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Association of pre-pregnant body mass index and gestational weight gain with the timing of delivery and fetal growth in singletons

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Abstract

Objective. *The aim of the study was to evaluate the effect of both pre-pregnant body mass index (BMI) and weight gain during pregnancy on fetal growth.* ***Methods.*** *The Pregnancy Risk Assessment Monitoring System (PRAMS - Phase IV) data (2000-2001) was used for analysis. The primary outcome was fetal growth, defined by small for gestational age (SGA) and large for gestational age (LGA). A multinomial logistic regression model and the Wald's test were used to estimate and compare odds ratios associated with risk factors and confounders.* ***Results.*** *The sample included 58,709 women, representing a population of 2,303,387. As compared to normal weight women with adequate weight gain, the risk of an SGA newborn was significantly increased in underweight women with low weight gain, and significantly lower in normal weight, overweight and obese women with excessive weight gain. LGA risk was significantly lower in under-, normal- and overweight women with low weight gain and increased in all women with excessive weight gain as well as in obese women with normal weight gain. The risk of LGA was also increased in women aged over 35 years, for those reporting an unintended pregnancy, no prenatal care or presenting with diabetes mellitus.* ***Conclusions.*** *Variations and interactions between maternal pre-pregnant BMI and weight gain appear to be closely intertwined, highlighting the importance of studying the two factors together rather than separately.*

Keywords: *body mass index, weight gain, small for gestational age, large for gestational age, fetal growth*

Introduction

In 1990 the Institute of Medicine (IOM) published recommended ranges of maternal weight gain (WG) for singleton term deliveries, by pre-pregnant body mass index (BMI)[(1)]. Since the rate of WG in singleton pregnancies is considered linear from around 20 weeks to term, these WG ranges could be used to assess whether women delivering preterm achieve the target weight gain for any specific gestational age.

It has been shown that above or below guideline gestational WG is associated with large for gestational age (LGA) and small for gestational age (SGA), among newborns delivered at term[(2)]. However, there is little information with regard to this relationship among preterm births. Questions remain over how the risk of LGA or SGA, depending on gestational WG, is influenced by maternal pre-pregnant BMI[(3)]. Most previous studies have been restricted to one[(4)] or two[(5)] maternal BMI classes or analyze the effect of gestational weight gain following adjustments for maternal prepregnancy BMI[(6)].

The aim of our study was to evaluate the effect of both pre-pregnant BMI and WG during pregnancy, on the risk of SGA or LGA newborns.

Methods

The Pregnancy Risk Assessment Monitoring System (PRAMS - Phase IV) data for live births (2000-2001) was used for the analysis. PRAMS is a surveillance project implemented by the Centers for Disease Control and Prevention and 22 state health departments[(7-9)]. In each state, women having recently delivered a live birth were randomly sampled using stratified systematic sampling and asked to complete a self administered 14 pages questionnaire. All states provided an incentive for participation and over sampled women who were at risk of adverse pregnancy outcomes. The completed surveys were merged with the respective birth certificates. The data was weighted to adjust for survey design, non coverage, and non response, being representative for all state resident women[(7)]. Each participant was assigned a sample weight, enabling survey sample data to be extrapolated to the entire state population. Stata 9.2 (Stata Corporation, Lakeway Drive, College Station, Texas, USA) was employed for all analyses. The study was approved by the Medical University of South Carolina Institutional Review Board.

Using pre-pregnant weight and height measures, women were assigned to one of four pre-pregnant BMI classifications: underweight (UW <19.8 kg/m^2), normal weight (NW=19.8-26 kg/m^2), overweight (OW = 26.1-29 kg/m^2) and obese (OB >29 kg/m^2)[(1)]. For each pre-pregnant BMI category, the expected ideal WG range for term singletons was determined based on the Institute of Medicine (IOM) 1990 recommendations (12.70-18.14 kg for UW, 11.33-15.87 kg for NW and 6.80-11.33 kg for both OW and OB). Women who gained less than the minimum were classified

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as low weight gain (LWG), those who gained more than the maximum were classified as excessive weight gain (EWG) and all others as adequate weight gain (AWG).

