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Predictors of Infant Body Composition at 5 Months of Age: The Healthy Start Study

Katherine A. Sauder, PhD[1], Jill L. Kaar, PhD[1], Anne P. Starling, PhD[2], Brandy M. Ringham, PhD[3], Deborah H. Glueck, PhD[3], and Dana Dabelea, MD, PhD[1,2]

Objective To examine associations of demographic, perinatal, and infant feeding characteristics with offspring body composition at approximately 5 months of age.

Study design We collected data on 640 mother/offspring pairs from early pregnancy through approximately 5 months of age. We assessed offspring body composition with air displacement plethysmography at birth and approximately 5 months of age. Linear regression analyses examined associations between predictors and fat-free mass, fat mass, and percent fat mass (adiposity) at approximately 5 months. Secondary models further adjusted for body composition at birth and rapid infant growth.

Results Greater prepregnant body mass index and gestational weight gain were associated with greater fat-free mass at approximately 5 months of age, but not after adjustment for fat-free mass at birth. Greater gestational weight gain was also associated with greater fat mass at approximately 5 months of age, independent of fat mass at birth and rapid infant growth, although this did not translate into increased adiposity. Greater percent time of exclusive breastfeeding was associated with lower fat-free mass (-311 g; $P < .001$), greater fat mass (+224 g; $P < .001$), and greater adiposity (+3.51%; $P < .001$). Compared with offspring of non-Hispanic white mothers, offspring of Hispanic mothers had greater adiposity (+2.72%; $P < .001$) and offspring of non-Hispanic black mothers had lower adiposity (-1.93%; $P < .001$). Greater adiposity at birth predicted greater adiposity at approximately 5 months of age, independent of infant feeding and rapid infant growth.

Conclusions There are clear differences in infant body composition by demographic, perinatal, and infant feeding characteristics, although our data also show that increased adiposity at birth persists through approximately 5 months of age. Our findings warrant further research into implications of differences in infant body composition. *(J Pediatr 2017;183:94-9).*

The developmental origins of obesity theory posits that early life exposures, including intrauterine exposures, influence obesity risk across the lifespan.[1] There is compelling evidence that intrauterine exposure to maternal obesity is associated with increased obesity in offspring across the lifespan.[2] We and others have previously reported that greater maternal prepregnant body mass index (BMI) and gestational weight gain are each associated with greater offspring body size and adiposity at birth.[3-5] However, the degree to which these associations persist into the postnatal period is not well-understood.

There is evidence that intrauterine exposure to maternal obesity is associated with greater offspring fat mass and/or adiposity in the first few months of life.[6,7] Other studies report no associations,[8-10] or evidence of slowed "catch-down" growth, in fat mass and/or adiposity during infancy among offspring exposed to maternal obesity.[11,12] Some of the discrepancy between studies may be explained by differences in methodology, including the age at which infant body composition is measured. Other important considerations that vary across studies include adjustment for size at birth or speed of growth, as well as evaluation of the effect of infant feeding (breastmilk, formula, complementary foods). Infant feeding is particularly important to examine, because it has been shown to modify the effect of adverse intrauterine exposures on offspring obesity risk.[13]

The main purpose of this analysis was to evaluate whether maternal prepregnant BMI, gestational weight gain, and breastfeeding exclusivity are associated independently with offspring body size and composition at 5 months of age. In addition, we sought to determine whether these effects are independent of body composition at birth and early infant growth status. We also explored interactions between prepregnancy BMI, gestational weight gain, and breastfeeding to understand whether infant feeding modified the effect of intrauterine exposure to maternal obesity on offspring body composition.

BMI	Body mass index
WAZ	Weight-for-age *z*-score

From the [1]Department of Pediatrics, University of Colorado School of Medicine, Aurora, CO; [2]Department of Epidemiology; and [3]Department of Biostatistics and Informatics, Colorado School of Public Health, Aurora, CO

Supported by the National Institutes of Health (R01DK076648, UL1TR001082, T32DK07658, R01GM121081, K99ES025817). The authors declare no conflicts of interest.

http://dx.doi.org10.1016/j.jpeds.2017.01.014

Methods

The Healthy Start study is an ongoing prebirth cohort in Denver, Colorado. From 2009 to 2014, we recruited women in early pregnancy from obstetric clinics at the University of Colorado Anschutz Medical Campus. Women were eligible if they were >16 years of age, <24 weeks pregnant with a single fetus, had no chronic medical conditions (type 2 diabetes, cancer, etc), and no history of obstetric complications (prior stillbirth or birth at <25 weeks). Participants completed research visits in early pregnancy (median 17 weeks), midpregnancy (median 27 weeks), and at delivery (median 1 day after birth). The original protocol included a postnatal phone interview (median 5.2 months), which was converted to an in-person visit in January 2011. The study was approved by the Colorado Multiple Institutional Review Board and all women provided written informed consent.

