ATLANTIC-DIP: Excessive Gestational Weight Gain and Pregnancy Outcomes in Women With Gestational or Pregestational Diabetes Mellitus

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Context: Women who have diabetes mellitus during pregnancy are at higher risk of adverse outcomes. Excessive gestational weight gain (GWG) is also emerging as a risk factor for maternofetal complications, and in 2009, the Institute of Medicine published recommendations for appropriate GWG. It is unclear whether excessive GWG confers additional risk to women with diabetes in pregnancy and whether Institute of Medicine recommendations are applicable to this population.

Objective: The objective of this study was to examine whether excessive GWG in pregnancies complicated by diabetes mellitus is associated with higher adverse obstetric outcomes.

Design: This was an observational study.

Setting: The study was conducted at five antenatal centers along the Irish Atlantic seaboard.

Participants: 802 women with diabetes in pregnancy participated in the study.

Main Outcome Measure: Maternal outcomes examined included preeclampsia, gestational hypertension, and cesarean delivery. Fetal outcomes included large for gestational age (LGA), macrosomia, and small for gestational age.

Results: Excessive GWG was noted in 59% of women. In all women, excessive GWG resulted in higher odds for LGA [adjusted odds ratio (aOR) 2.01, 95% confidence intervals 1.24–3.25 in GDM; aOR 3.97, CI 1.85–8.53 in pregestational diabetes mellitus (PGDM)] and macrosomia (aOR 2.17, CI 1.32–3.55 in GDM; aOR 3.58, CI 1.77–7.24 in PGDM). Excessive GWG was also associated with an increased odds for gestational hypertension (aOR 1.72, CI 1.04–2.85) in women with GDM, and treatment with insulin further increased the odds for LGA (aOR 2.80, CI 1.23–6.38) and macrosomia (aOR 5.63, CI 2.16–14.69) in this group.

Conclusion: We show that in the already high-risk settings of both GDM and PGDM, excessive GWG confers an additive risk for LGA birth weight, macrosomia, and gestational hypertension. **(*J Clin Endocrinol Metab* 99: 212–219, 2014)**

Women who have diabetes mellitus during pregnancy are at higher risk of adverse maternal and neonatal outcomes when compared with the background population without diabetes (1–3). The ATLANTIC Diabetes in Pregnancy (DIP) program identified a prevalence of gestational diabetes mellitus (GDM), which was 12.4% within a cohort of Irish women in which universal screening was applied using the International Association of Diabetes and Pregnancy Study Groups (IADPSG) criteria (1). Within this cohort, pregnancies complicated by GDM were associated with significantly higher rates of adverse pregnancy outcomes (1, 4). Among pregnant women with

ISSN Print 0021-972X ISSN Online 1945-7197
Printed in U.S.A.

Received June 29, 2013. Accepted October 25, 2013.
First Published Online November 1, 2013

Abbreviations: aOR, adjusted odds ratio; BMI, body mass index; CI, confidence interval; DIP, diabetes in pregnancy; GDM, gestational diabetes mellitus; GWG, gestational weight gain; HbA1c, glycosylated hemoglobin; IADPSG, International Association of Diabetes and Pregnancy Study Groups; IOM, Institute of Medicine; LGA, large for gestational age; OB, obese; OW, overweight; PGDM, pregestational diabetes mellitus; SGA, small for gestational age.

a pregestational diagnosis of type 1 or type 2 diabetes mellitus, hereafter termed pregestational diabetes mellitus (PGDM), there was also a higher incidence of adverse maternal and neonatal outcomes within the ATLANTIC-DIP study cohort (2, 4).

Recent data have shown that excessive gestational weight gain (GWG) represents a potential risk factor for adverse pregnancy outcomes (5–7). In 2009, the Institute of Medicine (IOM) in the United States published guidelines describing body mass index (BMI) appropriate thresholds for GWG, upon which excessive weight gain during pregnancy could be defined (Table 1) (8). Thresholds were chosen based on historic data that described a linear increase in adverse neonatal and maternal outcomes in association with GWG in women without GDM and PGDM. It is estimated that approximately 36% of mothers demonstrate excessive GWG, and among women without diabetes, this is robustly associated with large for gestational age (LGA) birth weight, cesarean delivery, and lower Apgar scores (5–7). Additionally, in a cohort of largely Latina women with type 2 diabetes, excessive GWG was associated with significant perinatal morbidity, including LGA and macrosomia (9). A retrospective study comprising mainly Hispanic women with and without GDM who were untreated with diet, exercise, or antidiabetic medications during pregnancy showed a higher incidence of LGA infants in the presence of excessive GWG (10).

