows that unlike the women who maintained or gained weight after GDM diagnosis those who lost weight were more likely to be >35 years old, to be of Hispanic race/ethnicity, to be obese, and to be managed by diet alone. Among the 62 women who lost weight after GDM diagnosis the mean rate of weight loss was 0.29 kg/week (SD 0.31 kg/week) resulting in mean weight loss after GDM diagnosis of 1.4 kg (SD 1.3 kg). The prevalence of low birth weight was 7 % among women who maintained or gained weight after GDM diagnosis and 3 % among women who lost weight. The prevalence of SGA was 17 % among women who maintained or gained weight after GDM diagnosis and 16 % among women who lost weight.

Table 2 shows that among overweight women (pre-pregnancy BMI 25–29.9 kg/m²) weight loss after diagnosis of GDM was associated with mean infant birth weight 238.3 g (0.53 lbs) lower than women who maintained or gained weight (95 % CI –393.72, –82.95 g; $p = 0.003$) adjusting for clinic, maternal age at GDM diagnosis (years), parity, non-white race/ethnicity, gestational age at first A1C (weeks), A1C at GDM diagnosis, treatment with insulin or oral hypoglycemic agents, total weight gain prior to GDM diagnosis (kg), gestational age at delivery (weeks), and infant's sex. A similar, though not statistically

significant, association of weight loss after GDM diagnosis with lower mean infant birth weight was also evident among obese class I women (pre-pregnancy BMI 30–34.9 kg/m²) (Mean difference (g) –96.6, 95 % CI –317.09, 123.98 g). No difference was detected in mean infant birth weight between those with and without weight loss after GDM diagnosis among obese classes II/III women (pre-pregnancy BMI ≥ 35 kg/m²) women ($p = 0.89$).

Among women who met IOM guidelines for total gestational weight gain at the time of GDM diagnosis, weight loss after diagnosis was associated with mean infant birth weight 203.1 g (0.45 lbs) lower than women who gained or maintained weight (95 % CI –395.78, –10.36 g; $p = 0.04$) after adjustment for clinic, maternal age at GDM diagnosis (years), parity, non-white race/ethnicity, maternal pre-pregnancy BMI (overweight, obese I, obese II/III), gestational age at first A1C (weeks), A1C at GDM diagnosis, treatment with insulin or oral hypoglycemic agents, gestational age at delivery (weeks), and infant's sex (Table 3). After adjustment, among women with weight gain below IOM guidelines at time of GDM diagnosis, those with weight loss after GDM diagnosis had mean infant birth weight 341 g (0.75 lbs) lower than those who gained or maintained weight (95 % CI –648.56, –33.49 g; $p = 0.03$). Among women who had already exceeded IOM guidelines at the time of GDM diagnosis, weight loss after diagnosis was not associated with lower mean infant birth weight ($p = 0.47$).

There was no evidence of heterogeneity across clinics in the association of weight loss after GDM diagnosis and birth weight in any BMI category (overweight: p for interaction = 0.69; obese I: p for interaction = 0.29; obese II/III: p for interaction = 0.38). Similarly, there was no evidence of heterogeneity across clinics in the association of weight loss after GDM diagnosis and infant birth weight by weight gain prior to GDM (met IOM guidelines: p for interaction 0.40; below IOM guidelines: p for interaction 0.54; exceeded IOM guidelines: p for interaction 0.63).

Excluding women with preeclampsia from our analysis did not appreciably change our results for the association of weight loss after GDM diagnosis and infant birth weight by BMI category (overweight: mean difference –234.54 g, 95 % CI –387.90, –81.19 g; obese I: mean difference –66.35 g, 95 % CI –288.35, 155.65 g; obese II/III: mean difference –51.66 g, 95 % CI –368.49, 265.16 g). Similarly, excluding women with preeclampsia did not substantially change the association of weight loss after GDM diagnosis and infant birth weight stratifying by weight gain prior to GDM diagnosis (met guidelines: mean difference –245.87, 95 % CI –428.17, –63.57; below guidelines: mean difference –320.03, 95 % CI –637.78, –2.28; exceeded guidelines: mean difference 67.29, 95 % CI –153.20, 287.79).

Discussion

This study found that weight loss after GDM diagnosis was associated with lower mean infant birth weight among overweight women and possibly among obese class I women, but not among obese class II/III women. Additionally, we found that among women who met or were below IOM guidelines for total gestational weight gain at the time of GDM diagnosis weight loss after GDM diagnosis was associated with lower mean infant birth weight. Weight loss after GDM diagnosis was not associated with birth weight among women who

had already exceeded guidelines for total gestational weight gain at the time of GDM diagnosis.

