

Interaction between Maternal Prepregnancy Body Mass Index and Gestational Weight Gain Shapes Infant Growth

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ABSTRACT

OBJECTIVE: To quantify the combined effect of maternal prepregnancy obesity and maternal gestational weight gain (GWG) on the shape of infant growth throughout the first year of life.

METHODS: A retrospective cohort of mother–child dyads with children born between January 2007 and May 2012 was identified in a linked electronic medical record. Data were abstracted to define the primary exposures of maternal prepregnancy body mass index (BMI) and GWG, and the primary outcome of infant growth trajectory.

RESULTS: We included 499 mother–child dyads. The average maternal age was 28.2 years; 55% of mothers were overweight or obese before pregnancy, and 42% of mothers had excess GWG, as defined by the Institute of Medicine. Maternal prepregnancy BMI ($P < .001$) and the interaction between prepregnancy BMI and maternal GWG ($P = .02$) showed significant association with infant growth trajectory through the first year of life after controlling for breast-feeding and other covariates,

while GWG alone did not reach statistical significance ($P = .38$). Among infants of mothers with excess GWG, a prepregnancy BMI of 40 kg/m² versus 25 kg/m² resulted in a 13.6% (95% confidence interval 5.8, 21.5; $P < .001$) increase in 3-month infant weight/length percentile that persisted at 12 months (8.4%, 95% confidence interval 0.2, 16.5; $P = .04$).

CONCLUSIONS: The combined effect of excess maternal GWG and prepregnancy obesity resulted in higher infant birth weight, rapid weight gain in the first 3 months of life, with a sustained weight elevation throughout the first year of life. These findings highlight the importance of the preconception and prenatal periods for pediatric obesity prevention.

KEYWORDS: infants; mothers; obesity; pediatric; pregnancy; weight gain

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WHAT'S NEW

The combined effect of maternal obesity before pregnancy and excess maternal gestational weight gain results in rapid infant weight gain and sustained dysregulation of infant growth through the first year of life, suggesting new approaches to pediatric obesity prevention.

DESPITE A RECENT leveling of childhood obesity rates, the absolute prevalence of childhood overweight and obesity remains at 31.8%.¹ The lasting public health implications of this epidemic stem from the repeatedly demonstrated predisposition for obese children to become obese adults with increased risks of associated morbidity, such as the metabolic syndrome, type 2 diabetes, and coronary heart disease.^{2–7}

Recent work has provided evidence that infancy is a critical period of child development where rapid weight gain and altered adiposity can shift a child's growth trajectory toward a more obese phenotype in childhood and into adulthood.^{4,8} Previous work has shown that rapid

weight gain in the first 3 to 6 months of life has been associated with both a predicted prevalence of childhood obesity of 40% at age 3⁸ and the development of obesity and its metabolic consequences in early adulthood.^{4,6} Furthermore, children who are born small for gestational age and have rapid growth in the first several years of life have increased risk of coronary artery disease as adults.⁷ However, little has been done to characterize the determinants or predictive value of the shape of the infant growth trajectory throughout the first year of life.

In 2009, the Institute of Medicine (IOM) highlighted both prepregnancy body mass index (BMI) and excess gestational weight gain (GWG) as significant contributors to infant development.^{9–11} Noting the well-established association between maternal prepregnancy BMI with both elevated birth weight and later obesity, the IOM particularly focused on the link between excess GWG and excess infant adiposity as a modifiable risk factor to improve both pediatric and maternal health outcomes.^{9,12–16} These studies focused on evaluating maternal prepregnancy BMI or excess GWG as independent correlates to the later development of childhood obesity. Recently, the

interaction between prepregnancy BMI and maternal GWG has been shown to influence rapid infant weight gain, but the combined effect on the shape of infant growth has not been described.¹⁷

Our objective was to measure the interaction of maternal prepregnancy BMI and maternal GWG on infant growth trajectory in the first year of life. We hypothesized that infants of mothers who were obese before pregnancy and had excessive GWG, as defined by the IOM guidelines, would have a more rapid pattern of growth in the first 3 to 6 months of life that would persist throughout infancy compared to infants of mothers who were either obese before pregnancy or had excessive GWG alone. Elucidating the shape of the infant growth curve throughout the first year is an important next step in characterizing the phenotype for infants who are at risk for developing later obesity.

