The obese woman with gestational diabetes: effects of body mass index and weight gain in pregnancy on obstetric and glycaemic outcomes

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Summary

Background: Obese women with gestational diabetes mellitus (GDM) represent a high-risk group in pregnancy, although the effects of increasing degrees of obesity and weight gain in pregnancy in this group is poorly defined.

Methods: We performed a retrospective analysis of 375 singleton pregnancies complicated by maternal obesity and GDM. Women with a body mass index (BMI) of 30–35 kg/m² were compared with those with a BMI of ≥ 35 kg/m². Additionally, women were categorized according to weight gain in pregnancy: Group A (<0.18 kg/week), Group B (0.18–0.27 kg/week), Group C (>0.27 kg/week).

Results: Obstetric outcomes did not differ between the groups; however, postpartum dysglycaemia was more likely in women with a BMI ≥ 35 kg/m² (odds ratio [OR] 3.2, 95% confidence interval [CI]: 1.2–8.9). Group B and Group C had higher odds of LGA (OR 3.8, 95% CI: 1.3–11.3; OR 5.0, 95% CI: 2.0–12.1, respectively) compared with Group A. Group C also had a lower risk of SGA (OR 0.4, 95% CI: 0.2–1.0) and a higher risk of postpartum dysglycaemia (OR 6.8, 95% CI: 1.7–26.9) compared with Group A.

Conclusion: Greater degrees of obesity are associated with higher risk of abnormal metabolic outcomes after pregnancy.

Excessive weight gain in pregnancy in obese women increases adverse obstetric and glycaemic outcomes. Our findings suggest that targets for weight gain in pregnancy for obese women should be reduced from current recommendations.

Keywords: gestational diabetes, obesity, weight gain, pregnancy

INTRODUCTION

Obesity and gestational diabetes mellitus (GDM) are growing public health concerns. In Australia, the proportion of women who are overweight or obese exceeds 30% in those aged 18–24 years and is over 50% in those aged 25–44 years.¹ Simultaneously, the incidence of GDM in Australia has increased by more than 20% between 2000 and 2005 and the rates of GDM among certain ethnic groups is now over 10%.² Hence, women with obesity and GDM will represent a growing proportion of the women encountered in antenatal clinical services.

Both obesity and GDM are well-established risk factors for adverse pregnancy outcomes.^{3–6} Further, both portend a life-long health risk to the mother by dramatically increasing her likelihood of type 2 diabetes mellitus and cardiovascular disease. Well-established guidelines are available for management of GDM. However, few data exist regarding the influence of coexisting obesity on GDM. In particular, the optimal amount of weight gain in pregnancy for the obese woman with GDM is not well defined. The Institute of Medicine (IOM) 2009 guidelines⁷ define the optimal weight gain for an obese woman as 5–9 kg during the entire pregnancy. Other

studies have shown that less weight gain in the obese woman is associated with improved outcomes,^{8–10} but none have specifically addressed women with GDM.

In this study, we have identified a cohort of women with obesity and GDM. Our first aim was to assess whether the degree of obesity (body mass index [BMI] at initial antenatal visit) influenced obstetric and glycaemic outcomes. The second aim was to determine the effect of differing degrees of weight gain during pregnancy on obstetric and glycaemic outcomes.

METHODS

We utilized a database of 994 pregnancies complicated by GDM, identified by universal screening of all women attending the Antenatal Service at Blacktown Hospital, 2002–2009. Among these, 375 women with singleton pregnancies had a BMI of 30 kg/m² or more at the time of their first antenatal clinic visit. These became the study cohort for this retrospective analysis.

Demographic and anthropometric data were collected at routine antenatal visits. Obstetric outcomes (caesarean delivery, premature delivery [prior to 37 weeks gestation], birthweight lower than 10th centile [SGA] and birthweight greater than 90th centile [LGA]) were determined from the OBSTETRIX

database, maintained by NSW Health. Birthweight centiles were calculated using GROW-Centile v6.4 2009.¹¹

Routine screening for GDM was undertaken with the antenatal diagnostic two-hour 75 g oral glucose tolerance test (OGTT) performed usually at 24–28 weeks gestation and assessed using Australasian Diabetes in Pregnancy Society (ADIPS) criteria.¹² Glycosylated haemoglobin (HbA1c) at 35–38 weeks and a postnatal OGTT six weeks after delivery were performed in most women. Postpartum dysglycaemia was defined as any degree of abnormality of glucose handling using the American Diabetes Association (ADA) criteria for diagnosis of diabetes mellitus.¹³ The requirement for insulin or metformin treatment in pregnancy (which was initiated when fasting blood glucose level [BGL] ≥ 5.5 mmol/L and/or two-hour postprandial BGL ≥ 7.0 mmol/L) and the maximum daily insulin dosage were also recorded.