On the basis of these data, we hypothesized that in addition to the high risk conferred by a diagnosis of GDM and PGDM, excessive GWG confers additional adverse risk. In this study we describe for the first time the effects of excessive GWG defined using IOM criteria within a cohort of predominantly Caucasian women, all of whom were diagnosed with either PGDM or GDM (IADPSG criteria).

Materials and Methods

The ATLANTIC-DIP program comprises a number of prospective, observational studies on women with PGDM and GDM focusing on screening, management, and follow-up. It covers a regional population of 500 000 mixed urban and rural dwellers across five antenatal centers with 11 000 deliveries per year. Research ethics committee approval was obtained from participating centers, and data on women with GDM and PGDM were collected from study entry until 12 weeks postpartum. Women were recruited between September 2006 and April 2012. A cohort of women was extracted from ATLANTIC-DIP with a diagnosis of either GDM or PGDM, with singleton pregnancies carried to term (>37 weeks' gestation), and in whom weight and BMI had been recorded at the time of booking and the time of admission to the labor and delivery unit.

Women were classified as having PGDM on the following basis: 1) an established diagnosis of type 1 or type 2 diabetes mellitus prior to conception; 2) a glycosylated hemoglobin (HbA1c) greater than 6.5% in the first trimester; and 3) a new diagnosis of GDM according to IADPSG criteria within the first 14 weeks of pregnancy. GDM was diagnosed using IADPSG criteria, after a 75-g oral glucose tolerance test at 24–28 weeks' gestation (11, 12). Each woman received standard advice on diet and exercise along with a dietitian review. Education was provided to demonstrate self-directed glucose monitoring and to inform each woman regarding appropriate glycemic targets. Women were reviewed on a fortnightly basis. At each visit weight was measured and an assessment of glycemia was made. Insulin was commenced when blood glucose readings were outside the following ranges on more than 3 successive days: fasting glucose 5.0 mmol/L or a 2-h postprandial reading of 7.0 mmol/L, according to local practice. Oral hypoglycemic agents were not used in patients with GDM or PGDM. Data were prospectively recorded using an optimized digital database, namely DIAMOND (Hicom).

BMI was calculated at the first antenatal visit between 14 and 22 weeks and categorized according to World Health Organization (WHO) standards: underweight, less than 18.5 kg/m^2; normal, 18.5–24.5 kg/m^2; overweight (OW), 25–29.9 kg/m^2; obese (OB), greater than 30 kg/m^2. The difference between the first recorded weight in the second trimester and the predelivery weight was measured. Mean weight gain per week was then calculated and compared with IOM guidelines to assess whether the up-

Table 1. Institute of Medicine Guidelines for Gestational Weight Gain (8)

Pregestational BMI Category	BMI, kg/m^2	Recommended Total Weight Gain, kg	Recommended Mean Weight Gain: Trimesters 2 and 3, kg/wk
Underweight	<18.5	12.5–18.0	0.51 (0.44–0.58)
Normal weight	18.5–24.9	11.5–16.0	0.42 (0.35–0.50)
Overweight	25.0–29.9	7.0–11.5	0.28 (0.23–0.33)
Obese	≥30.0	5.0–9.0	0.22 (0.17–0.27)

per limit of IOM recommended weight gain as per BMI category was breached (Table 1) (8). Subsequently, women were categorized into one of two groups according to whether they demonstrated excessive or nonexcessive GWG. Measured maternal outcomes included gestational hypertension (blood pressure > 140/90 mm Hg on at least two occasions more than 6 h apart in women with normal booking blood pressure), preeclampsia [hypertension, proteinuria (>300 mg per 24 h) onset > 20 wk], and cesarean delivery. Fetal/neonatal outcomes examined included LGA (>90th centile by gestational age), macrosomia (birth weight > 4 kg), and small for gestational age (SGA) (<10th centile by gestational age) (13). Gestational age was determined at the booking visit using obstetric ultrasound.

