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Association of early pregnancy body mass index and children's birth weight with risk of being overweight in childhood

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Abstract

Objective: To examine the potential effects of mothers' early pregnancy body mass index (BMI) and children's birth weight on childhood overweight/obesity at 1 to 6 years of age.

Methods: We performed a cohort study in Tianjin, China, using the health care records from the Tianjin maternal and child health care system with 36,719 mother-child pairs from early pregnancy to children at 6 years of age. Logistic regression analyses were used to assess the single and joint associations of maternal early pregnancy BMI and children's birth weight with the risks of children being overweight at 1 to 6 years of age in multivariable-adjusted models.

Results: Both maternal early pregnancy BMI and children's birth weight were positively associated with the risk of children being overweight at 1 to 6 years of age. Compared with children who were born to normal weight mothers and had low or normal birth weight (NBW; birth BMI < 85%), higher risks of being overweight at 1 to 6 years were found among children with low or NBW who were born to overweight mothers, and children with high NBW (BMI ≥ 85%) or macrosomia who were born to normal weight or overweight mothers. Lower risks of being overweight were found among those with low birth weight who were born to normal weight mothers.

Conclusions: Maternal early pregnancy BMI may play a more important role than children's birth weight in the risk of being overweight from 4 to 6 years of age. Children with high or NBW need to be given more attention to prevent excessive weight gain.

Keywords

maternal obesity; childhood overweight; birth weight; early childhood risk factors; early pregnancy BMI

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Introduction

According to the report by the World Health Organization (WHO), childhood obesity is becoming “one of the most serious public health challenges of the 21st century.” There are over 41 million overweight children under the age of five, and half of them live in Asia (World Health Organization). Childhood obesity is likely to persist into adulthood, leading to increased risk of chronic diseases, such as cardiovascular diseases and type 2 diabetes, and even increasing the likelihood of morbidity and mortality (Bundred et al., 2001). However, we still know little about the best approach to ending childhood obesity. In a report published by the WHO (2016), there were 6 recommendations to prevent childhood obesity, including preconception and pregnancy care.

Maternal obesity and children’s birth weight both have an impact on the early development of children. Maternal obesity represents an over-nutritional status of the fetus, while children’s birth weight is considered an indicator of growth in utero. Maternal early pregnancy overweight/obesity is correlated with the offspring’s health across the lifespan, from macrosomia or large-for-gestational-age infants (Alberico et al., 2014; Yu et al., 2013) to obesity and metabolic disruption in childhood, (Whitaker, 2004) and even into early adulthood (Drake and Reynolds, 2010; Reynolds et al., 2010). Children’s birth weight also has a long term effect on children’s health (Roland et al., 2012). However, in previous studies, the associations between a child’s birth weight and later obesity were inconsistent (Jornayvaz et al., 2016; Leong et al., 2003; Qiao et al., 2015; Zhao et al., 2012). Nonetheless, in most studies evaluating maternal obesity in early pregnancy in relation to children’s later health, children’s birth weight was only considered as one of the pregnancy outcomes or a confounding factor. Therefore, it is important to use both maternal early pregnancy BMI and children’s birth weight when evaluating the risks for childhood overweight and obesity.

Since no universal agreement exists for defining newborn obesity (Ogden et al., 2012), children’s BMI at birth is not recommended for clinical use (Division of Nutrition, 2015). However, a recent study assessed the association between newborn BMI >85% and weight-for-age >85% with the overweight risk at 4 years of age, and found that birth BMI was more likely to be associated with children being overweight at 4 years of age and maternal pre-pregnancy obesity (Winter et al., 2016). This finding suggested that both children’s birth weight and birth BMI may offer strong predictive power for childhood overweight or obesity.

Childhood obesity is an increasingly important predictor of adult obesity. Thus, it is important to begin prevention as early as possible, especially before school age, because preschool age is a good time to shape children’s lifestyles and habits. With regard to modifiable and preventable factors, we need to identify the impacts of high maternal early pregnancy BMI and children’s birth weight on children’s risk of overweight/obesity. Therefore, the present study aimed to examine the single and joint effects of maternal early pregnancy BMI and children’s birth weight on childhood overweight/obesity at 1 to 6 years of age.

Methods

We performed a cohort study in Tianjin, China, using health care records from the Tianjin maternal and child health care system.