Currently, the IOM recommends a total gestational weight gain of 5.0–9.1 kg for obese women regardless of obesity class [2]. Prior studies of gestational weight gain among obese women indicate that total gestational weight gain below the current guidelines may not be associated with increased risk of SGA and low birth weight, particularly among those in higher obesity classes [4, 9, 28]. Unlike our study these earlier studies did not focus specifically on women with GDM and it is not clear if the findings from general obstetric populations apply to women with GDM.

Excessive weight gain in the first trimester is a risk factor for GDM, [8] but weight gain in the 2nd and 3rd trimester may be modified by management of GDM. Cheng et al. [13] examined the association between gestational weight gain and LGA and SGA in a cohort of women with GDM. They found that compared with women with weight gain of 0–8 lbs after GDM diagnosis women with weight gain <0 lbs after GDM diagnosis had a modest, and statistically insignificant increase in odds of SGA (OR 1.16, 95 % CI 0.78, 1.71). In contrast to our results the investigators reported no difference in these associations according to maternal pre-pregnancy overweight or obesity; however, unlike our study the investigators did not differentiate between obesity classes I, II, and III.

We also assessed the association of maternal weight loss and infant birth weight stratifying by gestational weight gain before diagnosis of GDM. Previously, Cheng et al. [13] assessed weight gain before and after GDM diagnosis and reported that, among women with GDM, low weight gain before GDM diagnosis was more strongly associated with SGA than low weight gain after GDM diagnosis. We found that among women who had already exceeded the recommended total gestational weight gain at the time of GDM diagnosis weight loss after diagnosis was not associated with decreased infant birth weight.

Strengths and Limitations

This study had several important strengths including the separation of overweight, obesity class I, and obesity classes II/III, and the ability to examine weight gain before and after diagnosis of GDM. In the United States an increasing number of women of reproductive age are obese [1] and recent findings indicate that women in obese classes II and III may have different gestational weight gain requirements compared to class I women, and may benefit from modest gestational weight loss [4, 9, 28]. Defining optimal gestational weight gain among women in higher obesity classes is of great public health concern. Additionally, weight gain during pregnancy is a risk factor for GDM, but may also be modified by management of GDM. Therefore, analyzing the association of total gestational weight gain and birth weight among women with GDM combines a woman's underlying risk of GDM with the impact of treatment. In order to explore the impact of weight gain during these two periods of pregnancy we analyzed the association of weight loss after GDM diagnosis stratifying by weight gain prior to GDM diagnosis. Our results may offer guidance to clinicians managing women after the onset of GDM.

Nevertheless, our study has several limitations. First, due to the relatively small sample size we examined infant birth weight as a continuous measure rather than using indicators of reduced fetal growth such as SGA or low birth weight. Additionally, since we lacked data on long-term developmental outcomes of the children and without this information the controversy regarding weight gain in pregnancy will continue. Second, this study was conducted among women in a single diabetes and pregnancy program using a standardized GDM management protocol that featured extremely tight glucose control; thus, our findings may not be generalizable to other populations of women with GDM who are not managed as aggressively. Finally, this study combined two very different patient populations with respect to demographic characteristics. While the two clinic populations had different demographic characteristics both clinics managed women using a common protocol and there was no evidence of heterogeneity of the association of weight loss after GDM diagnosis and infant birth weight between the two clinics. Additionally, adjustment for clinic may account for unmeasured characteristics associated with weight loss after GDM diagnosis and infant birth weight, which may differ between the two clinic populations.

Conclusion

Our findings indicate that weight loss after GDM diagnosis among women with GDM may not adversely impact fetal growth among those in obesity classes II/III and those already exceeding the IOM guidelines for total gestational weight gain at the time of GDM diagnosis. Therefore, modest weight loss after GDM diagnosis among obese class II/III women and those who exceed IOM guidelines for total gestational weight gain at the time of GDM diagnosis may not be a cause for concern. Further studies in larger populations are needed to confirm these findings and to determine if they extend to specific outcomes of clinical importance including SGA and low birth weight. Studies are also needed to examine the long-term impact of weight loss after GDM diagnosis including maternal postpartum weight retention, offspring developmental and behavioral outcomes, and childhood obesity.

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Abbreviations

GDM	Gestational diabetes
IOM	Institute of Medicine
BMI	Body mass index
LGA	Large for gestational age
SGA	Small for gestational age
GCT	Glucose challenge test

OGTT

Oral glucose tolerance test

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Fig. 1.
Exclusions based on maternal and pregnancy characteristics

Demographic, medical and obstetric history, and pregnancy and delivery characteristics of the study population, by clinic and weight loss after GDM diagnosis