The cohort was divided into two groups; Group 1 having a BMI of 30–35 kg/m² and Group 2 BMI ≥ 35 kg/m². Comparisons were made with respect to their obstetric and glycaemic outcomes.

The effect of weight gain in the second and third trimester of the pregnancy on obstetric and glycaemic outcomes was also assessed. Weight was recorded at each antenatal visit. Weight gain during the second and third trimesters was calculated as the difference between the last weight prior to delivery and the first weight recorded beyond 13 weeks gestation. Those who had their booking visit beyond 32 weeks gestation were excluded as were those who had their last weight recorded more than four weeks prior to delivery. The rate of weight gain was calculated as the weight gain during the second and third trimester divided by the number of weeks between the two measurements. Women were then classified into three groups according to the 2009 IOM guidelines⁷: Group A (gaining <0.18 kg/week), Group B (0.18–0.27 kg/week)

and Group C (>0.27 kg/week). These guidelines assume a weight gain of 0.5–2.0 kg in the first trimester. The three groups were compared with regard to obstetric and glycaemic outcomes.

Ethical approval was obtained from the Sydney West Area Health Service Human Research Ethics Committee.

Statistical analyses using analysis of variance and Kruskal–Wallis tests were used to detect differences between groups for continuous variables. Logistic regression models were used to detect differences among the groups for dichotomous-dependent variables. Two-tailed *P* values <0.05 were considered significant. All analyses were performed using SAS version 9.1 (SAS Institute, Cary, NC, USA).

Two models were fitted for each outcome studied in exploring the effect of increasing maternal obesity on obstetric and glycaemic outcomes. Model I included adjustment for all factors known to affect the outcome other than fasting BGL and hypertension. Model II included the adjustment for fasting BGL and hypertension (where applicable), which are potential effect modifiers in the relationship between maternal obesity and each outcome variable. This allowed demonstration of the magnitude and direction of the role of fasting BGL and hypertension independently.

In investigating the role of weight gain in pregnancy, fasting BGL and hypertension are not proven effect modifiers in the relationship between weight gain and the obstetric and glycaemic outcomes. Therefore, fasting BGL and hypertension were evaluated as potential confounders and retained in the model only if they were found to be significant on univariate analyses.

RESULTS

The characteristics of the 375 obese women with GDM are shown in Table 1. There were 209 (55.7%) women in Group 1 and 166

Table 1 Maternal and neonatal characteristics by category of body mass index in obese women with GDM

	Group 1 (<i>n</i> = 209)	Group 2 (<i>n</i> = 166)	<i>P</i> value
Age (years)	32.7 $\pm$ 5.1	32.91 $\pm$ 4.7	0.72
Body mass index (kg/m ²)	32.0 $\pm$ 1.5	40.4 $\pm$ 4.9	$<0.01^*$
Nulliparity, <i>n</i> (%)	46 (22)	44 (27)	0.32
Smoking, <i>n</i> (%)	19 (9)	26 (16)	0.05*
Hypertension, <i>n</i> (%)	14 (7)	23 (15)	0.02*
Family history of diabetes mellitus, <i>n</i> (%)	117 (57)	94 (57)	0.92
Previous history GDM, <i>n</i> (%)	44 (21)	33 (20)	0.78
Ethnicity, <i>n</i> (%)			
Caucasian	97 (46)	115 (70)	<0.01
Asian subcontinental	38 (18)	5 (3)	<0.01
Pacific islander	30 (14)	30 (18)	0.29
Other	44 (21)	16 (9)	<0.01
Gestational age at first prenatal visit (weeks)	16.3 (12–20) [†]	16.3 (13–19) [†]	0.6
Gestational age at GDM diagnosis (weeks)	27.4 (25.0–29.5) [†]	26.5 (25.0–29.0) [†]	0.43
Two-hour OGTT result (mmol/L)			
Fasting	5.1 (0.7)	5.4 (0.8)	<0.01
2 hours	8.9 (1.4)	8.8 (1.4)	0.37
HbA1c third trimester	5.8 [‡]	5.9 [‡]	0.58
Gestational age at birth (weeks)	38.7 (38.1–39.2) [†]	38.5 (38.0–39.1) [†]	0.12
Birthweight (g)	3485 [§]	3524 [§]	0.05
Male gender, <i>n</i> (%)	95 (45)	76 (46)	0.09