Data were analyzed using SPSS version 20.0 (IBM). GWG was modeled as continuous and categorical variables to explain neonatal and maternal outcomes. Multivariate analyses were performed and odds ratios calculated using a stepwise, backward logistic regression analysis adjusted for the following covariates; age, parity, ethnicity, use of insulin, booking BMI category, and cigarette smoking. Hypothesis testing was performed on the data of equal variance and normal distribution using an unpaired Student's *t* test. A χ^2 analysis was used to compare sample proportions. Data are expressed as means ± SD of the mean, adjusted odds ratios (aORs), and 95% confidence intervals (CIs). Statistical significance was accepted when the 95% CI did not contain one (regression analyses/ratios) or zero (multiple group comparisons/means). The significance level was accepted when $\alpha < .05$ for two-tailed analyses.

Results

Patient demographic details

Data from a total cohort of 802 women were analyzed. This group comprised 543 women with GDM (68%) and 259 with PGDM (32%), of whom 169 (65%) had type 1 and 90 (35%) had type 2 diabetes. Table 2 outlines the demographic details for these women. In total, 472 women (59%) demonstrated excessive GWG. Within this group, 108 (23%) had type 1 diabetes, 57 (12%) had type 2 diabetes, and 307 (65%) had GDM. Supplemental Table 1, published on The Endocrine Society's Journals Online web site at http://jcem.endojournals.org, outlines the mean weight gain per week in the second and third trimester for each BMI category. The mean booking BMI was similar in those with excessive and nonexcessive GWG, but a higher percentage of women in the excessive weight gain group had a booking BMI within the OW category (38% for excessive vs 25% for nonexcessive). A higher percentage of women with PGDM demonstrated excessive GWG (64%) when compared with women with GDM (57%), but this difference is not statistically significant ($P = .05$). There was no difference in age, ethnicity, smoking status, parity, gravidity, or insulin use during pregnancy between those who did and did not have excessive GWG. We further analyzed the effects of GWG on pregnancy outcomes specific to the diagnoses of GDM and PGDM in these women.

Table 2. Demographic Characteristics of Included Women (GDM and PGDM) (n = 802)

	Excessive Weight Gain	Nonexcessive Weight Gain	*P* Value
n, %	472 (59%)	330 (41%)	
Diabetes type			
Type 1 diabetes	108 (23%)	61 (18%)	
Type 2 diabetes	57 (12%)	33 (10%)	
GDM	307 (65%)	236 (72%)	
Age, y	32.98 ± 5.43	33.54 ± 4.94	.14
Smoker	46 (10%)	26 (8%)	.36
Caucasian	403 (85%)	281 (85%)	.93
Parity	1.08 ± 1.23	1.24 ± 1.52	.10
Gravida	2.53 ± 1.68	2.71 ± 194	.16
Booking BMI, kg/m^2	30.27 ± 6.33	30.48 ± 7.2	.66
Booking BMI category			
Normal	85 (18%)	90 (27%)	
Overweight	179 (38%)	82 (25%)	
Obese	208 (44%)	155 (47%)	<.001
Insulin use during pregnancy	264 (56%)	164 (50%)	.08

Data are expressed as mean ± SD and number of patients and percentage (in parentheses) of the total group.

Women with GDM

Among women with GDM, 307 (57%) demonstrated excessive GWG. These women were younger than those who did not have excessive GWG (32.9 ± 5.39 y vs 34.20 ± 4.73 y, $P = .01$). A higher percentage of those in the excessive GWG group were OW (35% vs 24%) and a lower proportion was OB (48% vs 56%) at time of the first antenatal visit compared with those in the nonexcessive GWG group. Mean BMI at booking was similar for excessive and nonexcessive GWG groups (30.75 ± 6.60 kg/m^2 vs 31.86 ± 7.30 kg/m^2, $P = .06$). There were no significant differences in ethnicity, parity, gravidity, smoking status, glucose levels at the time of the oral glucose tolerance testing, percentage of women treated with insulin, or third-trimester HbA1c between the groups (Table 3).