Table 1

	Total	Clinic		Weight loss after GDM diagnosis	
		Clinic A	Clinic B	No	Yes
<i>N</i>	322	162	160	260	62
Demographic characteristics					
Mean maternal age at GDM diagnosis (years) (SD)	31 (5.6)	32 (5.2)	31 (5.9)	31 (5.6)	34 (5.2)
Maternal age at GDM diagnosis (years) <i>n</i> (%)					
<25	42 (13)	16 (10)	26 (16)	41 (16)	1 (2)
25–30	75 (23)	36 (22)	39 (25)	63 (24)	12 (19)
30–35	112 (35)	54 (33)	58 (36)	92 (35)	20 (32)
>35	93 (29)	56 (35)	37 (23)	64 (25)	29 (47)
Nulliparous <i>n</i> (%)	119 (37)	75 (46)	44 (28)	101 (39)	18 (29)
Medicaid or uninsured <i>n</i> (%)	159 (49)	10 (6)	153 (94)	129 (47)	30 (48)
Race/ethnicity <i>n</i> (%)					
White	100 (31)	90 (56)	10 (6)	81 (31)	19 (31)
African-American	82 (25)	52 (32)	30 (19)	71 (27)	11 (18)
Hispanic	124 (39)	6 (4)	118 (74)	97 (37)	27 (43)
Asian Indian	10 (3)	10 (6)	0	7 (3)	3 (5)
Other	6 (2)	4 (2)	2 (1)	4 (2)	2 (3)
Pre-pregnancy BMI <i>n</i> (%)					
Overweight (25–29.9 kg/m ²)	141 (44)	72 (44)	69 (43)	121 (47)	20 (32)
Obese I (30–34.9 kg/m ²)	106 (33)	54 (33)	52 (32)	80 (31)	26 (42)
Obese II (35–39.9 kg/m ²)	47 (14)	20 (12)	27 (17)	37 (14)	10 (16)
Obese III (≥ 40 kg/m ²)	28 (9)	16 (10)	12 (8)	22 (8)	6 (10)
Medical and obstetric history					
Prior GDM <i>n</i> (%)	50 (16)	19 (12)	31 (19)	42 (16)	8 (13)
Prior preeclampsia/eclampsia <i>n</i> (%)	22 (7)	11 (7)	11 (7)	16 (6)	6 (10)
Polycystic ovarian syndrome <i>n</i> (%)	10 (3)	9 (6)	1 (1)	9 (4)	1 (2)
Spontaneous abortion <i>n</i> (%)	68 (21)	32 (20)	36 (23)	54 (21)	14 (23)

	Total	Clinic A	Clinic B	Weight loss after GDM diagnosis	
				No	Yes
Intrauterine fetal demise <i>n</i> (%)	7 (2)	2 (1)	5 (3)	4 (2)	3 (5)
Pregnancy					
Mean gestational week at first AIC (SD)	30 (2.5)	30 (1.8)	31 (2.9)	30 (2.5)	30 (2.4)
GDM diagnostic method <i>n</i> (%)					
3 h OGTT	234 (73)	133 (82)	101 (63)	182 (70)	52 (84)
GCT	68 (21)	26 (16)	42 (26)	60 (23)	8 (13)
RBG	20 (6)	3 (2)	17 (11)	18 (7)	2 (3)
AIC quartile (min-max) at GDM diagnosis <i>n</i> (%)					
1st (4.1–5.3)	68 (21)	52 (32)	16 (10)	54 (21)	14 (23)
2nd (5.4–5.6)	60 (19)	44 (27)	16 (10)	44 (17)	16 (26)
3rd (5.7–6.1)	110 (34)	46 (29)	64 (40)	87 (33)	23 (37)
4th (6.2–10.9)	84 (26)	20 (12)	64 (40)	75 (29)	9 (14)
Treatment <i>n</i> (%)					
Diet only	63 (20)	53 (33)	10 (6)	46 (18)	17 (28)
Glyburide	50 (15)	5 (3)	45 (28)	40 (15)	10 (16)
Insulin	187 (58)	103 (63)	84 (53)	157 (60)	30 (48)
Metformin	4 (1)	0	4 (2)	2 (1)	2 (3)
Other	18 (6)	1 (1)	17 (11)	15 (6)	3 (5)
Preeclampsia/eclampsia in current pregnancy <i>n</i> (%)	22 (7)	9 (6)	13 (8)	20 (8)	2 (3)
Mean gestational week at final antenatal visit (SD)	37 (1.9)	36 (2.0)	38 (1.5)	37 (1.9)	37 (2.3)
Weight gain before GDM diagnosis					
Mean (kg) (SD)	9.1 (5.90)	9.1 (5.90)	10.0 (6.35)	9.5 (6.35)	9.1 (4.99)
Median (kg) (IQR)	9.1 (5.90–12.70)	9.1 (5.90–12.25)	9.1 (5.44–12.70)	9.5 (5.44–13.15)	8.17 (5.90–11.79)
Relative to IOM guidelines for total gestational weight gain <i>n</i> (%)					
Met	108 (33)	57 (35)	51 (32)	84 (32)	24 (39)
Below	77 (24)	40 (25)	37 (23)	63 (24)	14 (22)
Exceeded	137 (43)	65 (40)	72 (45)	113 (44)	24 (39)
Weight gain after GDM diagnosis					
Mean rate (kg/week) (SD)	0.30 (0.45)	0.24 (0.37)	0.35 (0.50)	0.44 (0.36)	−0.29 (0.31)
Mean (kg) (SD)	2.02 (2.68)	1.72 (2.31)	2.36 (2.99)	2.86 (2.27)	−1.41 (1.27)

