



# Cesarean Delivery, Overweight throughout Childhood, and Blood Pressure in Adolescence

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**Objectives** To investigate whether children delivered by cesarean had a higher risk of being overweight from early until late childhood and whether they had a higher blood pressure in adolescence compared with children delivered vaginally.

**Study design** We used data from a Dutch birth cohort study with prenatal inclusion in 1996 and 1997. Mode of delivery (cesarean or vaginal delivery) was ascertained at 3 months after birth by questionnaire. During clinical examinations, height and weight (at age 4, 8, 12, and 16 years) and blood pressure (at age 12 and 16 years) were measured. We used mixed model analysis to estimate associations of cesarean delivery with overweight and blood pressure z scores in 2641 children who participated in at least 1 of the 4 examinations.

**Results** Children born by cesarean delivery (n = 236, 8.9%) had a 1.52 (95% CI 1.18, 1.96) higher odds of being overweight throughout childhood than children delivered vaginally. Children born by cesarean delivery had no higher systolic blood pressure z-score (0.11 SD, 95% CI -0.04, 0.26), nor a different diastolic blood pressure z-score (-0.00 SD, 95% CI -0.10, 0.09) in adolescence than children delivered vaginally.

**Conclusions** Compared with children delivered vaginally, children delivered by cesarean had a 52% higher risk of being overweight throughout childhood, but this was not accompanied by a higher blood pressure in adolescence. (*J Pediatr* 2016;179:111-7).

A cesarean delivery is meant to be performed when the health of the child or the mother is at risk. At present, 20%-30% percent of children in most developed countries are born through cesarean delivery.<sup>1</sup> This is worrisome because at such rates, a cesarean delivery does not result in lower maternal or neonatal mortality.<sup>2</sup> Adverse maternal outcomes associated with cesarean delivery<sup>3</sup> will then outweigh the benefits of this procedure. Evidence for health risks in the offspring is also accumulating. Compared with children delivered vaginally, children born by cesarean delivery are at increased risk of autoimmune diseases such as asthma,<sup>4,5</sup> allergies,<sup>4</sup> and type 1 diabetes.<sup>6</sup>

Children born by cesarean delivery also may have a higher risk of being overweight, but the evidence is conflicting.<sup>7-9</sup> Furthermore, few studies have investigated whether the association between cesarean delivery and overweight persists from early until late childhood. This is important because overweight especially in late childhood tracks into adulthood,<sup>10</sup> where it may lead to increased risk of cardiovascular diseases. Although one study observed a higher risk of being overweight when born by cesarean delivery throughout entire childhood,<sup>11</sup> 2 studies only observed a higher risk of being overweight in early childhood but not at older ages.<sup>12,13</sup>

If cesarean delivery is associated with being overweight, it may also be associated with other cardiovascular risk factors in childhood. In a population-based birth cohort, we investigated whether children delivered by cesarean had a higher risk of being overweight throughout childhood, and whether they had a higher blood pressure in adolescence, than children delivered vaginally.

## Methods

This study was nested in the Dutch Prevention and Incidence of Asthma and Mite Allergy (PIAMA) study, an ongoing prospective birth cohort study with prenatal inclusion and current follow-up until age 16 years. Pregnant women from the Northern, Western, and central part of The Netherlands were recruited by means of antenatal clinics between 1996 and 1997, which resulted in a baseline population of

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| BMI   | Body mass index                                     |
| DBP   | Diastolic blood pressure                            |
| PIAMA | Prevention and Incidence of Asthma and Mite Allergy |
| SBP   | Systolic blood pressure                             |

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3963 newborns. Details on the study design are described elsewhere.<sup>14,15</sup> For the aims of the present study, we excluded 67 children with missing data on the method of delivery and 1255 children without data from a clinical examination. The study population, thus, consisted of 2641 children (66.6% of baseline population). The study protocol was approved by the medical ethical committees of the participating institutes, and all parents, and at the age of 16 years also all children, gave written informed consent.

Questionnaires were sent to the parents during pregnancy, 3 months after delivery, annually from the child's age of 1 to 8 years and at 11 and 14 years of age. For the present study, data on exposure and confounders were obtained from questionnaires until the child's age of 1 year. Between 94% and 99% of parents completed these questionnaires. Data on the outcomes of this study were obtained from clinical examinations for which children were invited at 4, 8, 12, and 16 years of age (Figure 1; available at [www.jpeds.com](http://www.jpeds.com)). Because of funding restrictions, children invited to attend the examination at 4 and 16 years of age,<sup>15</sup> were restricted to research centers located in the central and Northern region.