OGTT, oral glucose tolerance test; GDM, gestational diabetes mellitus; HbA1c, glycosylated haemoglobin; BMI, body mass index

Group 1, women with BMI 30–35 kg/m²; Group 2, women with BMI ≥ 35 kg/m²

Data are presented as mean (standard deviation) for continuous variables and as number (%) for categorical variables

*Statistically significant *P* value <0.05

[†]Data are presented as mean (interquartile range)

[‡]Means adjusted for ethnicity, gestational age at diagnosis of GDM, glucose with interaction term

[§]Means adjusted for gestational age at birth, parity, ethnicity, smoking, gender, fasting glucose with interaction term

Table 2 Risk of adverse obstetric and glycaemic outcomes by category of body mass index in obese women with GDM

	Group 1	Group 2	Model I OR (95% CI)	Model II OR (95% CI)
Caesarean delivery	91 (44)	74 (45)	1.03 (0.64–1.65)	0.95 (0.57–1.57)
Premature delivery (<37 weeks)	17 (8)	17 (10)	1.65 (0.76–3.58)	1.38 (0.58–3.28)
Birthweight >90th centile	36 (17)	35 (21)	1.16 (0.66–2.05)	1.01 (0.55–1.85)
Birthweight <10th centile	20 (10)	13 (8)	0.58 (0.25–1.37)	0.67 (0.28–1.63)
Abnormal postpartum OGTT	16 (14)	22 (29)	3.48 (1.44–8.27)*	3.23 (1.17–8.91)*
Insulin use	104 (50)	95 (57)	1.28 (0.82–2.00)	0.94 (0.58–1.54)
Insulin dose (≥ 30 units per day)	42 (40)	51 (54)	1.53 (0.83–2.83)	1.28 (0.66–2.47)

OGTT, oral glucose tolerance test; GDM, gestational diabetes mellitus; BMI, body mass index

Group 1, women with BMI 30–35 kg/m²; Group 2, women with BMI ≥ 35 kg/m²

Categorical variables described by frequency (%)

Models controlling for: caesarean delivery – maternal age, parity, gender, ethnicity, smoking, fetal extreme birthweight (as defined by birthweight <10th centile or >90th centile), gestational age at birth, insulin use; premature delivery – smoking, race; LGA/SGA – parity, gender, gestational age at birth, ethnicity, smoking, early diagnosis of GDM (<24 weeks gestation); postpartum dysglycaemia – gestational age at diagnosis of GDM, family history of diabetes mellitus, ethnicity, previous history of GDM, insulin use in pregnancy; insulin use and dosage – gestational age at diagnosis of GDM, family history of GDM, ethnicity. Model II: Model I adjusted for fasting glucose on diagnostic two-hour OGTT, hypertension where applicable

*Denotes statistically significant *P* value <0.05

(44.3%) women in Group 2. Analysis of the difference in obstetric outcomes between the two groups did not reveal any increase in odds in the incidence of caesarean delivery, premature delivery, SGA or LGA with increasing BMI as shown in Table 2. However, rates of caesarean delivery were over 40% in both groups and the rate of LGA was over 15% in both groups highlighting the overall high obstetric risk in the study population.

There were increased odds of having persistent glucose abnormalities in those in Group 2 compared with those in Group 1, even after adjustment for the effects of fasting and two-hour blood glucose values on the diagnostic OGTT as shown in Table 2. That is, increasing degrees of maternal obesity were shown to confer a higher risk of postpartum dysglycaemia. Insulin treatment was required in 49.8% of Group 1 and 57.2% of women in Group 2. There was no effect of BMI on

the need for insulin treatment or insulin dose requirements (with an arbitrary cut-off of 30 units per day being used to differentiate 'high' and 'low' dose groups) on adjusted analyses.