Tianjin maternal and child health care system

The Tianjin maternal and child health care system is a three-tier care system, consisting of community-based health centers, district-level Women's and Children's Health Centers (also including secondary hospitals), and a city-level (Tianjin) Women's and Children's Health Center (also including tertiary hospitals). All women were registered at their community health centers every time they got pregnant, and then referred to a secondary hospital or a tertiary hospital for health care from the 32nd gestational week until delivery. All children were given health examinations at birth (<3 days after birth), in the postnatal period (<42 days after delivery), infancy (each year during years 1 to 3), and at preschool (each year during years 3 to 7). Every woman was assigned a unique identification number (maternal health care ID) the first time she registered at the community health center, and every child was assigned another unique identification number (child health care ID) linked with his/her biological mother's maternal health care ID, when he/she was born in the hospital in Tianjin. In different phases and examination locations, trained health care practitioners conducted the necessary examinations for pregnant women and their children, collected the data, and entered the data into an electronic health information system (Li et al. 2013; Liu et al., 2014). Both the maternal health care ID and the child health care ID were "key chains" to link all the mother's pregnancy health care records and her child's health care records until 7 years of age. Health care records for both pregnant women and their children have been collected and available in electronic form since 2009 (Tianjin Women's and Children's Health Center, 2010).

Health care records for pregnant women began within the first 12 weeks of pregnancy, including general information (age, education, occupation, date of the first visit, numbers of pregnancy/infants, last menstrual period, expected delivery date, and smoking habits), medical history, family history of diseases, clinical measurements (height, weight, blood pressure, gynecological examinations, ultrasonography, gestational diabetes screening test and other lab tests), complications during pregnancy, pregnancy outcomes (delivery modes and labor complications), and postnatal period examinations (<42 days after delivery).

Health care records for children began with children's birth, including information from newborns (date of birth, sex, gestational week of birth, birth weight, birth recumbent length, and Apgar score), postnatal period (names of the child and his/her parents, family history of diseases, feeding modalities, weight, and recumbent length), infancy (date of examination, weight, recumbent length before 24 months and height from 24 months, head circumference, number of teeth, and blood hemoglobin), and preschool (date of examination, weight, height, number of teeth, blood hemoglobin, and blood pressure), as well as the information of feeding modalities (exclusive breastfeeding, mixed breast and formula feeding, weaned from breastfeeding, and exclusive formula feeding) during the first 6 months.

Study population

We collected the records of both mothers and their infants who were born between June 2009 and May 2011 in the central urban districts and two suburban districts (Jinnan and Beichen) of Tianjin. A total of 52,632 mother-child health care records were available. In the present study, we included 36,719 mother-child pairs (69.8%), after excluding multiple births (n=1268), premature infants with gestational age <37 weeks (n=2497), and the mother-child pairs missing mothers' weight or height information at the first prenatal visit or children's birth clinical measurements (n=13,594). Compared with the excluded mother-child pairs, children and mothers included in this study were younger (6.13 vs. 6.18 years at the latest follow-up point and 27.8 vs. 28.7 years at delivery, respectively) and there were fewer boys (51.7% vs. 55.2%). Of 36,719 mother-child pairs, the rates of child health examination at 1 year, 2 years, and 3 years (mainly administrated in community health centers) were 98.3%, 97.6%, and 98.6%, respectively, and the average rate for 4 to 6 years (mainly carried out in preschool) was 93.5% (6-year-old data collection was still ongoing). Our study was approved by the Human Subjects Committee of Tianjin Women's and Children's Health Center (TWCHC). Since we used the electronic health care records in this study, TWCHC agreed to waive the need for written informed consent from all participants.