We enrolled 1410 women in Healthy Start, of which 1102 were eligible for the in-person infant visit when it was added to the protocol (**Figure**; available at www.jpeds.com). Participants were eligible for the current analysis if infants were full term (gestational age > 37 weeks), had body composition measurements at birth and approximately 5 months of age, and complete data on all covariates.

Exposure Assessments

Women self-reported demographic information at enrollment, including date of birth, race/ethnicity, education, annual household income, and gravidity. At the pregnancy and delivery visits, women self-reported smoking, alcohol consumption, and vitamin use. After delivery, we obtained data on prepregnancy BMI, gestational weight gain, diagnosis of gestational diabetes, date of delivery, mode of delivery, offspring sex, birth weight, birth length, and gestational age at birth from clinical records. At the approximately 5-month visit, women reported breastfeeding status, use of formula (including infant age at introduction and relative proportion of formula to breastmilk), and introduction of solid foods (ie, age at which the infant began consuming foods other than breastmilk, formula, or water on a daily basis). We quantified breastfeeding with breastmilk months, a metric that reflects both duration and exclusivity of breastfeeding. For example, 6 months of exclusive breastfeeding equates to 6 breastmilk months, whereas 4 months of exclusive breastfeeding followed by 2 months of 50% breastmilk and 50% formula equates to 5 breastmilk months. To account for differences in age at the infant visit, we divided breastmilk months by offspring age to obtain the percent time each infant was breastfed exclusively. These data can be interpreted on a continuous scale, such that 0% indicates exclusively formula fed, 50% indicates one-half breastfed, one-half formula fed, and 100% indicates exclusively breastfed from birth to the approximately 5-month visit.

Outcome Assessments

Offspring body composition was measured at the in-person delivery and infant visits via air displacement plethysmography (PEA POD, COSMED, Rome, Italy), which has excellent validity and reliability in infants.[14,15] The PEA POD device measures total body volume by detecting differences in air pressure between a test chamber in which the infant is placed and a control chamber with known air pressure.[16] Body mass and volume measurements are used to calculate body density, and fat and fat-free mass density coefficients[17] are used to obtain estimates of fat-free mass (g), fat mass (g), and adiposity (percent fat mass). Trained research personnel measured each offspring outcome twice, with a third measurement obtained when percent fat mass differed by >2.0%. The average of the 2 closest readings was used for analysis. We quantified early infant growth by calculating birth and approximately 5-month sex-specific weight-for-age *z*-scores (WAZ) using the 2006 World Health Organization growth charts. Rapid growth was defined as a change of >0.67 in WAZ from birth to the approximately 5-month visit, which corresponds with upward crossing of a percentile band on standardized growth charts and indicates a clinically significant increase in weight.[18]

Data Analyses

Analyses were conducted in SAS 9.4 (SAS Institute, Cary, North Carolina). We fit separate multivariable linear regression models for the outcomes of fat-free mass, fat mass, and adiposity. The primary predictors of interest were maternal prepregnant BMI, gestational weight gain, and percent time of exclusive breastfeeding. We used a backward stepwise model-fitting approach, wherein nonsignificant covariates were removed, starting with the highest *P* value. As covariates, we considered the continuous variables of maternal age, gravidity, weeks of daily prenatal vitamin use, gestational age at birth, and offspring age at the postnatal visit; categorical variables of race/ethnicity, education, and household income; and binary variables for introduction of solids by the approximately 5-month visit, diagnosis of gestational diabetes, any maternal smoking during pregnancy, any maternal alcohol consumption during pregnancy, mode of delivery, and offspring sex. We also considered second- and third-order interactions, hypothesized a priori, between maternal prepregnant BMI, gestational weight gain, and percent time of exclusive breastfeeding. Examination of jackknifed studentized residuals confirmed the assumptions of normality and homoscedasticity. Variance inflation factors were inspected to confirm that multicollinearity between predictors was not prohibitive (all <2.0). We removed covariates that were statistically nonsignificant ($P > .05$) for all body composition measures, including the interaction terms, and present 3 models for interpretation. Model 1 includes the primary predictors (prepregnant BMI, gestational weight gain, breastfeeding exclusivity) and significant covariates (race/ethnicity and sex). Model 2 includes model 1 predictors plus the respective body composition measure at birth (eg, fat-free mass at birth for the model predicting fat-free mass at approximately 5 months of age). Model 3 includes model 2 predictors and additionally adjusts for the binary status of rapid growth in WAZ from birth to approximately 5 months.