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Gestational weight gain and adverse pregnancy outcomes in a nulliparous cohort

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ABSTRACT

Objective: Excessive gestational weight gain (GWG) is an important contributing factor to the obesity epidemic in women and is associated with pregnancy complications. We investigated the relationship between GWG and caesarean delivery in labour, large for gestational age (LGA), small for gestational age (SGA) infants and pregnancy-induced hypertension by maternal pre-pregnancy body mass index (BMI) in a contemporary nulliparous cohort.
Study design: Using 2009 Institute of Medicine guidelines, participants in the SCOPE study (from Cork, Ireland, Auckland, New Zealand and Adelaide, Australia) were classified into GWG categories (low, normal and high) according to pre-pregnancy BMI. Maternal characteristics and pregnancy outcomes were compared between weight gain categories. SGA and LGA were defined as <10th and >90th customised birthweight centile. Multivariable analysis adjusted for confounding factors that impact on GWG including BMI.
Results: Of 1950 participants, 17.2% (n = 335) achieved the recommended GWG, 8.6% (n = 167) had low and 74.3% (n = 1448) had high GWG. Women with high GWG had increased rates of LGA infants [adjusted OR 4.45 (95% CI 2.49–7.99)] and caesarean delivery in labour [aOR 1.46 (1.03–2.07)]. SGA was increased in women with low GWG [aOR 1.79 (1.06–3.00)].
Conclusion: Three quarters of participants had high GWG, which was associated with an independent risk of LGA infants and caesarean in labour. Low GWG was associated with SGA infants. These adverse outcomes are potentially modifiable by achievement of normal GWG, which should be an important focus of antenatal care.

1. Introduction

The global obesity epidemic affecting women of reproductive age is a major contributor to adverse pregnancy outcomes [1,2]. Excessive gestational weight gain (GWG) is reported to be a contributing factor to this obesity epidemic in women [1–5]. Furthermore, excessive GWG has been associated with increased rates of pregnancy complications [3,4,6–11] including large for gestational age (LGA) infants [3,4,7,8,10,12,13], increased non-elective caesarean delivery [3,4,10,12,14], preeclampsia and gestational hypertension [3,15]. Conversely, limiting GWG, especially in obese women, has been associated with improved pregnancy outcomes [9,10,12]. Inadequate GWG, on the other hand, may increase the risk of small for gestational age (SGA) infants [3,4,7,8,10,12,13,16,17]. Some of these previous studies have been retrospective [10,11,13,16,18], have used self-reported maternal height and weight [3,7,10,12,13,18] and not adjusted GWG for gestation at delivery [7,9,10].

The Institute of Medicine (IOM) guidelines on GWG were developed in 1990 (prior to the obesity epidemic) to optimise birthweight and to prevent "premature births and SGA infants" [1,5]. The guidelines were revised in 2009 to match the "dramatic shifts in the demographic and epidemiologic profile" in "U.S. women of childbearing age" [5]. At this time several publications had highlighted the relationship between excessive GWG and pregnancy complications, especially among obese women [3–6,19]. The updated guidelines reduced the recommended weight gain for obese women and increased recommended GWG ranges for underweight women [5].

Currently there are no published data regarding GWG groups and the impact of GWG on pregnancy outcome in New Zealand or Ireland and no Australian data apart from a study from a birth cohort in the 1980s [14]. The aims of this study, in participants

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from the Screening for Pregnancy Endpoints (SCOPE) study, were to (1) report GWG gain categories in a contemporary nulliparous cohort and (2) establish the independent relationship between GWG and rates of caesarean delivery in labour, SGA, LGA and pregnancy-induced hypertension.

2. Materials and methods

2.1. Study design and ethics approval

The participants were healthy, nulliparous women with singleton pregnancies recruited to the SCOPE study between November 2004 and February 2011, in Cork, Ireland, Auckland, New Zealand, and Adelaide, Australia. The SCOPE study is a prospective, multicentre international screening study which aims to develop screening tests to predict preeclampsia, SGA infants and spontaneous preterm birth. Ethics approval was obtained from local ethics committees (New Zealand AKX/02/00/364, Australia REC 1712/5/2008, and Cork ECM5 (10) 05/02/08) and all women provided written informed consent. All women who agreed to participate were seen at 14–16 weeks of gestation, when they completed an extensive interview and had physical measurements obtained. Height and weight were measured by a research midwife at this visit. The data were entered into an Internet accessed central database with a complete audit trail (MedSciNetAB, Stockholm, Sweden). Pregnancy outcome data were collected, usually within 72 h of birth. Detailed methods have been described elsewhere [20,21]. Exclusion criteria are detailed in Fig. 1. The participants in this study were those who had a weight recorded at 14–16 weeks of gestation and at the end of pregnancy. From this, the woman's total weight gain for the second and third trimesters was calculated as per IOM standards [5].