Women who delivered preterm were not expected to gain as much weight as those who delivered at term, WG categories were therefore calculated for each gestational age to adjust for preterm birth. Since the IOM rate of ideal WG differs from the first half to the second half of pregnancy, the WG expected in the first 20 weeks was considered separately from that expected in the second 20 weeks. Firstly, for each BMI, the IOM average WG at 20 weeks was subtracted from the minimum and maximum WG at term (5.71 kg for UW, 4.80 kg for NW, 3.08 kg for OW and 1.72 kg for OB). These remainders were then equally apportioned across the following 20 weeks to obtain the minimum and maximum WG range expected at each gestational age from 20 weeks to term. Finally, each delivery was categorized as LWG, AWG or EWG and adjusted for gestational age and pre-pregnant BMI. For WG analyses only, deliveries over 41 weeks were omitted (the assumption that WG continued linearly beyond 41 weeks could not be confirmed). For other analyses, all gestational ages were included.

The following demographic characteristics were obtained from both the PRAMS database and birth certificates: maternal age, maternal race, type of medical insurance, prenatal care, maternal blood pressure and presence of diabetes, participation in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC Program), pregnancy intention, and mode of delivery. Data concerning birth weight and gestational age at delivery were collected from birth certificates and used to calculate fetal growth status. The variable 'prenatal care' is an indicator that combines the gestational age when prenatal care began and the number of prenatal visits during pregnancy[10]. The pregnancy was considered unintended where women answered the question 'How did you feel about becoming pregnant?' with 'I didn't want to be pregnant then or at any time in the future'. Hypertensive disorders and diabetes were identified from the question 'Did you have any of these problems during your pregnancy?': 'High blood pressure (including pre-eclampsia or toxemia), retained water (edema)' or 'High blood sugar (diabetes)'.

The primary outcome was fetal growth categorized into 3 levels: appropriate for gestational age (AGA), small for gestational age (SGA) and large for gestational age (LGA), based on the updated growth charts of Babson and Benda[11]. Women presenting with multiple pregnancies were excluded from the analysis due to the particularities of twin growth patterns.

The univariate relationship between fetal growth status and potential risk factors or confounders was studied using the Chi square test. All factors for which the univariate relationship with fetal growth was characterized by a $p < 0.2$ and included in a multivariate analysis, using the multinomial logistic regression model to allow for simultaneous comparison of SGA and LGA risks to AGA[12]. The Wald's test was then used to perform an additional comparison between specific risks for SGA and LGA, and the results were expressed as p-values. In the multivariate model, potential confounders were entered individually and excluded from the model where their associations were characterized by $p > 0.2$. Significance was defined as $p < 0.05$. Potential interactions in the model were tested and pre-pregnant BMI was found to modify the relationship between WG and both SGA and LGA status ($p < 0.001$). Subsequently, we introduced a 12-level variable combining the 4 classes of pre-pregnant BMI with the 3 classes of weight gain, the reference class being that of NW women with AWG intake.

Results

The PRAMS IV sample included 66,250 women with singleton pregnancies, corresponding to a population of 2,677,484 women. The following subject data were excluded from the analysis: 3,373 women with missing pre-pregnant BMI (5.01%) and 4,168 women (6.29%) with missing WG during pregnancy, resulting in a final sample of 58,709 women representing a population of 2,303,387. The demographic characteristics are presented in Table 1.

Survey analysis showed that among the population providing the sample, the proportion (95% CI) of women who were pre-pregnant NW, UW, OW and OB were 53% (51.8-54.2), 15.2% (14.4-15.9), 11.7% (11.2-12.2) and 20.1% (18.8-21.3). The rates of women having AWG, LWG and EWG were 32.6% (31.9-33.31), 22.7% (21-24.3) and 44.7% (43.1-46.4). The proportion of SGA and LGA newborns in the entire population was 7.5% (6.1-9) and 9% (8.2-9.9) (Figures 1 and 2).

The risk of an SGA newborn was significantly increased in UW women with LWG and was significantly lower in NW, OW and OB women who had EWG (Tables 2 and 3). LGA risk however, was significantly lower in UW, NW and OW women with LWG and increased in all women with EWG and in OB women with AWG. There was a significant association between LWG and an increased risk of SGA when compared to LGA in all women, with the exception of OB. The risk of LGA was significantly higher than that of SGA, in all women with EWG, regardless of pre-pregnant BMI. BMI appears to be closely associated with fetal growth and its effect may compensate that of inadequate WG.

