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Excessive weight gain in women with a normal pre-pregnancy BMI is associated with increased neonatal adiposity

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Summary

Background—More than 40% of women with a normal pre-pregnancy body mass index (BMI) exceed the 2009 Institute of Medicine (IOM) guidelines' recommended weight gain of 25–35 lb. Excessive gestational weight gain is one modifiable factor that may be contributing to childhood overweight and obesity.

Objective—The objective of this study was to evaluate differences in adiposity from neonates born to mothers with a normal pre-pregnancy BMI who either gained within or above IOM guidelines.

Methods—Neonatal adiposity was measured within 72 h of birth by the method of air displacement plethysmography.

Results—Compared with mothers who gained within IOM guidelines (N = 27), mothers with excessive gestational weight gain (N = 11) (mean 29.0 vs. 45.2 lb) had neonates with 50% more fat mass (348 vs. 525 g) and 3% greater body fat (10.7 vs. 13.9%).

Conclusions—Increased adiposity at birth may predispose these children to increased risk of obesity and highlight the importance that women avoid gaining excessive weight in pregnancy.

Keywords

Gestational weight gain; neonatal adiposity; newborn body composition

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Conflicts of Interest Statement

The authors have no conflicts of interest to disclose.

The Institute of Medicine (IOM) published revised guidelines for weight gain in pregnancy three years ago (1) in an effort to address post-partum weight retention and increased risk of offspring obesity. As more than 40% of women with a normal pre-pregnancy body mass index (BMI) exceed the IOM recommended amount of weight gain of 25–35 lb (2), excessive gestational weight gain (GWG) is one modifiable factor that may be contributing to childhood overweight and obesity (3,4). Several studies have demonstrated that offspring of women whose weight gain exceeded the IOM guidelines (1990 guidelines) are more likely to become overweight (5–7).

Most studies associating excessive GWG to childhood obesity have used childhood BMI as a correlate for obesity. However, BMI measurements include both fat and lean tissue mass (8) and a high proportion of either one leads to increased readings. Therefore, using BMI as a proxy for adiposity in children has major limitations (9). A few studies have reported associations of excessive GWG with increased offspring adiposity, both at birth and in early childhood (7,10,11). These studies either failed to adjust for maternal diabetes status during pregnancy (10), a known risk factor for offspring obesity (12), or used methodologies with high measurement variation, such as skinfold thickness, to measure fat mass (7). None of the aforementioned studies reported maternal glucose levels.

Preliminary data have been gathered through a pilot study on the impact of GWG on neonatal adiposity, using a new, validated method of air displacement plethysmography to measure newborn body fat (Pea Pod Infant Body Composition System, Cosmed, Rome, Italy) (13). The objective of this analysis was to evaluate differences in neonatal body fat and cord blood biomarkers in offspring of mothers with a normal pre-pregnancy BMI who either gained within or above IOM guidelines.

Pregnant women with a normal pre-pregnancy BMI ($18\text{--}25\text{ kg m}^{-2}$) and a normal diabetes screening test result (14), planning to deliver at Northwestern Memorial Hospital were recruited. Participants in this study had singleton, term pregnancies (>37 weeks), and were not hypertensive. Participants presented to the clinical research unit at 36–38 weeks gestation for a fasting blood draw and measurement of height and weight. Measured height and self-reported pre-pregnancy weight, confirmed by chart review in most cases, was used to calculate pre-pregnancy BMI. GWG was calculated by subtracting the self-reported pre-pregnancy weight from the weight at the last prenatal visit before delivery. All subjects provided written informed consent and the study was approved by the Northwestern University Institutional Review Board.

Umbilical cord blood was collected at delivery and stored, along with maternal blood, at -70°C until assayed simultaneously. Plasma glucose was measured with Synchron CX Delta Systems instrumentation (Beckman Coulter, Inc., Brea, CA, USA) employing an oxygen rate method using a glucose oxygen electrode and had an inter-assay coefficient of variation of 2.0–2.3%. Concentrations of C-peptide, leptin and adiponectin were assayed using radioimmunoassay kits from Millipore Corporation (Billerica, MA, USA). The intra- and inter-assay coefficients of variation ranged from 2.1 to 4.4% and 2.9 to 5.9%, respectively. All biochemical assays were performed in duplicate.

Neonatal anthropometric measurements were obtained within 72 h following birth. Infant length was obtained using a hard-surface measuring board. Abdominal circumference was measured at the level of the umbilicus. Measurements were recorded to the nearest 0.1 cm, performed in duplicate, and the results averaged. Infant weight and volume were measured by air displacement plethysmography with the Pea Pod Infant Body Composition System (Cosmed), which has been previously described (15). Briefly, the machine was calibrated according to manufacturer's guidelines, the infant placed naked on the scale, weighed to the nearest 0.0001 kg and, lastly, placed inside the Pea Pod chamber for the 2-min volume measurement. Using pressure–volume equations, body composition, including fat mass and fat-free mass, was calculated to provide % body fat.