In order to estimate as closely as possible the pre-pregnancy body mass index (BMI) required to generate IOM pregnancy weight gain categories the recently published IOM guidelines were adhered to [5]. Accordingly 1.25 kg (the average of 0.5–2.0 kg weight gain in the first trimester reported in the 2009 guideline) was subtracted from the weight measured at 14–16 weeks of gestation [5,22]. Pre-pregnancy BMI categories were then calculated using WHO criteria (underweight BMI < 18.5 kg/m^2, normal BMI 18.5–24.9 kg/m^2, overweight BMI 25.0–29.9 kg/m^2 and obese BMI ≥ 30.0 kg/m^2). Underweight women were excluded due to low numbers (Fig. 1).

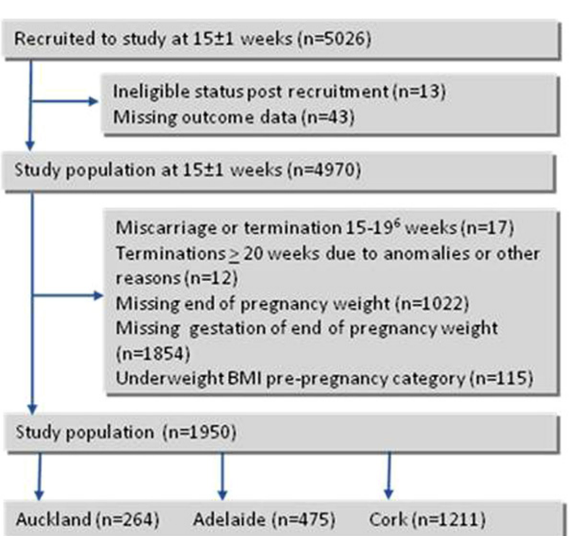

Fig. 1. Recruitment flow chart.

Table 1
IOM guidelines for recommended gestational weight gain based on pre-pregnancy BMI[5].

	Weight gain (kg/wk)		
	Low	Normal	High
Normal weight (18.5–24.9 kg/m^2)	<0.35	0.35–0.50	>0.50
Overweight (25.0–29.9 kg/m^2)	<0.23	0.23–0.33	>0.33
Obese ($\geq$ 30.0 kg/m^2)	<0.17	0.17–0.27	>0.27

The IOM 2009 guidelines for recommended rates of weight gain for the second and third trimesters for the three pre-pregnancy BMI categories (Table 1) were used to establish weight gain categories [5]. A woman's GWG per week in the second and third trimesters adjusted for gestation at delivery was calculated using the following formula: GWG (kg/week) = Total weight gain (kg)/(Week at final weight measurement − Week at first visit measurement) [10,22]. The gestational week in which the final weight measurement was recorded was added to the SCOPE database in October 2007 and therefore was missing in 49% of this cohort. These women were excluded from the current study (Fig. 1). Weight gain categories were classified as normal for those within the recommended range, high for those above the range and low for those below the range, using pre-pregnancy BMI criteria.

2.2. Definitions

Socio-economic index, a measure of socio-economic status (higher score indicating a higher status) was based on the New Zealand Socio-economic index [23]. Mean arterial blood pressure (MAP) was defined and calculated as diastolic BP + ((systolic BP − diastolic BP)/3). Pregnancy-induced hypertension included either gestational hypertension defined as sBP $\geq$ 140 mmHg and/or dBP $\geq$ 90 mmHg on at least 2 occasions 4 h apart after 20 weeks gestation but before the onset of labour) or preeclampsia defined as gestational hypertension plus proteinuria >= 300 mg/24 h or spot urine protein: creatinine ratio >= 30 mg/mmol creatinine or urine dipstick protein >= ++ or any multi-system disease [24]. SGA and LGA were defined as birth weight less than the 10th and greater than the 90th customised centile respectively and were adjusted for maternal height, booking weight and ethnicity as well as gestational age at delivery, and sex of the infant [25].