Overall, the rate of metformin use was low with 23 out of the 375 women (6.1%) receiving the drug during pregnancy. Owing to the small proportion of metformin use, and as 'metformin use' modelled categorically did not predict the study outcomes on univariate analyses (data not shown) this variable was not included in subsequent models.

There were 347 obese women with GDM in whom weight recordings were available for analysis. There were 113 women in Group A (32.6%), 68 women in Group B (19.6%) and 166 women in Group C (47.8%). The characteristics of the women according to their weight gain category are shown in Table 3. The adjusted means for third trimester HbA1c was higher in those in Group C

Table 3 Maternal and neonatal characteristics by category of weight gain in pregnancy in obese women with GDM

	Group A	Group B	Group C	<i>P</i> value
Age (years)	33.2 (4.7)	33.6 (4.8)	32.2 (5.1)	0.11
Body mass index (kg/m ²)	36.4 (5.9)	34.9 (4.8)	35.6 (5.4)	0.22
Nulliparity, <i>n</i> (%)	24 (21)	12 (21)	48 (28)	0.38
Smoking, <i>n</i> (%)	23 (21)	4 (7)	6 (11)	<0.01*
Hypertension, <i>n</i> (%)	10 (9)	6 (11)	19 (11)	0.84
Family history of diabetes mellitus, <i>n</i> (%)	70 (63)	27 (47)	99 (57)	0.14
Previous history GDM, <i>n</i> (%)	23 (20)	11 (19)	35 (20)	0.98
Ethnicity, <i>n</i> (%)				
Caucasian	67 (60)	25 (43)	105 (60)	0.08
Asian subcontinental	15 (13)	12 (21)	14 (8)	0.04
Pacific Islander	14 (13)	10 (17)	31 (18)	0.47
Other	17 (15)	11 (19)	26 (15)	0.74
Gestational age at first prenatal visit (weeks)	15.8 (11.0–19.0) [†]	15.9 (13.0–19.0) [†]	16.3 (13.0–19.0) [†]	0.79
Gestational age at GDM diagnosis (weeks)	25.8 (25.0–28.5) [†]	27.1 (25.0–29.0) [†]	27.6 (26.0–30.0) [†]	<0.01*
Two-hour OGTT result (mmol/L)				
Fasting	5.2 (0.8)	5.2 (0.8)	5.2 (0.7)	0.89
2 hours	8.7 (1.2)	9.0 (1.5)	8.8 (1.5)	0.45
HbA1c third trimester	5.6 [†]	5.7 [†]	6.0 [†]	<0.01*
Gestational age at birth (weeks)	38.7 (38.1–39.3) [†]	38.7 (38.3–39.6) [†]	38.5 (37.9–39.0) [†]	0.44
Birthweight (g)	3340 [§]	3490 [§]	3642 [§]	<0.01*
Male gender, <i>n</i> (%)	52 (46)	28 (48)	96 (55)	0.34

OGTT, oral glucose tolerance test; GDM, gestational diabetes mellitus; BMI, body mass index; HbA1c, glycosylated haemoglobin

Group A, women with <0.18 kg/week weight gain in second and third trimesters; Group B, women with 0.18–0.27 kg/week weight gain in second and third trimesters; Group C, women with >0.27 kg/week weight gain in second and third trimesters

Data are presented as mean (standard deviation) for continuous variables and as number (%) for categorical variables

*Denotes statistically significant *P* value <0.05[†]Data are presented as mean (interquartile range)[‡]Means adjusted for ethnicity, gestational age at diagnosis of GDM and first prenatal visit, glucose with interaction term, weight and height[§]Means adjusted for gestational age at birth, parity and first prenatal visit, ethnicity, smoking, gender, fasting glucose with interaction term, weight and height

than in Group A (6.0% versus 5.7%, $P < 0.01$) as was the adjusted means of their birthweights (3644 versus 3337 g, $P < 0.01$).

