

Cesarean Delivery and Risk of Childhood Obesity

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Objective To investigate whether birth by cesarean delivery rather than vaginal delivery is a risk factor for later childhood obesity.

Study design Healthy, full-term infants were recruited. Overweight and obesity were defined using measured weight and height according to World Health Organization reference data. Associations between cesarean delivery and being overweight or obese were investigated at age 2, 6, and 10 years (n = 1734, 1244, and 1170, respectively) by multivariate logistic regression models adjusted for socioeconomic status, child characteristics, and maternal prepregnancy characteristics.

Results Mothers who gave birth by cesarean delivery (~17%) had a higher mean prepregnancy body mass index (23.7 kg/m² vs 22.5 kg/m²), greater mean gestational weight gain (15.3 kg vs 14.5 kg), and shorter mean duration of exclusive breastfeeding (3.4 months vs 3.8 months) compared with those who delivered vaginally. The proportion of obese children was greater in the cesarean delivery group compared with the vaginal delivery group at age 2 years (13.6% vs 8.3%), but not at older ages. Regression analyses revealed a greater likelihood of obesity at age 2 years in the cesarean delivery group compared with the vaginal delivery group at age 2 years (aOR, 1.68; 95% CI, 1.10-2.58), but not at age 6 years (aOR, 1.49; 95% CI, 0.55-4.05) or age 10 years (aOR, 1.16; 95% CI, 0.59-2.29).

Conclusion Cesarean delivery may increase the risk of obesity in early childhood. Our results do not support the hypothesis that an increasing rate of cesarean delivery contributes to obesity in childhood. (*J Pediatr* 2014;164:1068-73).

Over the last 20 years, the prevalence of cesarean delivery has increased in Germany (from 15.3% in 1991 to 31.9% in 2010).¹ Delivery by cesarean is a recognized risk factor for short-term lung function impairment, hypoglycemia, reduced breast feeding initiation,^{2,3} altered immune responses,⁴ and long-term effects on immune-related conditions, such as asthma,⁵ respiratory morbidity,⁶ and type 1 diabetes.⁷ Mode of delivery shapes the acquisition and structure of infants' microbiota. Infants born by cesarean delivery acquire different bacterial communities compared with those delivered vaginally.^{8,9}

Several cohort and case-control studies have reported conflicting results regarding the association between cesarean delivery and childhood obesity.¹⁰⁻¹⁸ A recent meta-analysis found a moderately strong association between cesarean delivery and later overweight and obesity.¹⁹ The "hygiene hypothesis" is the background for this possible relationship.²⁰ In addition, altered postnatal feeding and metabolic control in born infants via cesarean delivery vs those delivered vaginally may have long-term effects on appetite regulation or energy metabolism that may contribute to the significant increase in body mass.²

Generalizing the findings of previous studies is challenging, given that these studies were performed in different countries, with participants born in different time periods and followed for different durations, with various strategies used to control confounding. In particular, several important potential confounders were not consistently included in the analyses. For instance, maternal prepregnancy body mass index (BMI) may influence both the decision to perform a cesarean delivery²¹ and the risk of obesity in offspring,²² preterm or small for gestational age infants may have different growth trajectories compared with full-term infants^{23,24} and thus be at greater risk for obesity later in life,^{25,26} and early feeding patterns and a lower rate of breastfeeding initiation and shorter breastfeeding duration are known to be consequences of cesarean delivery²

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BMI Body mass index

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and may play a role in the biological pathway between cesarean delivery and later-life obesity.²⁷

The effect of cesarean delivery on long-term growth in childhood remains controversial. In the present study, we used longitudinal data from a German birth cohort that recruited healthy full-term infants to examine whether cesarean delivery is associated with growth and whether the effect of cesarean delivery on growth persists into school age, after adjusting for socioeconomic status and maternal and child characteristics.

Methods

Data were analyzed from the ongoing German birth cohort LISApplus (Influences of Lifestyle-Related Factors on the Immune System and the Development of Allergies in Childhood plus Air Pollution and Genetics). The design of this birth cohort study has been described previously.²⁸ Between November 1997 and January 1999, a total of 3097 healthy full-term neonates (gestational age >37 weeks and birth weight >2500 g) were recruited from Munich, Leipzig, Wesel, and Bad Honnef. Infants with congenital disorders or perinatal problems were excluded. Physical examinations, including anthropometric measurements, were performed when the children were 2, 6, and 10 years old. The numbers of children with available data on mode of delivery and anthropometric measurements were 1734 at age 2 years, 1244 at age 6 years, and 1170 at age 10 years.