Measurements

Using the standardized protocol, all mothers' heights and weights were measured in light indoor clothing and without shoes by trained practitioners in community health centers during the pregnancy. Children's anthropometric data, including body weight, height or recumbent length (before 24 months) were collected at birth (<3 days after birth) in delivery hospitals by nurses, every year between 1 and 3 years in community health centers by health practitioners, and every year between 3 and 7 years in preschool by Tianjin or district-level Women's and Children's Health Center(s), using the same devices. Measurement devices and standards have been described elsewhere (LiLiuGuoPanLiWangLiuWangLiu and Hu, 2013; Li et al., 2014). Validity studies were also conducted to compare the health care records and measurements (LiLiuGuoPanLiWangLiuWangLiu and Hu, 2013). The correlations between electronic health care records and measurement data for pregnant women and children were 0.998 and 0.999 (for body weight), and 0.997 and 0.999 (for height/recumbent length), respectively. Women's gestational weight gain was significantly different between pre-pregnancy and delivery weight when categorized as inadequate, adequate, or excessive weight according to 2009 American Institute of Medicine guidelines for weight gain during pregnancy (Institute of Medicine (US) and National Research Council (US) committee., 2009).

Early pregnancy body mass index

Body mass index (BMI) was obtained by dividing weight (kilograms) by the square of height (meters). We calculated the maternal early pregnancy BMI using the weight and height measured at the first prenatal visit within the first 12 weeks of the index pregnancy. The average gestational age at the first weight measurement was 10.3 weeks and the range was 4.0 to 12.9 weeks. Therefore, in the study, we treated the BMI at the first prenatal visit as early pregnancy BMI. According to the Chinese BMI cut-offs (Zhou, 2002), maternal

early pregnancy BMI was categorized as underweight ($<18.5 \text{ kg/m}^2$), normal weight ($18.5\text{--}23.9 \text{ kg/m}^2$), overweight ($24.0\text{--}27.9 \text{ kg/m}^2$), and obese ($\geq 28.0 \text{ kg/m}^2$).

Childhood overweight/obesity

Childhood overweight/obesity was defined by children's Z scores for BMI-for-age, which is a gender-independent classification system, representing equivalent BMI-for-age percentiles based on the World Health Organization (WHO) growth reference (World Health Organization., 2006). Children's Z scores for BMI-for-age (from 3 months to 6 years old) were calculated based on the protocol from the WHO. Although BMI under 2 years old is not recommended for clinical use (Division of Nutrition, 2015) and there is no universal agreement on the definition of obesity in toddlers under 2 years of age (Ogden et al., 2012), in order to describe a child's growth using the same standard from birth to 6 years of age (weight-for-length Z-score is not available after 5 years old), we defined normal weight as a BMI less than the 85th percentiles for age and gender based on the WHO growth reference (Z-score <1.035) and overweight/obesity as a BMI above the 85th percentiles (Z-score ≥ 1.035) (Ogden et al., 2012). According to birth weight, all children were also categorized into a low birth weight (LBW) group ($<2500 \text{ g}$), a normal birth weight (NBW) group ($2500\text{--}4000 \text{ g}$), and macrosomia ($>4000 \text{ g}$). To detect the role of birth BMI on NBW children's later overweight risks, NBW children were further grouped into two subgroups (low NBW as BMI $<85\%$ and high NBW as BMI $\geq 85\%$) based on their Z scores for birth BMI-for-gestational age, which were calculated according to the means and standard deviations of our own study population (Li et al., 2013).

Statistical analyses

We compared the general characteristics of both mothers and children according to maternal early pregnancy BMI using one-way ANOVA and chi-square tests. To eliminate the impact of other factors on the associations, we performed logistic regression analyses to assess the single and joint associations of maternal early pregnancy BMI and children's birth weight with the risk of childhood overweight at 1 to 6 years old in three multivariable-adjusted models: Model 1 adjusted for maternal age; Model 2 adjusted for maternal age, education, family income, weight gain during pregnancy, smoking status, hypertensive disorders of pregnancy, gestational age at delivery, and infant feeding modes; Model 3 adjusted for variables in Model 2 as well as children's birth weight (in early pregnancy BMI analyses) or early pregnancy BMI (in children's birth weight analyses). Maternal early pregnancy BMI was first categorized into four groups (underweight: $<18.5 \text{ kg/m}^2$, normal weight: $18.5\text{--}23.9 \text{ kg/m}^2$ — reference, overweight: $24.0\text{--}27.9 \text{ kg/m}^2$, and obese: $\geq 28.0 \text{ kg/m}^2$) in single association analyses and then into two groups (normal weight: <24 and overweight: $\geq 24 \text{ kg/m}^2$) in joint association analyses. Children's birth weight was grouped into LBW, low NBW with birth BMI $<85\%$ (reference), high NBW with birth BMI $\geq 85\%$ and macrosomia in the single and joint association analyses. The different categories of maternal early pregnancy BMI and children's birth weight were included in the models (as dummy variables) and the significance of the trend over different categories was tested in the same models with the median of each category as a continuous variable. We performed all the analyses using IBM SPSS Statistics 24.0 (IBM SPSS, Chicago, IL) with a statistical significance at 0.05.

