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Associations of maternal obesity and excessive weight gain during pregnancy with subcutaneous fat mass in infancy

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ABSTRACT

Background: Not much is known about the associations of maternal obesity and excessive gestational weight gain with body fat in infancy.
Objective: To examine the associations of maternal pre-pregnancy body mass index and gestational weight gain with infant subcutaneous fat.
Methods: In a population-based prospective cohort study among 845 mothers and their infants, we obtained maternal pre-pregnancy body mass index and measured maternal weight during pregnancy. At 1.5, 6 and 24 months, we estimated infant total subcutaneous fat (sum of biceps, triceps, suprailiacal and subscapular skinfold thicknesses) and central-to-total subcutaneous fat ratio (sum of suprailiacal and subscapular skinfold thicknesses/total subcutaneous fat).
Results: Maternal body mass index was positively associated with higher infant body mass index from 6 months onwards. Maternal body mass index was not associated with infant subcutaneous fat measures at 1.5 or 6 months. A 1-standard deviation scores (SDS) higher maternal body mass index was associated with a 0.09 (95% Confidence Interval 0.01, 0.17) SDS higher infant total subcutaneous fat at 24 months, but not with central-to-total subcutaneous fat ratio. No associations were present for maternal total or period-specific gestational weight gain with infant fat.
Conclusion: Maternal body mass index was positively associated with infant body mass index and total subcutaneous fat in late infancy. Maternal total and period-specific gestational weight gain were not associated with infant body fat mass measures.

1. Introduction

Maternal pre-pregnancy obesity and excessive weight gain during pregnancy are associated with an increased risk of obesity in childhood [1,2]. Body mass index is a suboptimal measure of body fat mass and provides no information about body fat distribution [3]. Several studies have shown that compared to body mass index, central fat distribution is more strongly associated with an adverse cardiovascular risk profile [4]. Previously, we reported that maternal obesity and excessive weight gain especially in early-pregnancy seem to be associated with an adverse body fat distribution, such as higher android-to-gynoid fat mass ratio, at 6 years [5,6]. We have also shown that maternal pre-pregnancy body mass index tended to be more strongly associated with childhood total and abdominal fat than paternal body mass index, suggesting that intra-uterine mechanisms might be involved [6]. Thus far, previous studies did not assess the associations and explore the underlying mechanisms of maternal obesity and excessive weight gain during pregnancy with detailed offspring fat mass measures already from early infancy onwards, which is a well-known critical period for adiposity development in later life [7]. Skinfold thickness is a valid measurement of total and regional subcutaneous fat mass in infancy [8]. We have previously shown that subcutaneous fat mass measured by skinfolds tends to track throughout infancy and is positively associated with cholesterol levels at school-age children [9,10].

Therefore, we examined in a population-based prospective cohort study among 845 parents and their infants, the associations of maternal pre-pregnancy body mass index and weight gain in different periods of pregnancy with subcutaneous fat mass measures throughout infancy.

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We also compared the strength of the associations of maternal and paternal body mass index with infant fat mass measures to obtain further insight in the underlying mechanisms.

2. Methods

2.1. Study design

This study was embedded in the Generation R Study, a population-based prospective cohort study from early pregnancy onwards among 9778 mothers and their children living in Rotterdam, the Netherlands [11]. The local Medical Ethical Committee approved the study. Written informed consent was obtained from parents. Additional detailed assessments of growth and development were conducted in a subgroup of Dutch mothers and their children from late pregnancy onwards. Of all approached women, 80% agreed to participate. From the total of 1205 mothers and their singleton children participating in the subgroup study, 1033 mothers had information about pre-pregnancy body mass index. Missing information about pre-pregnancy body mass index was mainly because of later enrolment in the study and nonparticipation in the first questionnaire. Body mass index or skinfold thicknesses measured at the age of 1.5, 6 or 24 months were available in 845 children (Flow chart is given in Supplemental Fig. S1). Missing body fat mass measurements during infancy were due to loss to follow-up or crying behavior.