The study was approved by the respective local Ethics Committees (Bavarian General Medical Council, University of Leipzig, Medical Council of North Rhine-Westphalia), and all participating families provided written consent.

BMI (weight in kg/[height in m]²) was calculated using recorded height and weight measurements. BMI z-scores were calculated using World Health Organization macros.²⁹ Overweight and obesity were defined using World Health Organization reference data (overweight, BMI ≥85th and <95th percentile for age and sex; obese, BMI ≥95th percentile for age and sex).³⁰

Information regarding mode of delivery was collected by questionnaire at enrollment. Mode of delivery was defined as a binary variable, cesarean or vaginal delivery. Data on whether the cesarean delivery was elective or emergency and on perinatal maternal exposure to antibiotics were not available.

Potential influencing factors included city of recruitment, parental education, duration of gestation, birth weight, head circumference at 3 days of age, maternal age, maternal prepregnancy BMI, and maternal smoking during pregnancy. Sociodemographic data and maternal characteristics were collected by questionnaire at enrollment and during follow-up visits. We categorized parental education according to the greatest number of years that either parent attended school (low, <10 years; medium, 10 years; high, >10 years). In addition, the feeding variables (ie, breastfeeding initiation, exclusive breastfeeding duration, and timing of solid food introduction) were considered as potential mediators.

Study characteristics are presented stratified by mode of delivery; all available data were used in the analyses. Multivariate linear and logistic regression models were used to evaluate the associations between cesarean delivery and BMI z-score, overweight, and obesity.

Results from 3 models are provided. Model 1 includes only the association between mode of delivery and the 3 outcome variables (crude model). Model 2 includes an adjustment for parental education, city of recruitment, birth weight, duration of gestation, and head circumference. Model 3 is additionally adjusted for maternal age, maternal prepregnancy BMI, and maternal smoking during pregnancy. In addition, stratified analyses by feeding variables and further adjustment for these variables were performed.

Differences in study characteristics between children delivered by cesarean and vaginal delivery were tested using the Student *t*-test for continuous variables, the χ^2 test for binary variables, and the Fisher exact test for multilevel variables (with the first level serving as the reference level). Study characteristics are described as mean (SD) or number (%). Model results are presented as linear regression coefficients (β) and as OR with corresponding 95% CI. A *P* value <.05 was considered statistically significant. All analyses were performed using R version 2.14.1.³¹

Results

Participant characteristics at each time point are summarized in the **Table** (available at www.jpeds.com). Approximately 17% of the children were delivered by cesarean (range at different time points, 17.01%-17.44%). At the age 2 year evaluation, the mothers who delivered by cesarean had higher mean prepregnancy BMI (23.7 kg/m² vs 22.5 kg/m²; *P* < .05), mean gestational weight gain during pregnancy (15.3 kg vs 14.5 kg; *P* < .05), and proportion of smoking during pregnancy (19.4% vs 14.3%; *P* < .05), and shorter mean exclusive breastfeeding duration (3.4 months vs 3.8 months; *P* < .05) compared with those who delivered vaginally. Distributions of the foregoing variables were similar at 6 and 10 years of age.

A similar distribution of birth weight was observed in the cesarean delivery and vaginal delivery groups. Children delivered by cesarean had a higher mean BMI at age 10 years compared with those delivered vaginally (17.5 kg/m² vs 17.2 kg/m²; *P* < .05). BMI z-scores at age 2 years and 10 years were higher in the cesarean group (0.37 vs 0.25; *P* < .05 at 2 years and 0.33 vs 0.09; *P* < .05 at 10 years). The prevalence of obesity at age 2 years also was higher in the cesarean group (13.6% vs 8.3%; *P* < .05). This difference did not persist to age 6 or 10 years.

A comparison of basic characteristics of participants and nonparticipants revealed no major differences in BMI characteristics and cesarean delivery rate between participants and nonparticipants for all time points. Children recruited in Leipzig and those born to a young mother or to parents with a low educational level (<10 years) were more likely to drop out.

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