	Total	Clinic		Weight loss after GDM diagnosis	
		Clinic A	Clinic B	No	Yes
Median (kg) (IQR)	1.81 (0.45–3.63)	1.36 (0.23–2.81)	1.81 (0.45–4.08)	2.27 (1.36–4.08)	–0.91 (–0.45 to –1.8)
Total gestational weight gain					
Mean (kg) (SD)	11.34 (6.80)	10.80 (7.26)	12.11 (7.26)	12.25 (6.80)	7.71 (4.99)
Median (kg) (IQR)	11.34 (7.26–14.97)	11.34 (6.80–14.06)	11.34 (7.26–15.88)	12.25 (8.17–16.33)	7.26 (4.08–10.43)
Relative to IOM guidelines for total gestational weight gain <i>n</i> (%)					
Met	108 (34)	53 (33)	55 (34)	85 (33)	23 (37)
Below	53 (16)	33 (20)	20 (13)	31 (12)	22 (36)
Exceeded	161 (50)	76 (47)	85 (53)	144 (55)	17 (27)
Delivery and infant					
Male infant	178 (55)	84 (52)	94 (59)	139 (57)	29 (47)
Mean gestational age (weeks) at delivery (SD)	39 (1.4)	39 (1.3)	39 (1.4)	39 (1.4)	39 (1.4)
Preterm delivery <i>n</i> (%)	29 (9)	14 (9)	15 (9)	23 (9)	6 (10)
Low birth weight <i>n</i> (%)	19 (6)	9 (6)	10 (6)	17 (7)	2 (3)
SGA <i>n</i> (%)	54 (17)	31 (19)	23 (14)	44 (17)	10 (16)

Unadjusted and adjusted coefficients for differences in mean birth weights (g) comparing women with weight loss after GDM diagnosis with those who gained or maintained weight, by maternal pre-pregnancy overweight/obesity

Table 2

Pre-pregnancy BMI	Weight loss <i>n</i> (%)	Mean difference in birth weight (g) (95 % CI)			
		Unadjusted	<i>p</i>	Adjusted ^a	<i>p</i>
Overweight					
No	121 (86)				
Yes	20 (14)	-118.6 (-300.48, 63.28)	0.20	-238.3 (-393.72, -82.95)	0.003
Obese I					
No	80 (75)				
Yes	26 (25)	-126.3 (-347.63, 95.08)	0.26	-96.6 (-317.09, 123.98)	0.39
Obese II/III					
No	59 (79)				
Yes	16 (21)	83.9 (-204.49, 372.26)	0.56	19.89 (-275.61, 315.38)	0.89

^a Adjusted for clinic (Clinic A, Clinic B), maternal age at GDM diagnosis (years), parity (0, 1), non-white race/ethnicity, gestational age at first A1C, A1C at GDM diagnosis, treatment (diet only, insulin or oral hypoglycemic agents), total weight gain prior to GDM diagnosis (lbs), gestational age at delivery (weeks), and infant's sex

Unadjusted and adjusted coefficients for differences in mean birth weights (g) comparing women who lost weight after GDM diagnosis with those who gained or maintained weight, by weight gain before GDM diagnosis relative to IOM recommendations

Table 3

GWM before GDM diagnosis relative to IOM	Weight loss n (%)	Mean difference in birth weight (g) (95 % CI)		p
		Unadjusted	Adjusted ^a	
Met				
No	84 (78)			
Yes	24 (22)	-121.5 (-305.99, 62.99)	-203.1 (-395.78, -10.36)	0.04
Below				
No	63 (82)			
Yes	14 (18)	-219.3 (-510.43, 71.75)	-341.0 (-648.56, -33.49)	0.03
Exceeded				
No	113 (82)			
Yes	13 (18)	72.5 (-133.08, 278.11)	81.9 (-142.59, 306.43)	0.47

^a Adjusted for clinic (Clinic A, Clinic B), maternal age at GDM diagnosis (years), parity (0, 1), maternal pre-pregnancy BMI (overweight, obese I, obese I/II), race/ethnicity, gestational age at first A1C (weeks), A1C at GDM diagnosis, treatment (diet only, insulin or oral hypoglycemic agents), gestational age at delivery (weeks), and infant's sex