Discussion

The present study shows that both pre-pregnant BMI and gestational WG are associated with fetal growth, that their effects are interlinked and hence should not be studied separately.

When compared to NW women with AWG, only UW women with LWG presented an increased risk for SGA, while NW, OW and OB women with LWG did not. When WG was adequate or excessive, LWG women no longer had a significant increase in risk of an SGA baby. Women with pre-pregnancy BMI over 19.8 kg/m^2 and EWG presented a significant lower risk of SGA babies when compared to NW women with AWG. This result demonstrates that risk of SGA is increased with LWG in pregnancy, and could be reduced by normal or high pre-pregnancy BMI; access to stored fat may therefore protect against SGA despite LWG.

The risk of an LGA newborn was significantly increased in all women with EWG regardless of pre-pregnancy BMI.

Table 1 Characteristics of 2,303,387 women represented by the survey sample

	Entire population (%)	UW women (%)	NW women (%)	OW women (%)	OB women (%)
Weight gain					
LWG	22.7	29.7	23.1	12.5	22.2
AWG	32.6	42.3	34.1	24.3	26.4
EWG	44.7	28.1	42.8	63.3	51.5
Age (years)					
<18	4	7.6	4.1	3	1.7
18-35	83.3	84.5	82.8	83.1	83.6
>35	12.7	7.8	13.1	13.9	14.7
Race					
White	77.6	79.7	78.9	76	73.6
Black	17.5	13.5	16.2	19.8	22.7
Asian	3	5.4	3.2	2	1.2
Indian	1.1	0.7	0.9	1.2	1.7
Other	0.8	0.7	0.8	1	0.8
Smoking					
No	89.1	85.7	90	89.6	89
Yes	10.9	14.3	10	10.4	11
Insurance					
Private	65.3	60.2	68.5	66.3	59.9
Medicaid	34.7	39.8	31.5	33.7	40.1
Pregnancy intention					
Yes	89.6	90.6	90.9	89.7	85.3
No	10.4	9.4	9.1	10.3	14.7
WIC Program					
No	59	56.5	62.6	59.7	51.1
Yes	41	43.5	37.4	40.3	48.9
Prenatal care					
Adequate	75.5	72.6	76	76.4	75.7
Intermediate	19	20.7	18.8	18.6	18.5
Inadequate	5	6.1	4.7	4.5	5.2
None	0.6	0.6	0.5	0.5	0.6
HBP					
No	80.5	87.5	83.7	75.3	69.8
Yes	19.5	12.5	16.3	24.7	30.2
Diabetes					
No	92	95.6	93.7	91.4	85.2
Yes	8	4.4	6.3	8.6	14.8
Preterm birth					
No	84.2	81.9	85.1	84.4	83.4
Moderate	14.4	16.4	13.7	13.9	14.8
Very preterm	1.5	1.7	1.2	1.7	1.8
Delivery					
Vaginal	68.7	75.9	69.9	67.7	60.4
Forceps	2.1	2.8	2.3	1.7	1.3
Vacuum	4.5	5	4.9	3.9	3.4
VBAC	2.2	1.4	2.1	2.6	2.7
CS	13.8	10.1	12.9	15.3	17.9
Repetitive CS	8.8	4.7	7.8	8.8	14.3
Fetal growth					
Normal	83.4	84.8	84.7	83.9	78.7
SGA	7.5	10.3	7	5.9	7.7
LGA	9	5.9	8.3	10.2	13.6

Abbreviations: *UW - underweight, NW - normal weight, OW - overweight, OB - obese women; LWG - low weight gain, AWG - adequate weight gain, EWG - excessive weight gain during pregnancy; WIC Program - women's participation in the Special Supplemental Nutrition Program for Women, Infants, and Children; HBP - high blood pressure; SGA - small for gestational age, LGA - large for gestational age newborn*