Comparison between the three groups with respect to their obstetric and glycaemic outcomes is shown in Table 4. Those in Group C had a higher risk of LGA but a lower risk of SGA than those in Group A. In addition, even those in Group B had higher odds of LGA than those in Group A. There were higher rates of postpartum dysglycaemia in Group C compared with Group A (OR 6.8, 95% CI 1.7–26.9) but the groups did not differ in their insulin requirements.

DISCUSSION

Effect of degree of obesity and obstetric outcome

We did not find any significant differences in obstetric outcomes in women with GDM according to their degree of obesity (BMI 30–35 or ≥ 35 kg/m²). Very few studies have

examined pregnancy outcomes in obese women with GDM. Our data show similar results to Yogev and Langer,¹⁴ who compared obstetric outcomes between those with BMI of 30–35 kg/m² versus those with BMI of ≥ 35 kg/m² and who had GDM. They found no difference between these groups in rates of LGA and macrosomic babies, metabolic complications, need for neonatal intensive care and/or respiratory support, rate of shoulder dystocia or caesarean section.

More recently, the HAPO BMI substudy investigated the effects of increasing BMI in 23,316 women on a range of pregnancy outcomes. The women were divided into six categories based on their BMI. They found that the association with fetal size (as assessed by odds of birthweight >90 th centile) was flattened in the highest BMI categories; however, there was a dose–response relationship with increasing BMI and rates of primary caesarean section and preeclampsia. Although the women in this study did not have GDM, the independent effect of BMI was measured by adjusting for the effects of fasting BGL.¹⁵

It has been postulated that a BMI cut-off of 30 kg/m² has surpassed the threshold beyond which obstetric risk is increased in obesity, and so comparisons between groups of obese women may not yield differential risks.^{14,15} In contrast, studies comparing women with even higher degrees of obesity support the notion that increasing degrees of obesity do confer additional risks.

Alanis *et al.*¹⁶ compared women with ‘superobesity’ (defined as BMI ≥ 50 kg/m²) with less obese women (BMI 16–48 kg/m²) in the USA. They found that those with superobesity had the highest rates of preeclampsia, caesarean delivery, extreme birthweights and GDM. In addition, multivariate analyses found a positive association between BMI and many of these outcomes. Similarly, Knight *et al.*¹⁷ assessed the prevalence and risks of superobese women in the UK and found higher rates of preeclampsia, GDM, preterm delivery, general anaesthesia, intensive care admission and a marked increase in the need for caesarean deliveries of 50% compared with 22% in the comparison group which comprised women with BMI of 16–48 kg/m².

Thus, while we did not show an effect of the degree of obesity on obstetric outcomes in women in GDM this may have been due to our relatively small sample size, or to the BMI categories used which were chosen according to the WHO classification of obesity. Studies with comparator groups with extreme obesity are more likely to show differential effects of BMI. Overall, rates of adverse outcomes are considerable in women with obesity and GDM, especially rates of caesarean delivery and LGA. This highlights the need for preconception counselling regarding the adverse effects of obesity in pregnancy.

Effect of degree of obesity and glycaemic control

To our knowledge, this is the first study to compare women with different degrees of obesity and GDM with regards to dysglycaemia postpartum. We found that those with BMI of ≥ 35 kg/m² were more likely to have dysglycaemia postpartum than their less obese counterparts. The fasting BGL on the diagnostic antenatal two-hour oral glucose tolerance test was significantly higher in the more obese group (5.4 mmol/L versus 5.1 mmol/L). This supports existing knowledge that the most consistent factor associated with the development of type 2 diabetes mellitus on postpartum screening is the fasting BGL during pregnancy.^{18,19} It should also be noted that in those

Table 4 Risk of adverse obstetric and glycaemic outcomes by category of weight gain in pregnancy in obese women with GDM