Results

Overall, the mean Z-scores for BMI (Standard Deviation, SD) of children were 0.07 (1.01) at birth, 0.69 (1.02) at 1 year (± 2 months), 0.42 (1.01) at 2 years (± 3 months), 0.27 (1.07) at 3 years (± 3 months), 0.19 (1.11) at 4 years (± 6 months), 0.22 (1.20) at 5 years (± 6 months), and 0.30 (1.35) at 6 years (± 6 months) and the prevalence of childhood overweight was 35.7%, 26.2%, 20.8%, 18.2%, 19.6%, and 24.8% at 1 to 6 years old, respectively. Table 1 presents the general characteristics of both mothers and children according to maternal early pregnancy BMI. A total of 64.0% of mothers were classified with pre-pregnancy normal weight, while 18.9% and 6.4% of mothers were overweight and obese, and 10.7% of mothers were underweight. Overweight and obese mothers were older, they had lower education levels and family income, and were more likely to be diagnosed with hypertensive disorders of pregnancy compared with their normal-weight counterparts (all $P < 0.001$). Moreover, overweight and obese mothers' offspring had greater mean values of birth weight and were more likely to have macrosomia, in comparison with the children born to normal-weight mothers (all $P < 0.001$).

Increased maternal early pregnancy BMI levels were associated with greater multivariable-adjusted (maternal age, education, family income, weight gain during pregnancy, smoking status, hypertensive disorders of pregnancy, gestational age at delivery, and infant feeding modes – Model 2) odds ratios (ORs) of childhood overweight status in each age group of 1 to 6 years (all P for trend < 0.001) (Table 2). After additional adjustment for children's birth weight (Model 3), the positive associations were somewhat attenuated but still remained significant (all P for trend < 0.001).

There were positive associations between children's birth weight and childhood overweight risks at 1 to 6 years of age (Table 3). The multivariable-adjusted (Model 2) ORs for LBW, low NBW [reference group], high NBW, and macrosomia groups were 0.41, 1.00, 1.63, and 1.88 at 1 year old (P for trend < 0.001), 0.37, 1.00, 1.58, and 2.02 at 2 years old (P for trend < 0.001), 0.54, 1.00, 1.57, and 2.10 at 3 years old (P for trend < 0.001), 0.42, 1.00, 1.51, and 2.17 at 4 years old (P for trend < 0.001), 0.56, 1.00, 1.54, and 2.16 at 5 years old (P for trend < 0.001), and 0.80, 1.00, 1.47, and 1.96 at 6 years old (P for trend < 0.001), respectively. When we further adjusted for maternal early pregnancy BMI, these positive associations still remained significant (all P for trend < 0.001).

Figure 1 presents the joint associations of maternal early pregnancy BMI and children's birth weight with childhood overweight status at ages 1 to 6. Compared with low-NBW-children born to normal weight mothers, LBW-children born to normal weight mothers had a lower risk of developing childhood obesity; LBW-children born to overweight mothers had a similar risk of developing childhood obesity. The other 5 groups of children all had higher risks of developing childhood overweight status at ages 1 to 6; among them, macrosomia-children born to overweight mothers had the highest childhood overweight risk at 1 to 6 years of age, ranging from 2.27–3.82.

To further figure out the roles of maternal early pregnancy overweight status and children's high birth weight on the risk of long-term childhood overweight status, we compared the

relative risk of childhood overweight status at 1 to 6 years of age between LBW-children or low-NBW-children born to overweight mothers and those high-NBW-children or macrosomia-children born to normal weight mothers (Figure 2). LBW-children or low-NBW-children born to overweight mothers showed lower odds of being overweight at 1 year (OR 0.75; 95% CI 0.69–0.82) and 2 years of age (OR 0.87; 95% CI 0.79–0.82), similar odds of being overweight at 3 years old (OR 1.01; 95% CI 0.92–1.11), and higher odds of being overweight at 4 (OR 1.21; 95% CI 1.09–1.33), 5 (OR 1.30; 95% CI 1.17–1.43), and 6 years of age (OR 1.43; 95% CI 1.27–1.62), compared with their counterparts.