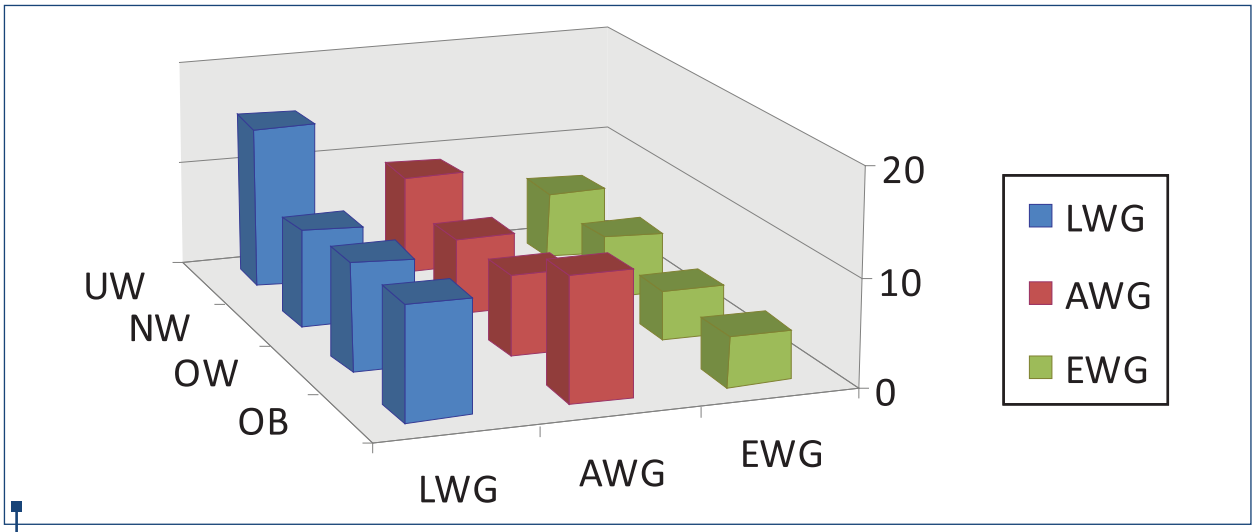

Figure 1. Proportion of small for gestational age neonates, based on maternal weight gain category and pre-pregnancy body mass index (UW - underweight, NW - normal weight, OW - overweight, OB - obese women; LWG - low weight gain, AWG - adequate weight gain, EWG - excessive weight gain during pregnancy)

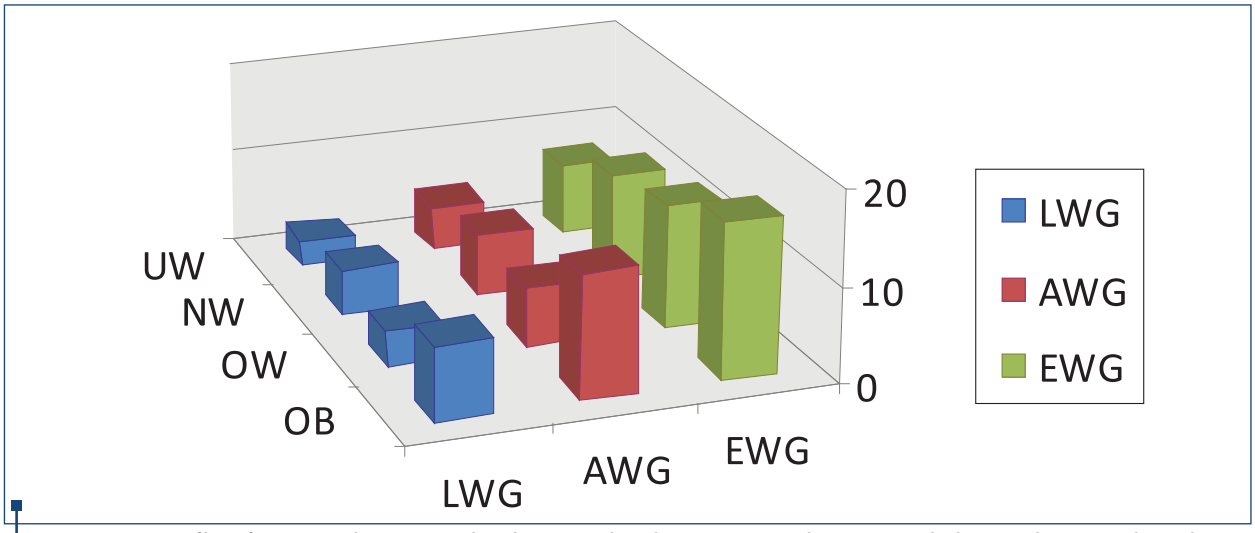

Figure 2. Proportion of large for gestational age neonates, based on maternal weight gain category and pre-pregnancy body mass index (UW - underweight, NW - normal weight, OW - overweight, OB - obese women; LWG - low weight gain, AWG - adequate weight gain, EWG - excessive weight gain during pregnancy)