	N (%)	Odds ratio (95% CI)
Caesarean delivery		
Group A	45 (40)	1.0*
Group B	30 (52)	1.54 (0.77–3.09)
Group C	76 (44)	1.18 (0.68–2.03)
Premature delivery (<37 weeks)		
Group A	9 (8)	1.0*
Group B	5 (9)	1.25 (0.36–4.32)
Group C	15 (9)	1.06 (0.38–2.93)
Birthweight >90th centile		
Group A	9 (8)	1.0*
Group B	10 (17)	3.81 (1.29–11.29) [†]
Group C	43 (24)	4.95 (2.03–12.11) [†]
Birthweight <10th centile		
Group A	14 (12)	1.0*
Group B	5 (9)	0.52 (0.17–1.66)
Group C	12 (7)	0.38 (0.15–0.95) [†]
Abnormal postpartum OGTT		
Group A	6 (10)	1.0*
Group B	6 (19)	2.89 (0.55–15.31)
Group C	23 (27)	6.75 (1.69–26.92) [†]
Treatment with insulin		
Group A	61 (54)	1.0*
Group B	34 (59)	1.58 (0.76–3.27)
Group C	92 (52)	1.11 (0.65–1.89)
Insulin dosage (≥ 30 units/day)		
Group A	25 (41)	1.0*
Group B	14 (41)	1.08 (0.41–2.89)
Group C	49 (53)	1.74 (0.82–3.69)

OGTT, oral glucose tolerance test; GDM, gestational diabetes mellitus
Group A, women with <0.18 kg/week weight gain in second and third trimesters;
Group B, women with 0.18–0.27 kg/week weight gain in second and third trimesters; Group C, women with >0.27 kg/week weight gain in second and third trimesters

Categorical variables described by frequency (%)

Models controlling for: caesarean delivery – maternal age, parity, gender, ethnicity, smoking, fetal extreme birthweight (as defined by birthweight <10 th centile or >90 th centile), gestational age at birth, insulin use, weight, height; premature delivery – smoking, ethnicity, weight, height, hypertension, interaction terms; LGA/SGA – parity, gender, gestational age at birth, ethnicity, smoking, weight, height, fasting glucose, interaction terms; postpartum dysglycaemia – gestational age at diagnosis of GDM, family history of diabetes mellitus, ethnicity, previous history of GDM, insulin use in pregnancy, weight, height, fasting glucose interaction terms; insulin treatment/dosage – ethnicity, age at diagnosis of GDM, family history of diabetes mellitus, weight, height, fasting glucose, interaction terms

*Reference category

[†]Denotes statistically significant P value <0.05

with a normal oral glucose tolerance test postpartum the metabolic risk remains high with an eight-fold increased risk of developing type 2 diabetes mellitus at five years indicating the need for long-term metabolic follow-up.¹⁸

The degree of obesity was not shown to affect insulin requirements or insulin dosages. We also did not show any differences between obstetric outcomes according to the treatment modality received (data not shown).

Effect of weight gain in pregnancy in obese women with GDM

There is a paucity of information regarding gestational weight gain in obese women with GDM. To our knowledge, there are no studies relating to this specific group of patients investigating the role of weight gain in pregnancy. We found that those who gain weight excessively in the second and third trimesters are at higher odds of LGA, lower risk of SGA and higher risk of postpartum dysglycaemia. Our study concurs with the current literature that excess weight gain in pregnancy increases the risk of LGA^{8,20–22} and that excess weight gain is protective against SGA.^{8,20,22,23}

The lower target of weight gain in pregnancy in obese women has been the subject of much debate. The main concern has been that no weight gain (or even weight loss) in pregnancy may cause ketonuria or ketonaemia which may be harmful to the mother and growing fetus.²⁴ A recent review by Artal *et al.*²⁵ reports that this concern has been discredited as numerous studies have demonstrated no neurodevelopmental effects on offspring who were exposed to ketone bodies during pregnancy. In addition, although low weight gain is associated with SGA, this may merely reflect underlying medical and obstetric conditions rather than the inadequate weight gain *per se* causing SGA.²⁵ Therefore, in the absence of any adverse medical and obstetric conditions it may be safe for women to gain less weight than prescribed presently.