Discussion

In the present study, we found that maternal early pregnancy BMI and infants' birth weight were both positively associated with childhood overweight risks at 1 to 6 years of age, independent of each other. The positive association between children's birth weight and childhood overweight risk was confirmed among children who were born from normal weight and overweight mothers. Moreover, we found that maternal overweight status may play a more important role than children's high birth weight in the development of childhood overweight status at 3 to 6 years of age.

According to a previous study, a high correlation existed between self-reported pre-pregnancy weight and recorded early pregnancy weight (Mamun et al., 2011). Many studies examined the effects of maternal pre-pregnancy BMI on infants and later obesity risk (Hochner et al., 2012; Jin et al., 2016; Liu et al., 2012) and our findings were consistent with previous studies. Yu's meta-analysis study revealed a positive association between maternal pre-pregnancy overweight or obesity and the risk of offspring's overweight/obesity (Yu et al., 2013). Some related studies of Asians only focused on pregnancy outcomes or early toddlers (Choi et al., 2011; Jin et al., 2016; Li et al., 2015; Liu et al., 2012). Our previous studies among the same population have demonstrated that maternal overweight increased the risk of offspring macrosomia and overweight status in children under 3 years of age (Li et al., 2013; Li et al., 2017). The present study continued to follow the same group of children until they were 6 years old, and further found a consistent and positive association of maternal pre-pregnancy BMI with childhood overweight status from 1 to 6 years of age.

The association of birth weight and later obesity has been assessed in many previous studies. Two studies found a U-shaped relation between birth weight and later obesity in people aged 35 to 75 years (Jornayvaz et al., 2016) and women aged 50 to 79 years (Leong et al., 2003). One recent meta-analysis covering 66 studies with 643,902 persons aged 1 to 75 years indicated that low birth weight (<2500 g) was associated with a decreased risk of overweight (OR 0.67; 95% CI 0.59–0.76), while high birth weight (>4000 g) was associated with an increased risk of overweight (OR 1.66; 95% CI 1.55–1.77), in comparison with normal-birth-weight infants (Schellong et al., 2012). Another meta-analysis showed that only high birth weight was associated with an increased risk of overweight/obesity in adults (Zhao et al., 2012). The present study with large sample sizes showed a positive association between birth weight and the risk of being overweight at 1 to 6 years of age. These inconsistent findings may be due to different age ranges of the target population.

Very few studies have assessed the joint association of maternal early pregnancy BMI and children's birth weight with the risk of being overweight in childhood. In most previous studies, children's birth weight was considered one of the pregnancy outcomes when evaluating maternal BMI and children's health. Mesman, et al. (2009) found that nearly one third of the association between maternal pre-pregnancy BMI with children's weight and BMI at 14 months decreased after controlling for birth weight. Our results indicated that both maternal early pregnancy BMI and children's birth weight were constantly associated with children's overweight/obesity risks at 1 to 6 years of age. Furthermore, children's birth weight had a greater effect than maternal early pregnancy BMI on children's overweight risks at 1 and 2 years of age. However, maternal early pregnancy BMI showed a greater effect than children's birth weight in predicting risk of being overweight when children reached 4 to 6 years of age.

The underlying mechanisms of these findings vary. The effects of maternal early pregnancy on childhood obesity risks persisted during both prenatal and postnatal periods. During the prenatal period, offspring inherit the obesity susceptibility genes (Chagnon et al., 2003), and the mother provides an intrauterine environment affected by maternal obesity (Oken and Gillman, 2003). During the postnatal period, mothers shape their children's eating and activity environment (Whitaker, 2004). However, the effects of children's birth weight on childhood obesity risks are most strongly shown during the prenatal period, because children's birth weight indicate their intrauterine nutrition, and it has been associated with mothers' metabolic level, weight gain, lifestyle during pregnancy, and pre-pregnancy weight (Sommer et al., 2015). Therefore, it is possible for maternal early pregnancy BMI to have greater effects on children's later risk of being overweight as children grow older.