Low BMI did not compensate for the effect of EWG, as UW women with EWG had a significantly higher risk of LGA compared to NW women with AWG. It should be noted that the relationship between BMI, WG, and LGA status was independent of the occurrence of diabetes mellitus.

Extensive research has been carried out into the influence of WG during pregnancy on fetal growth and it is known that LWG is associated with an increased risk of SGA infants, while EWG is a risk factor for LGA and macrosomia[2,3]. However, in most of the studies WG is not stratified by gestational age which may lead to an overestimation of the number of women with LWG delivered before 37-38 weeks[2].

The advantage of such a large survey study is represented by the higher number of women available for the analysis[3]. This large sample was able to be divided into groups and subgroups allowing sufficient numbers in each stratum without compromising the statistical power of the analysis. Some studies evaluated maternal BMI in relation to obstetric outcome for the whole sample, and consider gestational WG as a confounder and to include it in the multivariate analysis[6,13]. Our study however, demonstrates that the use of 12 stratums was rigorously required due to statistically significant interactions between pre-pregnant BMI and WG. These interactions render inadequate the classical logistic regression, using BMI and WG as independent variables. Furthermore, it is clear that the large sample number allowed statistical interactions to reach significance, which would probably not have been possible in a cohort study with a sample group of a few hundred women.

One of the strengths of this study was the use of WG categories based on gestational age, as described above,

enabling women having delivered before 37 week-gestation to be included in the analysis, in addition to term pregnancies.

Instead of the classical binary logistic regression model, our statistical analysis employed the multinomial logistic regression model allowing the investigation of the relationship between an outcome variable with more than two categories and a set of covariates[12], and further a comparison of odds ratios corresponding to the same risk factor, using the Wald's test. Therefore, an assessment was possible as to whether or not the risk for SGA was higher than that for LGA, where women presented with a specific risk factor (Tables 2 and 3).

Our observations are comparable to the study of Cedergren, who analyzed the effects of weight gain in different maternal BMI classes on various obstetric outcomes, using a large population based-cohort[14]. In this study the author applied two thresholds values to define weight gain classes (8 and 16 kg) for all women having delivered from 37 to 42 week-gestation. In women having delivered at term, it was reported that regardless of pre-pregnancy BMI, gestational WG of less than 8 kg significantly increased and decreased the risk for SGA and LGA. Gestational WG of more than 16 kg significantly increased the risk of LGA in all women, and decreased the risk of SGA in women with BMI inferior to 35 kg/m^2. Certain differences between the results of the two studies may be explained by the differing definitions of WG classes.

Low WG appeared to lessen the risk of LGA in obese women. Bianco and contributors reported a similar relationship stating that morbidly obese women with WG inferior to 25 lb were no more likely to deliver an LGA baby than non obese women[5]. In addition, poor WG did not appear to increase the risk of delivery of a low birth weight neonate, leading to the conclusion that maternal obesity may protect against the effects of LWG[5].

Maternal LWG may be associated with certain unfavorable conditions, such as smoking, drugs, alcohol, and low socioeconomic status[2,15], that increase the risk of SGA. These associations make it difficult to estimate the real and independent effect of LWG on obstetrical or neonatal outcomes, even following multivariate adjustments. Okah and colleagues reported that the risk of low birth weight was increased two fold in women who smoked during pregnancy, when other health-compromising behaviors were taken into account[15]; whereas Medicaid insurance status only tended towards a significant association[15]. In our study, smoking during pregnancy significantly increased and decreased the risk of SGA and LGA, independent of maternal BMI and WG.