There were higher odds for LGA birth weight [aOR 2.01 (1.24 to 3.25); $P = .01$] and macrosomia [aOR 2.17 (range 1.32–3.55); $P < .01$] in women demonstrating excessive GWG. These effects of excessive GWG were further compounded by an additive effect of insulin therapy.

Table 3. Women With GDM (n = 543): Demographic Characteristics and Prevalence of Adverse Outcomes

	Excessive Weight Gain	Nonexcessive Weight Gain	*P* Value
n, %	307 (57%)	236 (43%)	
Age, y	32.97 ± 5.39	34.20 ± 4.73	.01
Smoker	28 (9%)	13 (6%)	.11
Caucasian	254 (83%)	200 (85%)	.53
Parity	1.09 ± 1.23	1.32 ± 1.58	.06
Gravida	2.50 ± 1.51	2.80 ± 2.03	.05
Booking BMI, kg/m^2	30.75 ± 6.60	31.86 ± 7.30	.06
Booking BMI category			
Normal	54 (18%)	46 (20%)	
Overweight	106 (35%)	57 (24%)	
Obese	147 (48%)	132 (56%)	.03
Glucose 0 min, mmol/L	5.28 ± 0.90	5.16 ± 0.91	.13
Glucose 60 min, mmol/L	10.18 ± 2.17	10.32 ± 1.59	.41
Glucose 120 min, mmol/L	7.85 ± 2.20	8.20 ± 2.14	.06
Insulin use during pregnancy	107 (34.9%)	79 (33.5%)	.74
Third-trimester HbA1c, %	5.53 ± 0.44	5.52 ± 0.50	.73
Normal vaginal delivery	186 (60.6%)	134 (56.8%)	.37
Adverse outcomes			
Preeclampsia	27 (8.5%)	14 (5.9%)	.21
Gestational hypertension	56 (18.2%)	29 (12.3%)	.06
Cesarean delivery	121 (39.4%)	102 (43.2%)	.37
Macrosomia	67 (21.8%)	35 (14.8%)	.04
LGA	71 (23.1%)	30 (12.7%)	<.01
SGA	18 (5.9%)	15 (6.4%)	.05

Data are expressed as mean ± SD and number of patients and percentage (in parentheses) of total group.

The combined effects of insulin and excessive GWG increased the odds for LGA infants [aOR 2.80 (1.23, 6.38); $P = .01$] and macrosomia [aOR 5.63 (range 2.16–14.69); $P < .001$] above the individual contribution of either variable. Interestingly, women with GDM who were taking insulin gained less weight than those not on insulin therapy (0.62 ± 0.30 kg/wk vs 0.84 ± 0.58 kg/wk; $P < .001$). Excessive GWG was also associated with higher odds for gestational hypertension [aOR 1.72 (range 1.04–2.85); $P = .04$] (Table 4).

Women with PGDM

Among the 259 women with a diagnosis of PGDM, excessive GWG occurred in 165 (64%). One hundred eight women with type 1 diabetes (64%) and 57 women with type 2 diabetes (63%) demonstrated excessive GWG. Women with PGDM had an overall lower BMI at first antenatal visit than their GDM counterparts (28.54 ± 5.8 kg/m^2 vs 31.28 ± 6.93 kg/m^2, $P < .001$), but among those with PDGM demonstrating excessive GWG, booking BMI was higher than those with nonexcessive GWG (29.4 ± 5.7 kg/m^2 vs 27.0 ± 7.7 kg/m^2, $P < .01$). Consequently, there were higher proportions with a booking BMI in the OW and OB categories within the excessive GWG compared with the nonexcessive GWG group (44% vs 27% for OW and 37% vs 25% for OB). The use of insulin during pregnancy was similar for both groups as were the average first- and third-trimester HbA1c levels (Table 5).