Our study was a large-scale population-based study of mother-child pairs from the prenatal period to early childhood with anthropometry measurements by trained health practitioners. Moreover, we conducted this study in Tianjin, China, in order to enrich the birth cohort research in Asian populations. However, there are some limitations to our study. First, due to missing information, nearly 30% of mother-child pairs were excluded from the present study. Although we have adjusted for maternal age, and used Z-scores independent of children's age to evaluate childhood overweight status, the results still might differ from the true value because of the imbalance. Second, since we used health care records as the main source of data, some childhood lifestyle factors, such as physical activity and nutrition, were not available. Third, we excluded premature and multiple birth infants and information about assisted reproductive technology pregnancies was not available, therefore, one should be cautious when generalizing the findings.

In conclusion, the positive associations of maternal early pregnancy BMI and children's birth weight with the risk of being overweight were significant and did not diminish or vanish among Chinese children at 1 to 6 years of age. Maternal early pregnancy overweight status might play a more important role than infants' high birth weight in the development of childhood overweight at 4 to 6 years of age. Children's health care should not only focus on low-birth-weight infants and macrosomia, but also on normal-birth-weight children with high BMI>85% at birth to prevent childhood overweight and obesity.

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Figure 1.

Odds ratios of childhood overweight status at 1 to 6 years old based on different levels of maternal early pregnancy body mass index and children's birth weight. Adjusted for maternal age, education, family income, weight gain during pregnancy, smoking status, hypertensive disorders of pregnancy, gestational age at delivery, and infant feeding. (A. 1 year, B. 2 years, C. 3 years, D. 4 years, E. 5 years, and F. 6 years)

Figure 2.

Odds ratios of childhood overweight status among children who were born to mothers who were overweight during early pregnancy and had LBW or low NBW compared with those who were born to normal weight mothers during early pregnancy and had high NBW or macrosomia, adjusted for maternal age, education, family income, weight gain during pregnancy, smoking status, hypertensive disorders of pregnancy, gestational age at delivery, and infant feeding.

Table 1.

Maternal and child characteristics of study participants

	Maternal early pregnancy body mass index (kg/m ²)				P for difference
	<18.5	18.5–23.9	24.0–27.9	>28.0	
No. of subjects	3927	23,483	6954	2355	
Maternal characteristics					
Age, y	26.8±2.94	27.7±3.21	28.2±3.48	28.1±3.58	<0.001
Gestational age at delivery, wk	39.2±1.10	39.2±1.10	39.2±1.15	39.0±1.17	<0.001
Early pregnancy body mass index, kg/m ²	17.6±0.79	21.2±1.49	25.6±1.11	30.6±2.43	<0.001
Gestational weight gain, %					
Inadequate	11.5	5.0	4.0	6.0	<0.001
Excessive	61.2	76.8	90.5	85.0	
Adequate	27.2	18.3	5.5	9.0	
Education, %					<0.001
12 years	27.2	24.8	30.6	43.1	
13–15 years	27.4	26.5	27.7	27.0	
16 years	45.4	48.7	41.6	29.9	
Family Income, %					<0.001
<2000 yuan/month	21.5	20.9	23.7	31.9	
2000–2999 yuan/month	24.0	21.6	24.8	25.2	
3000 yuan/month	54.5	57.4	51.5	42.9	
Smoking during pregnancy, %	1.4	1.1	1.2	1.8	<0.001
Hypertensive disorders of pregnancy, %	0.7	1.3	3.1	9.0	<0.001
Child characteristics					
Boy, %	50.1	51.7	51.9	53.0	0.144
Birth weight, g	3257±385	3404±415	3507±453	3590±492	<0.001
Birth weight, %					<0.001
< 2500g, %	1.7	1.0	0.9	1.1	
2500g-4000g with BMI <85%, %	89.7	82.5	73.8	64.7	
2500g-4000g with BMI ≥85%, %	4.7	7.8	10.5	13.2	
> 4000g (Macrosomia), %	3.9	8.7	14.8	21.0	
Mode of infant feeding, %					<0.001
Exclusive breast-feeding	16.4	16.5	14.6	11.6	
Mixed breast and formula feeding	69.1	70.9	71.3	70.0	
Exclusive formula feeding	2.0	1.9	2.6	2.9	
Weaned from breast feeding	12.6	10.8	11.6	15.5	

Values are means ± SD unless otherwise specified.