Conclusions

This large sample study adds value to our understanding of the relationship between pre-pregnant BMI and WG during pregnancy and fetal growth. Our results stress the utility of IOM guidelines and the importance of achieving established WG recommendations during pregnancy for each woman, to ensure the health of mother and newborn. In order to verify the validity of our results, the relationship between pre-pregnancy weight, accurate maternal weight gain, and risk of inadequate fetal growth should be prospectively evaluated in any future study. ■

Table 2 Relationship between pre-pregnant body mass index, gestational weight gain and the likelihood of small and large for gestational age neonates (multinomial logistic regression model, N=2,303,387 women; adjustment made for maternal age, maternal race, pregnancy intention, medical insurance, prenatal care, smoking during pregnancy, high blood pressure disorders during pregnancy and diabetes mellitus)

	SGA	LGA	Wald's test
	ORa (95%CI)	ORa (95%CI)	P
NW and AWG	1	1	
NW and LWG	1.1 (0.71-1.7)	0.74 (0.57-0.95)	0.02
NW and EWG	0.77 (0.66-0.90)	1.8 (1.6-2.1)	<0.001
UW and AWG	1.2 (0.88-1.7)	0.78 (0.47-1.3)	0.19
UW and LWG	2 (1.4-2.8)	0.46 (0.32-0.65)	<0.001
UW and EWG	0.78 (0.52-1.2)	1.4 (1.1-1.7)	0.04
OW and AWG	1 (0.62-1.7)	0.93 (0.64-1.4)	0.87
OW and LWG	1.2 (0.60-2.4)	0.49 (0.31-0.79)	0.006
OW and EWG	0.56 (0.42-0.75)	2 (1.7-2.4)	<0.001
OB and AWG	1.5 (0.80-2.7)	2.1 (1.4-3.3)	<0.001
OB and LWG	1.3 (0.85-1.9)	1.2 (0.80-1.7)	0.32
OB and EWG	0.56 (0.38-0.82)	2.5 (2.2-2.9)	<0.001

Abbreviations: *SGA - small for gestational age, LGA - large for gestational age newborn; UW - underweight, NW - normal weight, OW - overweight, OB - obese women; LWG - low weight gain, AWG - adequate weight gain, EWG - excessive weight gain during pregnancy.*

Table 3 Factors associated with the likelihood of small and large for gestational age neonates (multinomial logistic regression model, N=2,303,387 women; adjustment made for the 12 categories of pre-pregnant body mass index and gestational weight gain)

	SGA	LGA	Wald's test
	ORa (95%CI)	ORa (95%CI)	P
Age (years)			
<18	1.1 (0.81-1.4)	0.31 (0.19-0.51)	<0.001
18-35	1	1	
>35	1.3 (0.78-2.2)	1.2 (1-1.3)	0.03
Race			
White	1	1	
Black	1.6 (1.2-2.2)	0.48 (0.37-0.63)	<0.001
Asian	1.7 (1.1-2.5)	0.58 (0.40-0.86)	0.01
Indian	0.76 (0.47-1.2)	1.3 (0.93-1.9)	0.23
Other	0.76 (0.44-1.3)	1.2 (0.60-2.2)	0.58
Smoking during pregnancy			
No	1	1	
Yes	2 (1.6-2.6)	0.43 (0.35-0.51)	<0.001
Pregnancy intention			
Yes	1	1	
No	1.1 (0.96-1.2)	1.5 (1.1-2)	0.05
Insurance			
Private	1	1	
Medicaid	1.5 (1.1-2.2)	0.80 (0.71-0.90)	<0.004
Prenatal care			
Adequate	1	1	
Intermediate	1.1 (0.96-1.2)	0.91 (0.79-1)	0.24
Inadequate	0.80 (0.59-1.1)	0.90 (0.74-1.1)	0.27
None	0.94 (0.60-1.5)	2.1 (1.2-3.6)	0.04
HBP			
No	1	1	
Yes	1.7 (1.4-2.1)	1.1 (0.95-1.4)	<0.001
Diabetes mellitus			
No	1	1	
Yes	1 (0.78-1.3)	1.9 (1.5-2.4)	<0.001

Abbreviations: *SGA - small for gestational age, LGA - large for gestational age newborn; HBP - high blood pressure disorders during pregnancy*

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