2.3. Statistical analysis

All analyses were performed using the statistical software package SPSS 19 (SPSS Inc., version 19.0, Chicago, IL, USA). Chi-square tests and analysis of variance were used for categorical and continuous variables respectively to compare maternal demographic characteristics at 14–16 weeks and pregnancy outcomes between each weight gain category. Statistical significance was defined at the 5% level.

Univariable analysis was performed using binary logistic regression modelling to determine the effect of GWG on pregnancy complications. Multivariable analysis adjusted for the following confounding factors that impact on GWG; pre-pregnancy BMI, maternal age, maternal ethnicity, MAP, smoking status at 14–16 weeks of gestation, socio-economic index, SCOPE centre, infant gender and gestational age at delivery.

3. Results

Of the 5026 women recruited to the SCOPE study in the three participating centres 1950 were eligible for this study – 1211 from Cork, 264 from Auckland and 475 from Adelaide (Fig. 1). In the

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Table 2
Maternal characteristics and pregnancy outcomes by gestational weight gain categories (*n* = 1950).

	Weight gain category (by IOM guidelines)			*P*	
	Low (*n* = 167; 8.6%)	Normal (*n* = 335; 17.2%)	High (*n* = 1448; 74.3%)	Low vs. normal	High vs. normal
Age (years)*				0.128	0.040
<25	53 (31.7)	74 (22.1)	320 (22.1)		
25–29	42 (25.1)	92 (27.5)	457 (31.6)		
30–34	51 (30.5)	116 (34.6)	519 (35.8)		
≥35	21 (12.6)	53 (15.8)	152 (10.5)		
European ethnicity	154 (92.2)	315 (94.0)	1365 (94.3)	0.449	0.897
Socio-economic index*	37.9 (16.3)	40.2 (15.8)	39.4 (16.1)	0.145	0.463
BMI groups*				0.001	<0.001
18.5–24.9	101 (60.5)	249 (74.3)	724 (50.0)		
25.0–29.9	33 (19.8)	57 (17.0)	476 (32.9)		
≥30.0	33 (19.8)	29 (8.7)	248 (17.1)		
MAP (mmHg)*	78 (9)	79 (8)	79 (8)	0.783	0.075
Smoking status*				0.096	0.849
Non smoker	138 (82.7)	296 (88.3)	1284 (88.7)		
Current smoker	29 (17.4)	39 (11.6)	164 (11.3)		
Centre				<0.001	0.002
Auckland	44 (26.3)	57 (17.0)	163 (11.3)		
Adelaide	72 (43.1)	86 (25.7)	317 (21.9)		
Cork	51 (30.5)	192 (57.3)	968 (66.9)		
Pregnancy-induced hypertension	17 (10.2)	38 (11.4)	241 (16.7)	0.694	0.016
Preeclampsia	5 (3.0)	12 (3.6)	78 (5.4)	0.73	0.174
Gestational hypertension	12 (7.2)	26 (7.8)	163 (11.3)	0.818	0.062
Mode of delivery †				0.552	0.002
Caesarean (pre-labour)	12 (7.2)	23 (6.9)	154 (10.6)		
Caesarean (in labour)	30 (18.0)	48 (14.3)	294 (20.3)		
Vaginal birth	125 (74.9)	264 (78.8)	1000 (69.1)		
Birth weight (g)	3284 (530)	3310 (518)	3523 (535)	0.605	<0.001
Gestation at delivery (wks)	39.8 (1.6)	39.8 (1.9)	39.9 (1.6)	0.908	0.220
SGA infant	35 (21.0)	42 (12.5)	135 (9.3)	0.018	0.085
LGA infant	8 (4.8)	13 (3.9)	198 (13.7)	0.641	<0.001

Data are mean (SD) or number (%) as appropriate.
BMI: body mass index; MAP: mean arterial blood pressure; SGA: small for gestational age; LGA: large for gestational age.
P values are for comparing between GWG groups using Chi square or Analysis of variance Test.
* Data collected at 14–16 weeks of gestation.