Excessive GWG was associated with higher odds for LGA birth weight [aOR 3.97 (range 1.85–8.53); $P < .001$]

Table 4. Multivariable Analysis of Adverse Outcomes Associated With Excessive GWG in Women With GDM

	Excessive GWG		Excessive GWG and Insulin Use	
Outcome	aOR (95% CI)	*P* value	aOR (95% CI)	*P* Value
Preeclampsia	1.59 (0.81–3.12)	.18	1.62 (0.79–3.32)	.19
Gestational hypertension	1.72 (1.04–2.85)	.04	1.79 (1.05–3.07)	.01
Cesarean delivery	0.84 (0.51–1.37)	.48	1.32 (0.63–2.73)	.44
Macrosomia	2.17 (1.32–3.55)	<.01	5.63 (2.16–14.69)	<.001
LGA	2.01 (1.24–3.25)	.01	2.80 (1.23–6.38)	.01
SGA	1.01 (0.47–2.18)	.98	0.85 (0.21–3.4)	.81

Adjusted for age, parity, ethnicity, use of insulin, booking BMI category, and cigarette smoking.

Table 5. Women With PGDM (n = 259): Demographic Characteristics and Prevalence of Adverse Outcomes

	Excessive Weight Gain	Nonexcessive Weight Gain	*P* Value
n, %	165 (64%)	94 (36%)	
Diabetes type			
Type 1 diabetes	108 (65%)	61 (65%)	
Type 2 diabetes	57 (35%)	33 (35%)	
Age, y	33.00 ± 5.52	31.89 ± 5.10	.11
Smoker	18 (11%)	13 (14%)	.49
Caucasian	149 (90%)	81 (86%)	.31
Parity	1.06 ± 1.22	1.04 ± 1.34	.90
Gravida	2.59 ± 1.96	2.49 ± 1.68	.68
Booking BMI, kg/m^2	29.4 ± 5.7	27.03 ± 5.7	<.01
Booking BMI category			
Normal	31 (19%)	44 (47%)	
Overweight	73 (44%)	25 (27%)	
Obese	61 (37%)	23 (25%)	<.001
Insulin use during pregnancy	157 (95%)	85 (90%)	.14
First-trimester HbA1c, %	6.83 ± 1.52	6.97 ± 1.34	.46
Third-trimester HbA1c, %	6.66 ± 1.28	6.63 ± 1.44	.95
Normal vaginal delivery	58 (35.2%)	47 (50%)	.02
Adverse outcomes			
Preeclampsia	22 (13.3%)	11 (11.7%)	.70
Gestational hypertension	43 (26.1%)	20 (21.3%)	.40
Cesarean delivery	107 (64.8%)	47 (50%)	.02
Macrosomia	55 (33.3%)	13 (13.8%)	<.001
LGA	53 (32.1%)	12 (12.8%)	<.001
SGA	9 (5.5%)	9 (9.6%)	<.01

Data are expressed as mean ± SD and number of patients and percentage (in parentheses) of total group.

and macrosomia [aOR 3.59 (range 1.77–7.24); $P < .001$] (Table 6). Because most women with PGDM were taking insulin during pregnancy, the additive effects of insulin therapy were not analyzed for PGDM.

Discussion

GDM and PGDM represent high-risk conditions individually associated with adverse maternal and neonatal outcomes (1, 3). We show that in the already high-risk settings of both GDM and PGDM, excessive GWG is significantly associated with an additive risk for LGA birth weight, macrosomia, and gestational hypertension. This is the first time that an analysis of GWG has been undertaken, using the IOM criteria in a large, exclusively diabetic cohort of women.

Table 6. Multivariable Analysis of Adverse Outcomes Associated With Excessive GWG in Women With PGDM

	Excessive GWG	
Outcome	aOR (95% CI)	*P* Value
Preeclampsia	0.48 (0.15–1.54)	.22
Gestational hypertension	0.79 (0.32–1.96)	.62
Cesarean delivery	1.61 (0.74–3.51)	.23
Macrosomia	3.58 (1.77–7.24)	<.001
LGA	3.97 (1.85–8.53)	<.001
SGA	0.77 (0.26–2.28)	.63

Adjusted for age, parity, ethnicity, use of insulin, booking BMI category, and cigarette smoking.

Overall, more than half of women with PGDM and GDM gained excessive weight during pregnancy, and this occurred despite an intensive, multidisciplinary lifestyle intervention program in the setting of combined diabetes/obstetric care. These characteristics are similar to those in a previous study of women with GDM that reported 41%–57.9% excessive GWG, depending on the BMI category (10). Given the large proportion of women affected, the challenge relating to management of GWG is apparent.