Large epidemiological studies investigating the role of gestational weight gain in obstetric populations have observed that minimal weight gain is safe in obese women. For example, Kiel and Dodson⁸ studied 120,170 obese women and investigated the role of gestational weight gain on pregnancy outcomes (preeclampsia, caesarean delivery, LGA and SGA). Women were divided into three groups according to the class of obesity. The optimal weight gain was found to be 10–25 lbs (4.5–11.4 kg) in Class I obesity and 0–9 lbs (0–4.1 kg) in Class II obesity and beyond. Similarly, Cedergren *et al.*¹⁰ found that in the obese subgroup of the 298,648 singleton pregnancies in Sweden between 1994 and 2004, the optimal weight gain in obese women was less than 13 lb (less than 6 kg) to minimize the composite outcome of obstetric (including preeclampsia, venous complications and shoulder dystocia) and neonatal variables (including birth trauma, perinatal death and Apgar score less than 7 at five minutes).

Thus, it is likely that current recommendations for weight gain in obese parturients (including by the IOM guidelines) are still too generous. In our study, even women gaining weight at the 'recommended' rates had higher odds of LGA than those gaining the least amount of weight; indicating that weight gain in excess of 0.18 kg per week in the second and third trimesters may increase obstetric risks.

Furthermore, postpartum screening for glucose abnormalities in a specific cohort of obese women with GDM has not previously been studied. We found an increased incidence of

postpartum glucose abnormalities in the group with highest pregnancy weight gain highlighting the deleterious effects which this may have on a young woman's long-term health; and during pregnancy, it may be the only opportunity in which her ominous metabolic deterioration can be salvaged.

Guidelines for optimal weight gain in pregnancy have predominantly focused on fetal outcome and have paid less regard to the mother's long-term metabolic health. While the 2009 IOM guidelines do incorporate postpartum weight retention as an important determinant of optimal weight gain in pregnancy, the long-term metabolic risks, such as type 2 diabetes mellitus and hypertension in the mother in relation to their weight gain in pregnancy are not included, nor have they been adequately studied. Pregnancy is a time when a young woman can be persuaded to pay special attention to her own health. A woman who is obese and has GDM faces a very significant long-term health risk, which is likely to be further exacerbated if she has excessive weight gain during her pregnancy. Her health-care providers have an obligation to look beyond the short-term obstetric outcomes when advising her about diet, lifestyle and medication.

LIMITATIONS

The limitations of our study include its retrospective nature which necessitated the dichotomization of some variables (including smoking, hypertension and caesarean delivery).

Postpartum glycaemic data were unavailable for approximately half the cohort in this study; however, this is similar to rates of postpartum glucose tolerance screening in other reports.^{4,26} In addition, some women may have had unrecognized pre-existing diabetes.

There was also no prepregnancy weight recorded to verify the assumption of 0.5–2.0 kg weight gain in the first trimester which is often in excess of 2 kg. Thus, it is possible that there was an underestimation of the number of women who had gained weight in excess of the IOM guidelines. In addition, postpartum weight was not recorded so analyses pertaining to short-term weight retention were not performed.

CONCLUSION

In conclusion, women who are obese and have GDM are at high risk for adverse pregnancy outcomes. In particular, increasing degrees of obesity confers additional metabolic risk with persistent dysglycaemia postpartum. Weight gain during pregnancy also significantly affects obstetric and glycaemic outcomes. Guidelines for weight gain in this high-risk group need to be further refined and we would suggest that lower targets for pregnancy weight gain in obese women are safe and appropriate. Further attention to protection of long-term maternal metabolic wellbeing is also urgently required and should be incorporated into management guidelines.