whole cohort, 55% (*n* = 1074) of women were of normal weight, 29% (*n* = 566) were overweight and 16% (*n* = 310) were obese. High GWG was observed in 67% (*n* = 724) of normal weight women, 84% (*n* = 476) of overweight women and 80% (*n* = 248) of obese women. The first and last recorded weights used to calculate gestational weight gain were recorded at 15.5 (SD 0.70) and 36.7 (SD 2.9) weeks respectively. The mean weight gain from 14 to 16 weeks until delivery in the whole cohort was 12.3 ± 5.5 kg with a normal distribution across the cohort. The estimated total weight gain from conception until delivery was 13.55 kg for the whole study cohort [5]; 13.91 ± 4.6 kg for normal, 13.77 ± 5.2 kg for overweight and 11.92 ± 8.1 kg for obese women. Of concern, 1448 (74.3%) participants had high GWG, while 335 (17.2%) had normal GWG and 167 (8.6%) had low GWG (Table 2). Compared to those with normal GWG, high GWG was more common in women who were overweight or obese. Those with high GWG had higher rates of caesarean section in labour, LGA babies and pregnancy-induced hypertension. The low GWG group had a trend to higher rates of SGA compared to the normal GWG group.

Mean gestational age at delivery was not different between GWG categories. There were five stillbirths (foetal loss ≥20 weeks) and two neonatal deaths in the whole cohort, of whom two mothers had normal and five had high GWG. After adjusting for confounders, the rate of caesarean section in labour was significantly higher in women with high GWG compared to those with normal GWG (aOR 1.46 (1.03–2.07)) (Table 3). The rate of infants LGA by customised centiles was increased more than four-fold in those with high versus normal GWG (aOR 4.45 (2.49–7.99)) and they had a decreased risk of an SGA infant (adj OR 0.67 (0.46, 0.99)). The rate of pregnancy-induced hypertension, however, was no longer significantly increased in the high GWG group (Table 3). Those with low GWG compared with normal GWG had an

Table 3
Risk of pregnancy and delivery complications by gestational weight gain categories (*n* = 1950).

	Normal reference (*n* = 335, 17.2%)	Low GWG (*n* = 167, 8.6%)			High GWG (*n* = 1448, 74.3%)		
	n (%)	*n* (%)	Unadjusted OR	Adjusted OR	*n* (%)	Unadjusted OR	Adjusted OR
Pregnancy-induced hypertension	38 (11.3)	17 (10.2)	0.89 (0.48–1.62)	0.85 (0.44–1.62)	241 (16.6)	1.56 (1.08–2.25)	1.32 (0.89–1.95)
Preeclampsia	12 (3.6)	5 (3.0)	0.83 (0.29–2.40)	0.76 (0.25–2.29)	78 (5.4)	1.53 (0.83–2.85)	1.52 (0.78–2.97)
Gestational hypertension	26 (7.8)	12 (7.2)	0.92 (0.45–1.87)	0.98 (0.46–2.09)	163 (11.3)	1.51 (0.98–2.32)	1.23 (0.78–1.95)
Caesarean in labour	48 (14.3)	30 (18.0)	1.31 (0.80–2.16)	1.04 (0.62–1.76)	294 (20.3)	1.52 (1.09–2.12)	1.46 (1.03–2.07)
SGA infants	42 (12.5)	35 (21.0)	1.85 (1.13–3.03)	1.79 (1.06–3.00)	135 (9.3)	0.72 (0.50–1.04)	0.67 (0.46–0.99)
LGA infants	13 (3.9)	8 (4.8)	1.25 (0.51–3.07)	1.24 (0.50–3.10)	198 (13.7)	3.92 (2.21–6.97)	4.45 (2.49–7.99)

SGA: small for gestational age; LGA: large for gestational age.
Multivariate models presented as odds ratio (OR) (Confidence interval at 5%). ORs were adjusted for age group, maternal ethnicity group, mean arterial BP at 14–16 week visit, smoking (Y/N) at 14–16 weeks, gestational age at delivery, socioeconomic index (SEI), pre-pregnancy BMI, infant gender and centre.

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increased rate of infants SGA by customised birthweight centiles (aOR 1.79 (1.06–3.00)) (Table 3).