By understanding how the combined effect of maternal prepregnancy BMI and excess GWG during pregnancy influences growth during a child's first year of life, we can support meaningful preventive recommendations to parents and health care providers to help turn the tide of this pervasive childhood obesity epidemic.

METHODS

STUDY DESIGN AND DATA SOURCES

We assembled a retrospective cohort of mother–child dyads, who were identified in the electronic medical record (EMR). Index children were born between January 2007 and May 2012 and were patients at the pediatric primary care clinics at a large urban academic medical center in Nashville, Tennessee. Patients served by these practices come from a broad range of socioeconomic strata and include a large cross section of diverse cultural backgrounds. A preexisting link between the index child's medical record and the mother's medical record was used to identify mother–child dyads. All dyads received medical care at the primary care clinics throughout pregnancy and the first year of the child's life. These clinics consisted of faculty-only practices and resident continuity clinics. This study was conducted at a single institution and was approved by the Vanderbilt University Medical Center institutional review board.

POPULATION

Once mother–child dyads had been identified electronically, a strict set of inclusion and exclusion criteria were used to avoid the potential for confounding. Children were eligible if they: 1) were at least 1 year old as of June 1, 2013; 2) had measures of height and weight taken concurrently on at least 3 occasions in the first year of life; 3) had at least 1 concurrent measurement of child height and weight before 6 months of life; and 4) had 1 measurement after 6 months of life and at ≤ 15 months of life. Mothers were eligible if they: 1) were at least 18 years old at the time of the index child's birth; 2) had height recorded in the EMR within 365 days of the estimated date of conception (defined as delivery date minus estimated

gestational age); and 3) had maternal weight recorded in the EMR up to 365 days before the estimated date of conception. To preserve independence of observations, only a mother's first eligible pregnancy was included in the cohort, although it may not have been her first pregnancy. Exclusion criteria included: 1) multiple gestation; 2) children with medical conditions known to affect infant growth as defined by ICD-9 search in the EMR (eg, trisomy 21, hypothyroidism, cancer); 3) children with a diagnosis of failure to thrive in the first year of life; 4) children who required a percutaneous gastrostomy tube in the first year of life, as defined by CPT code in the EMR; 5) maternal insulin use during pregnancy; and 6) enrollment in another ongoing clinical trial. Children born between May 1, 2007, and May 31, 2012, were included, with potential data collected up to 1 year before and 15 months after.

CHART ABSTRACTION AND DATA COLLECTION

Data were abstracted from the EMR using a combination of information electronic data abstraction and manual chart reviews. A trained team of research nurses conducted the manual chart review data collection. Research nurses were trained by the principal investigator, who reviewed the first 10 charts and then a random sampling of 10% of the charts thereafter for accuracy.

EMR data that were abstracted electronically were obtained using a computer algorithm, and the principal investigator verified accuracy by manually reviewing 10% of medical records. Once length and weight measurements were obtained, a blinded reviewer visually inspected all growth curves to remove points such as a loss of height or other implausible measurements. In 3 such instances, data were changed to missing. Subsequently, the difference in both raw length and weight was calculated for each child between each measured time point. The highest and lowest 10% of measurements were verified from the EMR. Study data were managed using the secure Research Electronic Data Capture (REDCap) tools hosted at Vanderbilt University.¹⁸

PREPREGNANCY BMI AND MATERNAL GWG

We evaluated maternal prepregnancy BMI and maternal GWG obtained from EMR measurements obtained as a part of routine clinical care visits. Prepregnancy BMI was calculated from weight and height measurements recorded within 1 year of the estimated date of conception. GWG was calculated by subtracting the prepregnancy weight from the last recorded weight before delivery. Excess GWG was defined on the basis of the 2009 IOM recommendations (Table 1) and represented a range of weight gain for each of 4 categories of maternal prepregnancy BMI (underweight, normal weight, overweight, obese).⁹ Although maternal prepregnancy BMI was included in the statistical models as a continuous variable, in some places, it is reported categorically for ease of interpretation. These categorizations are based on US Centers for Disease Control and Prevention recommendations: 1) underweight, BMI < 18.5 kg/m²; 2) normal weight, BMI

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