Table 2.
Odds ratios for childhood overweight at 1 to 9 years old according to maternal early pregnancy body mass index

	Maternal early pregnancy body mass index (kg/m ²)				P for trend
	<18.5	18.5–23.9	24.0–27.9	>28.0	
Year 1					
Overweight (%)	27.2	34.7	40.8	45.3	
Multivariable odds ratios ¹	0.70 (0.64, 0.76)	1.00	1.30 (1.25, 1.38)	1.57 (1.43, 1.72)	<0.001
Multivariable odds ratios ²	0.73 (0.67, 0.79)	1.00	1.26 (1.19, 1.34)	1.52 (1.38, 1.67)	<0.001
Multivariable odds ratios ³	0.75 (0.69, 0.82)	1.00	1.21 (1.14, 1.29)	1.38 (1.25, 1.52)	<0.001
Year 2					
Overweight (%)	17.3	24.6	32.1	40.0	
Multivariable odds ratios ¹	0.63 (0.58, 0.69)	1.00	1.46 (1.38, 1.56)	2.02 (1.85, 2.22)	<0.001
Multivariable odds ratios ²	0.66 (0.60, 0.73)	1.00	1.41 (1.32, 1.50)	2.00 (1.79, 2.16)	<0.001
Multivariable odds ratios ³	0.69 (0.62, 0.75)	1.00	1.35 (1.27, 1.44)	1.79 (1.63, 1.97)	<0.001
Year 3					
Overweight (%)	11.2	18.8	27.5	36.6	
Multivariable odds ratios ¹	0.53 (0.47, 0.59)	1.00	1.66 (1.56, 1.78)	2.52 (2.29, 2.78)	<0.001
Multivariable odds ratios ²	0.56 (0.50, 0.62)	1.00	1.59 (1.49, 1.70)	2.39 (2.17, 2.64)	<0.001
Multivariable odds ratios ³	0.58 (0.52, 0.65)	1.00	1.52 (1.42, 1.63)	2.20 (1.99, 2.43)	<0.001
Year 4					
Overweight (%)	7.89	15.8	25.6	36.8	
Multivariable odds ratios ¹	0.44 (0.39, 0.50)	1.00	1.87 (1.74, 2.00)	3.16 (2.87, 3.48)	<0.001
Multivariable odds ratios ²	0.46 (0.40, 0.52)	1.00	1.78 (1.66, 1.91)	2.99 (2.71, 3.30)	<0.001
Multivariable odds ratios ³	0.48 (0.42, 0.54)	1.00	1.71 (1.60, 1.84)	2.74 (2.48, 3.03)	<0.001
Year 5					
Overweight (%)	8.45	16.9	28.3	40.6	
Multivariable odds ratios ¹	0.44 (0.39, 0.50)	1.00	1.99 (1.86, 2.13)	3.44 (3.12, 3.79)	<0.001

	Maternal early pregnancy body mass index (kg/m ²)				P for trend
	<18.5	18.5–23.9	24.0–27.9	>28.0	
Multivariable odds ratios ²	0.46 (0.40, 0.52)	1.00	1.89 (1.76, 2.02)	3.18 (2.88, 3.51)	<0.001
Multivariable odds ratios ³	0.47 (0.42, 0.54)	1.00	1.82 (1.70, 1.95)	2.93 (2.65, 3.24)	<0.001
Year 6					
Overweight (%)	9.71	21.7	35.5	50.0	
Multivariable odds ratios ¹	0.37 (0.31, 0.43)	1.00	2.03 (1.87, 2.21)	3.68 (3.24, 4.18)	<0.001
Multivariable odds ratios ²	0.39 (0.33, 0.45)	1.00	1.93 (1.77, 2.10)	3.39 (2.98, 3.86)	<0.001
Multivariable odds ratios ³	0.40 (0.34, 0.47)	1.00	1.87 (1.72, 2.03)	3.18 (2.79, 3.62)	<0.001

¹ Adjusted for maternal age.

² Adjusted for maternal age, education, family income, weight gain during pregnancy, smoking status, hypertensive disorders of pregnancy, gestational age at delivery, and infant feeding.

³ Adjusted for above variables and also for children's birth weight.