2.2. Parental anthropometrics

As previously described, maternal pre-pregnancy weight was obtained by questionnaire at enrolment [11]. Maternal height (cm) and paternal height (cm) and weight (kg) were measured without shoes and heavy clothing at enrolment. Body mass index (kg/m^2) was calculated. Maternal and paternal body mass index were categorized into 4 categories (underweight (<20 kg/m^2), normal weight (20–24.9 kg/m^2), overweight (25–29.9 kg/m^2), and obese (≥30 kg/m^2)). We measured maternal weight without shoes and heavy clothing at median 12.8 (95% range 9.9,17.0), 20.4 (95% range 18.6,22.7) and 30.4 (95% range 28.5,32.5) weeks of gestation. In a subgroup of 509 mothers, information about maximum weight during pregnancy was assessed by questionnaire 2 months after delivery. Based on the timing of maternal weight measurements within our study cohort, we defined early-, mid- and late-pregnancy weight, using self-reported and measured maternal weight data, as: at 13 weeks of gestation (median 12.8, 95% range 9.9,18.9); at 26 weeks of gestation (median 29.9, 95% range 20.4,31.6); and at 40 weeks of gestation (median 39.0, 95% range 32.6,42.0), respectively. Using this method, information about early-, mid- and late-pregnancy weight was available for 762, 824 and 493 mothers, respectively. Among the subgroup of mothers with maximum weight during pregnancy available, we defined excessive gestational weight gain in relation to maternal pre-pregnancy body mass index according to the Institute of Medicine (IOM) guidelines [12].

2.3. Body fat measurements during infancy

We measured weight to the nearest gram in naked infants at the age of 1.5 and 6 months by using an electronic infant scale and at 24 months by using a mechanical personal scale (SECA, Almere, The Netherlands). Body length at the age of 1.5 and 6 months was measured in supine position to the nearest millimeter by using a neonatometer and body height at 24 months was measured in standing position by using a Harpenden stadiometer (Holtain Limited, Dyfed, UK). Body mass index (kg/m^2) was calculated. We measured skinfold thicknesses at the ages of 1.5, 6 and 24 months on the left side of the body at the biceps, triceps, suprailiacal and subscapular area by using a skinfold caliper (Slim Guide, Creative Health Products) [9]. We calculated total subcutaneous fat mass from the sum of all four skinfold thicknesses, and central subcutaneous fat mass from the sum of suprailiacal and subscapular skinfold thicknesses [13]. Measurements of body fat quantity and distribution require appropriate adjustment for body size or total fat mass, respectively, in order to undertake informative comparisons between children and within children over time. To create total subcutaneous fat mass independent of length or height and central subcutaneous fat mass independent of total subcutaneous fat mass, we estimated the optimal adjustment by log-log regression analyses [14]. Based on these analyses, total subcutaneous fat mass was only weakly correlated with length at 1.5 and 6 months or height at 24 months, and was not adjusted for it. A central-to-total subcutaneous fat mass ratio was calculated as central divided by total subcutaneous fat mass.

2.4. Covariates

Information on maternal and paternal age, educational level and parity was obtained at enrolment [11]. Information on maternal smoking was assessed by questionnaires during pregnancy. First trimester maternal nutritional information was obtained by food frequency questionnaire. Information about pregnancy complications, mode of delivery, child's sex, gestational age and weight at birth was obtained from medical records [15]. Information about breast feeding duration and timing of introduction of solid foods was obtained by questionnaires in infancy.

2.5. Statistical analysis

First, we examined differences in subject characteristics between maternal body mass index categories with 1-way ANOVA tests and χ^2 tests. Next, we examined the associations of maternal and paternal body mass index with infant subcutaneous fat mass measures at each time period using linear regression models. We also used repeated measurement regression models to assess the associations of parental pre-pregnancy overweight with the repeatedly measured infant fat mass measures. These models take the correlation between repeated measurements of the same subject into account, and allow for incomplete outcome data. Third, we examined the associations of maternal maximum gestational weight gain and excessive gestational weight gain according to the IOM criteria with infant subcutaneous fat mass measures using linear regression models. Since maternal weight measurements throughout pregnancy are strongly correlated, we performed conditional linear regression analyses to assess the independent associations of maternal pre-pregnancy weight and early-, mid- and late-pregnancy weight gain with infant subcutaneous fat mass measures. We obtained standardized residuals for each weight measurement from the regression of maternal weight at a specific time point on prior maternal weight measurements. These weight variables are statistically independent from each other, and can be simultaneously included in the regression models [16].

Models were adjusted for maternal and childhood socio-demographic and lifestyle-related characteristics. Covariates were included based on associations with the exposures and outcomes of interest in previous studies, or a change in effect estimates > 10%. We constructed SDS ((observed value − mean) / SD) for parental body mass index and gestational weight gain and infant fat mass measures to enable comparison of effect estimates. Since no significant interactions between parental body mass index or maternal gestational weight gain and child's sex in the associations with infant subcutaneous fat mass measures were present, no further stratified analyses were performed. Missing values in covariates were multiple-imputed, by using Markov chain Monte Carlo approach. Five imputed datasets were created and analyzed together. All statistical analyses were performed using the Statistical Package of Social Sciences version 21.0 for Windows (SPSS Inc., Chicago, IL, USA).