The background BMI was higher in women with GDM and PGDM when compared with previous analyses of normoglycemic women within the ATLANTIC-DIP cohort (14, 15). Two observations within the current study, relating to patterns of weight gain in the context of high BMI, were interesting. First, women who were OW displayed higher GWG when compared with those who were of normal or OB BMI. Second, women who gained excessive weight tended to be younger than those who did not. Although these results cannot be wholly explained by the current analysis, they may highlight a bias in the emphasis on management of diabetes during pregnancy among care providers, whereby the message relating to weight management is reinforced more vigorously in OB

rather than OW women. These data also suggest that older women, who have significant concerns relating to age-related obstetric outcomes may be more likely to comply with lifestyle advice during pregnancy to minimize perceived additional risk.

Our principal finding relates to neonatal outcome, specifically highlighting the effects of excessive GWG to confer a higher risk of LGA birth weight and macrosomia. These data conform with those of other authors who have shown similar effects of excessive GWG on birth weight for nondiabetic or mixed populations of pregnant women (7, 9, 10, 16, 17). However, our data are novel in presenting these findings for the first time in a high-risk sample, comprising exclusively women with a diagnosis of diabetes who were managed intensively throughout pregnancy according to international guidelines. The additive risk presented by excessive GWG is concerning when taken in the context of clinical complications associated with LGA birth weight and macrosomia including a 2- to 3-fold higher risk of intrauterine death, shoulder dystocia, and consequent brachial plexus injuries in addition to higher rates of cesarean section (18, 19). Longitudinal observational studies have also demonstrated poorer long-term outcomes for these infants including childhood obesity, asthma, and in later life the metabolic syndrome, type 2 diabetes, and cancer (19, 20).

There are data that support an improvement in obstetric outcomes using a management program to prevent excessive GWG; however, these studies include selected groups of women and may not be applicable to women with diabetes in pregnancy (21–23). Additionally, other evidence suggests that although lifestyle intervention is associated with restricted GWG, there is not clear evidence for a reduction in adverse outcomes as a result, particularly in the overweight and obese population (24). These findings combined with our data make a clear case for the design, implementation, and evaluation of intensive weight-centered management programs for all women with diabetes during pregnancy, irrespective of antenatal BMI. We propose that appropriate control of GWG, within the limits set by IOM guidelines, will avoid potential neonatal complications relating to birth weight and will also improve glycemic control, thereby reducing baseline risk related to diabetes.

Another interesting observation presented herein is the combined effects of excessive GWG and insulin use in women with GDM, which further increased the odds for higher birth weight. Exogenous insulin therapy, in the absence of excessive GWG, did not increase the odds for LGA birth weight or macrosomia. Interestingly, women with GDM taking insulin gained less weight overall when compared with their counterparts who were managed using lifestyle measures only. The potential mechanisms underlying these effects merit further discussion. The transplacental passage of exogenous insulin is negligible, and therefore, our observations are unlikely to result from a direct effect of exogenous insulin within the fetal circuit (25, 26). However, placentae of women with GDM who are treated with insulin demonstrate significantly higher trophoblastic expression of insulin receptors when compared with their non-insulin-treated counterparts (27). Moreover, trophoblastic insulin receptor activation results in increased downstream signaling of MAPKs responsible for trophoblastic expansion (28). Abnormal and prolonged trophoblastic expansion consequent to insulin therapy, combined with so-called maternal overnutrition, may underpin the additive risks of insulin and excessive GWG on neonatal birth weight. Further scientific studies of mechanism are necessary to investigate this.