For statistical analyses, Fisher's exact tests were used to compare categorical characteristics, and independent sample *t*-tests were used to compare means. A *P*-value < 0.05 was considered statistically significant. All statistical analyses were conducted using SAS 9.2 software (SAS Institute Inc., Cary, NC, USA).

There were 38 participants, 27 who gained within guidelines and 11 with excessive GWG. Maternal demographic characteristics and metabolic measurements are shown in Table 1. Women with excessive GWG had a similar pre-pregnancy BMI, age, glucose results on diabetes screening test and fasting glucose, compared with women who gained within guidelines. Women with excessive GWG had significantly higher-fasting C-peptide and leptin levels, and lower adiponectin levels, compared with women who gained within guidelines.

Cord blood was obtained from 35 of the 38 participants. The neonatal anthropometric characteristics and cord blood hormone levels of the neonates are shown in Table 2. At 1–3 d of life, neonates born to women with excessive GWG had a higher mean weight, length, fat mass and percent body fat compared with neonates born to women who gained within guidelines. Cord blood levels of leptin were significantly higher in the neonates born to women who gained excessively.

The women in this study had a similar pre-pregnancy BMI of 22 kg m⁻² in the normal weight category. However, the women who gained in excess of IOM recommendations had a metabolic profile of an obese woman by the end of pregnancy, as evidenced by higher serum C-peptide and leptin levels, slightly higher fasting glucose levels, and lower adiponectin levels (16,17). Neonates born to women who gained excessively were not, on average, considered large for gestational age, defined by a birth weight greater than 4 kg. However, these neonates were significantly larger in weight and length, and had a 50% increase in fat mass, leading to a 3% fat unit increase in total body fat. These preliminary results highlight the importance of women avoiding gaining excessive weight in pregnancy.

The timing of excessive weight gain in participants of this study is not known, although that information would further our understanding of neonatal adipose tissue development. In this study, self-reported pre-pregnancy weight was used to calculate GWG, rather than documented weight at the first prenatal visit, in order to capture weight gained prior to the

first prenatal visit. Previous studies report American women with a normal BMI to be very accurate in their reporting of pre-pregnancy weight (18).

In conclusion, GWG above the IOM guidelines for weight gain in pregnancy in women with a normal pre-pregnancy BMI was associated with increased newborn body fat content. These neonates had, on average, 175 g more fat mass, and a 3% increase in total body fat. This higher amount of body fat at birth may predispose these children to increased risk of obesity later in life.

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Table 1

Maternal characteristics and metabolic measurements

	Weight gain within guidelines (<i>N</i> = 27)	Excessive weight gain (<i>N</i> = 11)	<i>P</i> -value
Gestational weight gain (lb)	29.0 ± 3.2	45.2 ± 9.9	0.0003
Pre-pregnancy body mass index (kg m ⁻²)	21.7 ± 1.7	22.6 ± 1.8	NS
Age	33.2 ± 4.8	31.7 ± 8.1	NS
Race (% white)	74%	64%	NS
Delivery type (% C/S)	26%	27%	NS
Maternal blood sample at 24–28 weeks			
Glucose (mg dL ⁻¹) post-1 h 50 g glucose challenge test	97.9 ± 14.7	99.6 ± 13.9	NS
Maternal fasting blood sample at 36–38 weeks			
Glucose (mg dL ⁻¹)	79.6 ± 5.5	83.5 ± 7.7	NS
C-peptide (ng mL ⁻¹)	2.0 ± 1.7	3.1 ± 2.3	0.01
Leptin (ng mL ⁻¹)	20.5 ± 16.2	33.9 ± 13.6	0.01
Adiponectin (μg mL ⁻¹)	11.9 ± 4.2	8.7 ± 4.0	0.04

Data are displayed as mean ± standard deviation or percent.

NS, not significant.

Table 2

Neonatal characteristics

	Weight gain within guidelines (<i>N</i> = 27)	Excessive weight gain (<i>N</i> = 11)	<i>P</i> -value
Gestational age	39.8 ± 1.0	40.0 ± 1.2	NS
Gender (% female)	64%	67%	NS
Birth weight (g)	3389 ± 387	3832 ± 552	0.029
Pea pod weight (g)	3250 ± 370	3700 ± 560	0.028
Length (cm)	50.1 ± 1.6	51.7 ± 2.4	0.026
Fat mass (g)	348 ± 103	525 ± 178	0.009
Fat-free mass (g)	2898 ± 327	3174 ± 415	NS
Body fat %	10.7 ± 2.8	13.9 ± 3.3	0.012
Abdominal circumference (cm)	29.9 ± 2.3	31.2 ± 2.3	NS
Neonatal cord blood	<i>N</i> = 25	<i>N</i> = 10	
Glucose (mg dL ⁻¹)	78.0 ± 17.8	87.3 ± 28.4	NS
C-peptide (ng mL ⁻¹)	0.83 ± 0.32	1.0 ± 0.33	NS
Leptin (ng mL ⁻¹)	8.2 ± 4.9	13.4 ± 6.8	0.046
Adiponectin (μg mL ⁻¹)	35.5 ± 5.0	38.1 ± 9.1	NS

Data are displayed as mean ± standard deviation or percent.

NS, not significant.