Table 3.
Odds ratios for childhood overweight at 1 to 6 years old according to children's birth weight

	Children's birth weight				P for trend
	Low birth weight (<2500g)	Normal birth weight (2500–4000g)	Macrosonia (>4000g)		
		BMI<85%	BMI 85%		
Year 1					
Overweight (%)	17.7	33.3	46.1	48.6	
Multivariable odds ratios ¹	0.43 (0.33, 0.57)	1.00	1.72 (1.58, 1.86)	1.90 (1.76, 2.05)	<0.001
Multivariable odds ratios ²	0.41 (0.31, 0.54)	1.00	1.63 (1.50, 1.77)	1.88 (1.74, 2.03)	<0.001
Multivariable odds ratios ³	0.41 (0.31, 0.55)	1.00	1.58 (1.45, 1.71)	1.78 (1.65, 1.92)	<0.001
Year 2					
Overweight (%)	10.8	23.9	34.1	39.4	
Multivariable odds ratios ¹	0.39 (0.28, 0.54)	1.00	1.65 (1.52, 1.80)	2.08 (1.93, 2.24)	<0.001
Multivariable odds ratios ²	0.37 (0.26, 0.51)	1.00	1.58 (1.45, 1.72)	2.02 (1.88, 2.18)	<0.001
Multivariable odds ratios ³	0.37 (0.26, 0.52)	1.00	1.49 (1.37, 1.62)	1.86 (1.72, 2.01)	<0.001
Year 3					
Overweight (%)	8.21	16.2	23.5	30.0	
Multivariable odds ratios ¹	0.58 (0.42, 0.81)	1.00	1.66 (1.51, 1.81)	2.17 (2.01, 2.35)	<0.001
Multivariable odds ratios ²	0.54 (0.39, 0.75)	1.00	1.57 (1.43, 1.72)	2.10 (1.94, 2.28)	<0.001
Multivariable odds ratios ³	0.55 (0.39, 0.76)	1.00	1.46 (1.33, 1.60)	1.87 (1.72, 2.03)	<0.001
Year 4					
Overweight (%)	11.7	18.7	27.4	33.1	
Multivariable odds ratios ¹	0.46 (0.32, 0.68)	1.00	1.60 (1.46, 1.76)	2.23 (2.06, 2.42)	<0.001
Multivariable odds ratios ²	0.42 (0.28, 0.62)	1.00	1.51 (1.37, 1.66)	2.17 (2.00, 2.36)	<0.001
Multivariable odds ratios ³	0.43 (0.29, 0.64)	1.00	1.37 (1.24, 1.51)	1.87 (1.72, 2.04)	<0.001
Year 5					
Overweight (%)	11.7	17.6	25.6	31.9	

	Children's birth weight					P for trend
	Low birth weight (<2500g)	Normal birth weight (2500–4000g)			Macrosomia (>4000g)	
		BMI<85%	BMI 85%	BMI 85%		
Multivariable odds ratios ¹	0.63 (0.45, 0.88)	1.00	1.63 (1.49, 1.79)	2.22 (2.05, 2.41)	<0.001	
Multivariable odds ratios ²	0.56 (0.40, 0.79)	1.00	1.54 (1.40, 1.69)	2.16 (1.98, 2.34)	<0.001	
Multivariable odds ratios ³	0.57 (0.41, 0.81)	1.00	1.39 (1.26, 1.53)	1.84 (1.69, 2.01)	<0.001	
Year 6						
Overweight (%)	20.4	22.7	31.4	37.3		
Multivariable odds ratios ¹	0.89 (0.62, 1.27)	1.00	1.57 (1.40, 1.76)	2.05 (1.85, 2.28)	<0.001	
Multivariable odds ratios ²	0.80 (0.56, 1.15)	1.00	1.47 (1.31, 1.65)	1.96 (1.77, 2.18)	<0.001	
Multivariable odds ratios ³	0.81 (0.56, 1.18)	1.00	1.32 (1.17, 1.49)	1.67 (1.50, 1.86)	<0.001	

¹ Adjusted for maternal age.

² Adjusted for maternal age, education, family income, weight gain during pregnancy, smoking status, hypertensive disorders of pregnancy, gestational age at delivery, and infant feeding.

³ Adjusted for above variables and also for maternal early pregnancy BMI.