The mode of delivery, cesarean or vaginal, was reported by the parents in the questionnaire at the child's age of 3 months. Exposure was defined as "born by cesarean," with vaginal delivery as the reference category.

## Outcomes

At ages 4, 8, and 12 years, trained research staff measured weight and height at the hospital or at the child's home using portable measuring equipment. At age 16 years, weight and height were measured at the hospital only, using a calibrated weighing scale (Seca 813; Seca, Birmingham, United Kingdom) and stadiometer (Seca 222; Seca). Weight was measured to the nearest 0.1 kg, and standing height (cm) was measured to nearest decimal. Both anthropometric variables were measured while the children were wearing underwear only. Weight in kg was divided by height squared in m<sup>2</sup> to calculate body mass index (BMI). Overweight (including obesity) was defined based on international age- and sex-specific cut-off points for BMI.<sup>16</sup>

At values of BMI equal or above the cut-off points, the outcome was defined as being overweight, and below the cut-off point as not being overweight. Furthermore, because of a low number of obese children in our study population (n = 44, 61, 16, and 13 at age 4, 8, 12, and 16 years, respectively), we did not investigate associations in obese children separately. To supplement the analysis with BMI as a categorical variable, we also used a continuous dependent variable (ie, using age- and sex-specific BMI SDS according to reference data from the 1997 Dutch Growth Study).<sup>17</sup> The BMI SDS, thus, represent the deviation in BMI from the mean BMI of the general population of children of the same age and sex.

Systolic (SBP) and diastolic blood pressure (DBP) were measured during the clinical examinations at age 12 and 16 years. After subjects were calm and in a seated position for 10 minutes, 2 blood pressure measurements, with an interval of 5 minutes, were performed on the nondominant upper arm using an au-

tomatic oscillometric device, the M6 Monitor (OMRON Healthcare Europe B.V., Hoofddorp, The Netherlands). The proportion of children with left arm blood pressure measurements at age 12 years was 84.8% and did not differ between children delivered vaginally and by cesarean (84.9% and 83.5% respectively, *P* value of .50). The proportion of children with left arm blood pressure measurements at age 16 years was 87.3%, and was also not statistically significantly different between children delivered vaginally and by cesarean (87.5% and 82.6% respectively, *P* value of .32). The cuff was adjusted to the subjects arm circumference (large cuff when circumference  $\geq 22$  cm) and was placed directly on the skin. In case 2 consecutive measurements differed by more than 5 mm Hg, another measurement was taken. Subjects were instructed not to move their arm or talk during the measurements. Blood pressure measurements were averaged and then standardized by age-, sex-, and height-specific blood pressure z scores, according to the Fourth Report on the Diagnosis, Evaluation and Treatment of High Blood Pressure in Children and Adolescents.<sup>18</sup>

## Collection and Definitions of Covariates

The child's sex, birth weight, gestational age, maternal age, maternal smoking during pregnancy, maternal prepregnancy BMI, maternal gestational weight gain, gestational diabetes, and maternal educational level were considered as a priori confounders. Child's sex, birth weight in grams, gestational age in weeks, place of delivery (at home or at the hospital), and maternal age at delivery in years were reported in the questionnaire for 3-month-olds. Prematurity was defined as a gestational age below 37 weeks. Maternal smoking during pregnancy was assessed in the pregnancy questionnaire and was defined as smoking during at least the first 4 weeks of pregnancy. Maternal prepregnancy BMI (kg/m<sup>2</sup>) was calculated from prepregnancy weight in kg and height in cm as reported in the questionnaire for 1-year-olds and then dichotomized into no overweight (BMI <25 kg/m<sup>2</sup>) and overweight (BMI  $\geq 25$  kg/m<sup>2</sup>). Gestational weight gain in kg was also administered at 1 year of age and dichotomized into excessive and no excessive maternal weight gain. Excessive weight gain was defined as a weight gain greater than the upper range of the Institute of Medicine 2009 guidelines,<sup>19</sup> which is dependent on prepregnancy weight status. Maternal educational level was assessed at the child's age of 1 year and was used as a measure for socioeconomic status. Educational level was categorized into low (no education, primary school, lower secondary education), intermediate (intermediate vocational education, higher secondary education, pre-university education), and high education (higher professional education and university).

## Other Covariates

Besides a priori confounders, we considered confounding by paternal and child factors. We found no statistically significant or meaningful differences between children delivered vaginally and by cesarean with regard to paternal educational level at birth, and paternal smoking status (smoking in the house and number of cigarettes smoked per day) at the child's age

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