Clinically, our findings relating to insulin therapy in women GDM gaining excessive weight during pregnancy are somewhat surprising. The principal aim of instituting insulin therapy in GDM is to improve maternal and neonatal outcomes. Although our data may represent the influence of poorer baseline glycemic control in women with GDM who go on to require insulin, it also highlights the importance of added attention to weight management in pregnancy within this cohort, above that of glycemic control alone. Traditionally, we have used exogenous insulin as first-line pharmacological management of GDM. Only recently have convincing data suggesting the safety and efficacy of metformin emerged (29). Our findings add to the debate that suggests metformin may represent a suitable first-line therapy for future management of GDM. Metformin crosses the placenta during pregnancy, and hence, use of this agent during pregnancy is not currently routine (30). Nonetheless, encouraging data have supported the safety profile of metformin use with or without supplemental insulin in women with GDM, with some studies suggesting increased insulin sensitivity and improved longer-term outcomes in offspring (29, 31, 32). Other work has demonstrated that pregnant women treated with metformin, although heavier in the first trimester, gained less weight in pregnancy and lost less weight in the first year postpartum. However, their offspring weighed more at 1 year compared with children not exposed to metformin (33). The results of future studies will provide interesting insights into how we proceed in the future with the pharmacological management of GDM and indeed obesity during pregnancy (34).

The association of gestational weight gain with gestational hypertension in women with GDM highlighted the influence of weight gain and so-called maternal overnutrition in the development of an adverse metabolic milieu.

Excessive gestational weight gain did not produce an additive risk for the development of preeclampsia in this group of largely high BMI women with a high-baseline risk of preeclampsia by virtue of the diagnosis of diabetes (1, 2, 20).

Overall this was a robust, nested cohort analysis performed retrospectively using data collected and managed prospectively within the ATLANTIC-DIP study design using a validated database. Acknowledging the limitations associated with observational study design and associated influence of measured and unmeasured covariates, we have used adjusted multivariate regression analysis to provide convincing and strong associations between adverse pregnancy outcomes and excessive GWG. We have also used strong, validated classification systems for the definition of GWG and BMI. Potential covariates, which have not been measured during this study, include those of glycemic control in early pregnancy for women with GDM and socioeconomic status. Both of these are difficult to measure and require dedicated prospective study design. Glycemic control in GDM during early pregnancy may influence pregnancy outcome and future requirement for institution of insulin therapy. However, under current guidelines, the diagnosis of GDM is not made until 24–28 weeks, and hence, analysis was not possible during this study. We include third-trimester HbA1c as an index of glycemic control after the diagnosis of GDM, and in women with PGDM, we include both first- and third-trimester HbA1c. A lack of significant difference between the excessive and nonexcessive groups in relation to HbA1c supports our conclusion that excessive GWG is associated with adverse outcomes independent of glycemic control during pregnancy. Socioeconomic status was also difficult to adjust for in the context of the mixed urban-rural characteristics of the population of pregnant women included in this study.

We did not have accurate measurement of pregestational weights for calculation of BMI. We did not rely on self-reported maternal weight in our analysis and used accurate, objective measurements only. Booking BMI was therefore calculated between 14 and 22 weeks and used as a surrogate measurement for pregestational BMI. This methodology is supported by a study by Fattah et al (35), who demonstrate no change in mean maternal weight or body composition over the first trimester of pregnancy in a cohort of nondiabetic women. We also backcalculated pregestational weight, assuming a first-trimester weight gain in the midrange (subtraction of 1 kg) of IOM guidelines, and this did not result in a change of BMI category for any study participant (8, 20). Although limited by the absence of weight measurements from early pregnancy, our data nonetheless provide clinically relevant data that clearly relate the effects of excessive gestational weight gain over the second and third trimesters to adverse pregnancy outcome in a cohort of women with diabetes during pregnancy. Larger prospective studies, which collect data in the first trimester of pregnancy, are required to further address this aspect of study design and also to investigate changes across BMI subcategories as well as subcategories of PDGM.

For the first time, we apply the 2009 IOM guidelines for GWG in a sample of women with GDM and PGDM from a community who have undergone universal screening for GDM. We provide robust data of clinical significance that will guide multidisciplinary health care teams in managing this high-risk patient population. We advocate the use of IOM recommendations to classify GWG in women with GDM/PGDM and recommend targeted management of GWG in these women, particularly those who go on to commence insulin therapy. Future research focusing prospectively on active management to prevent or reverse excessive GWG will highlight the potential benefit in terms of maternofetal outcomes for these women and their offspring.

Acknowledgments

We thank the ATLANTIC-DIP partners. A special thanks goes to Louise Carmody for her assistance.

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This work was supported by a grant from the Health Research Board of Ireland.

Disclosure Summary: The authors have nothing to declare.

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