4. Comment

Disturbingly, we found that the large majority (74.3%) of healthy nulliparous participants in this study had excessive GWG. Of further concern, and consistent with previous publications [5,19], we also report that overweight and obese women were the most likely to have high GWG, with mean estimated GWGs of 13.77 $\pm$ 5.2 kg for overweight and 11.92 $\pm$ 8.1 kg for obese women compared with the recommended IOM optimum GWGs of 7–11 kg and 5–9 kg respectively [5]. These findings are important, as excessive GWG will contribute to later obesity in women who start pregnancy with a normal BMI, and will further exacerbate obesity in those who start pregnancy overweight or obese. Overall this leads to increasing morbidity for these individuals and increased health care costs for society [5], as well as potentially deterimental effects on their offspring throughout life.

Women with high GWG in our study had increased caesarean section rates in labour compared to those with normal GWG. This finding is consistent with those from previous studies in singleton pregnancies that adjusted for parity [4,10,12,14].

High GWG was associated with a fourfold increase in infants LGA by customised centiles after adjusting for confounding factors. Our data are consistent with findings from other studies which defined LGA as >90th population centile [3,4,7,8,10,13] or used an ultrasound-based weight measurement [7,12]. We believe ours is the first study of GWG to report LGA by customised centiles. The use of a customised birthweight standard to define LGA identifies a subgroup of infants, not identified by population standards, who are pathologically large for their mother's constitution and have increased perinatal morbidity [26].

The 2009 IOM guidelines suggested that "while the relationship between overweight/obese BMI and rates of hypertension is shown in literature, the relationship with high GWG requires more studies" [5]. Despite the moderately large sample size of our cohort our study was still underpowered to assess the relationship between high GWG and gestational hypertension and preeclampsia but the increased point estimates we observed are consistent with previous reports [3,15]. Adverse outcomes associated with higher GWG are potentially modifiable by strategies that achieve normal GWG without significantly increasing other adverse outcomes such as SGA births [9,10,12]. A recent meta-analysis of several small intervention trials targeting normal and/or overweight/obese women recently reported that dietary interventions reduced GWG by an average of 3.8 kg and also reduced gestational diabetes, preeclampsia and shoulder dystocia [27]. A recently published dietary intervention study by Walsh et al. [28] found that a low glycaemic index diet in pregnancy also reduced GWG in women who had previously delivered an infant greater than 4000 g. The results of two large trials in obese women are awaited to determine whether population-based strategies can be recommended [29,30].

In keeping with previous literature, after adjusting for confounding factors, we found that low GWG significantly increased the risk of SGA (aOR 1.79 (1.06–3.00)) [7,10,16,17]. Recently Margerison-Zilko et al. [4] reported that women with low GWG were more likely to have an SGA birth (aOR 1.48 (1.12–1.96)). This and other previous studies have used population birthweight centiles which do not adjust for maternal characteristics such as height and weight and may under-diagnose SGA especially in obese women [7]. Future studies should investigate the risk of SGA and LGA (using customised centiles) by GWG categories stratified by maternal BMI groups. We were underpowered to do this.

In contrast to most previous studies that categorised GWG by overall weight gained in pregnancy [4,12,13,16], we adjusted weight gain for the number of weeks between measurements to give a weekly GWG as recommended by the IOM guidelines.

One of the strengths of our study was that we used a cohort of healthy nulliparous women with height and weight measured by a research midwife to calculate the BMI at 14–16 weeks of gestation. We then applied the methodology recommended by IOM, which suggests the average weight gain in the first trimester is 1.25 kg, to calculate pre-pregnancy BMI [5]. This IOM recommendation may over-estimate first trimester weight gain as a more recent report suggests that maternal weight does not change in the first trimester regardless of BMI [32]. Overall, this small weight adjustment will have a minimal impact on the classification of pre-pregnancy BMI and GWG. Previous studies have commonly used self-reported weight and height to calculate pre-pregnancy BMI [3,7,10,12,13,18,19] although systematic biases exist with self-reported BMI; recalled weight is generally under-estimated and height over-estimated, particularly among pregnant women [31].

5. Conclusion

Approximately three-quarters of healthy nulliparous women in our study had high GWG. High GWG was associated with independent risks of caesarean in labour and LGA infants. Low GWG was associated with elevated risk of SGA infants. These adverse outcomes are potentially modifiable by achievement of normal GWG, which should be an important focus of antenatal care.

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Conflicts of interest

No conflict of interest disclosed.

Clinical trial registration

Australian New Zealand Clinical Trials Registry, www.anzctr.org.au, ACTRN12607000551493.

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