DECLARATIONS

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Guarantor: MM

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REFERENCES

- 1 Australian Institute of Health and Welfare. Australia's health 2010. *Australia's health series no. 12. Cat. no. AUS 122*. Canberra: AIHW, 2010
- 2 AIHW, Templeton M, Pieris-Caldwell I. *Gestational diabetes mellitus in Australia, 2005–06*. Diabetes series no. 10. Cat. no. CVD 44. Canberra: AIHW, 2008
- 3 Dennedy MC, Dunne F. The maternal and fetal impacts of obesity and gestational diabetes on pregnancy outcome. *Best Pract Res Clin Endocrinol Metab* 2010;**24**:573–89
- 4 Pridjian G, Benjamin TD. Update on gestational diabetes. *Obstet Gynecol Clin North Am* 2010;**37**:255–67
- 5 Yogeve Y, Catalano PM. Pregnancy and obesity. *Obstet Gynecol Clin North Am* 2009;**36**:285–300, viii
- 6 Ramachenderan J, Bradford J, McLean M. Maternal obesity and pregnancy complications: a review. *Aust N Z J Obstet Gynaecol* 2008;**48**:228–35
- 7 IOM (Institute of Medicine) and NRC (National Research Council). *Weight Gain During Pregnancy: Reexamining the Guidelines*. Washington, DC: The National Academies Press, 2009
- 8 Kiel DW, Dodson EA. Gestational weight gain and pregnancy outcomes in obese women: how much is enough? *Obstet Gynecol* 2007;**110**:752–8
- 9 Cedergren M. Effects of gestational weight gain and body mass index on obstetric outcome in Sweden. *Int J Gynaecol Obstet* 2006;**93**:269–74
- 10 Cedergren MI. Optimal gestational weight gain for body mass index categories. *Obstet Gynecol* 2007;**110**:759–64
- 11 Gardosi J, Francis A. *Customised Weight Centile Calculator – GROW-Centile v5.15/6.4 2009*. Gestation Network. See www.gestation.net (v5.15: individual; v6.4: bulk centiles) (Last checked 27 January 2011)
- 12 Hoffman L, Nolan C, Wilson JD, Oats JJ, Simmons D. Gestational diabetes mellitus – management guidelines. The Australasian Diabetes in Pregnancy Society. *Med J Aust* 1998;**169**:93–7
- 13 American Diabetes Association – Position Statement: Diagnosis and classification of diabetes mellitus. *Diabetes Care* 2009;**32**(Suppl 1):S62–7
- 14 Yogeve Y, Langer O. Pregnancy outcome in obese and morbidly obese gestational diabetic women. *Eur J Obstet Gynecol Reprod Biol* 2008;**137**:21–6
- 15 Hyperglycaemia and Adverse Pregnancy Outcome (HAPO) Study: associations with maternal body mass index. *BJOG* 2010;**117**:575–84
- 16 Alanis MC, Goodnight WH, Hill EG, Robinson CJ, Villers MS, Johnson DD. Maternal super-obesity (body mass index ≥ 50) and adverse pregnancy outcomes. *Acta Obstet Gynecol Scand* 2010;**89**:924–30
- 17 Knight M, Kurinczuk JJ, Spark P, Brocklehurst P. Extreme obesity in pregnancy in the United Kingdom. *Obstet Gynecol* 2010;**115**:989–97
- 18 Bellamy L, Casas JP, Hingorani AD, Williams D. Type 2 diabetes mellitus after gestational diabetes: a systematic review and meta-analysis. *Lancet* 2009;**373**:1773–9
- 19 Kim C, Newton KM, Knopp RH. Gestational diabetes and the incidence of type 2 diabetes: a systematic review. *Diabetes Care* 2002;**25**:1862–8
- 20 DeVader SR, Neeley HL, Myles TD, Leet TL. Evaluation of gestational weight gain guidelines for women with normal prepregnancy body mass index. *Obstet Gynecol* 2007;**110**:745–51
- 21 Bianco AT, Smilen SW, Davis Y, Lopez S, Lapinski R, Lockwood C. Pregnancy outcome and weight gain recommendations for the morbidly obese woman. *Obstet Gynecol* 1998;**91**:97–102
- 22 Stotland NE, Cheng YW, Hopkins LM, Caughey AB. Gestational weight gain and adverse neonatal outcome among term infants. *Obstet Gynecol* 2006;**108**(3 Part 1):635–43
- 23 Hellerstedt WL, Himes JH, Story M, Alton IR, Edwards LE. The effects of cigarette smoking and gestational weight change on birth outcomes in obese and normal-weight women. *Am J Public Health* 1997;**87**:591–6
- 24 Bloomgarden ZT. Gestational diabetes mellitus and obesity. *Diabetes Care* 2010;**33**:e60–5
- 25 Artal R, Lockwood CJ, Brown HL. Weight gain recommendations in pregnancy and the obesity epidemic. *Obstet Gynecol* 2010;**115**:152–5
- 26 Kim C, Tabaei BP, Burke R, et al. Missed opportunities for type 2 diabetes mellitus screening among women with a history of gestational diabetes mellitus. *Am J Public Health* 2006;**96**:1643–1648

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