Predicting Preschooler Obesity at Birth: The Role of Maternal Obesity in Early Pregnancy

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ABSTRACT. ***Objective.*** **Knowing risk factors at birth for the development of childhood obesity could help to identify children who are in need of early obesity prevention efforts. The objective of this study was to determine whether children whose mothers were obese in early pregnancy were more likely to be obese at 2 to 4 years of age.**

Methods. **A retrospective cohort study was conducted of 8494 low-income children who were enrolled in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) in Ohio and were followed from the first trimester of gestation until 24 to 59 months of age. Measured height and weight data from WIC were linked to birth certificate records for children who were born in the years 1992–1996. Obesity among 2- to 4-year-olds was defined as a body mass index (BMI) ≥95th percentile for age and gender. Mothers were classified as obese (BMI ≥30 kg/m²) or nonobese (BMI <30 kg/m²) on the basis of BMI measured in the first trimester of the child's gestation.**

Results. **The prevalence of childhood obesity was 9.5%, 12.5%, and 14.8% at 2, 3, and 4 years of age, respectively, and 30.3% of the children had obese mothers. By 4 years of age, 24.1% of children were obese if their mothers had been obese in the first trimester of pregnancy compared with 9.0% of children whose mothers had been of normal weight (BMI ≥18.5 and <25 kg/m²). After controlling for the birth weight, birth year, and gender of the children plus the mothers' age, race/ethnicity, education level, marital status, parity, weight gain, and smoking during pregnancy, the relative risk of childhood obesity associated with maternal obesity in the first trimester of pregnancy was 2.0 (95% confidence interval [CI]: 1.7–2.3) at 2 years of age, 2.3 (95% CI: 2.0–2.6) at 3 years of age, and 2.3 (95% CI: 2.0–2.6) at 4 years of age.**

Conclusion. **Among low-income children, maternal obesity in early pregnancy more than doubles the risk of obesity at 2 to 4 years of age. In developing strategies to prevent obesity in preschoolers, special attention should be given to newborns with obese mothers.** ***Pediatrics*** **2004;114:e29–e36. URL: http://www.pediatrics.org/cgi/content/full/114/1/e29;** ***obesity, child, mothers, birth weight, pregnancy.***

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ABBREVIATIONS. WIC, Special Supplemental Nutrition Program for Women, Infants, and Children; BMI, body mass index; WHZ, weight-for-height *z* score; OR, odds ratio.

Although there are twice as many obese children now as there were 20 years ago,[1] we still know little about the exact cause of this trend or how best to stop it. However, if the trend is to be slowed, then there are several reasons that obesity prevention may be a better approach than obesity treatment and why prevention efforts should begin very early in life. A major reason to begin prevention early is that the prevalence of obesity has increased even among preschoolers,[2–5] many of whom remain obese into adolescence.[6] Furthermore, obesity increases the risk of physiologic,[7] functional,[8] and emotional morbidity[9] in children, and obese children are also at increased risk of obesity[10,11] and mortality[12,13] in adulthood.

In the United States, obesity is now recognized as a major public health problem that requires population-level approaches to prevention that alter the environment to affect food intake and energy expenditure.[14–16] However, as a complement to this strategy, it will remain important to have an individual-level approach to prevention that involves behavioral counseling, especially for families whose children are at highest risk of becoming obese early in life.[17] One major difficulty with the latter approach is that few available data allow identification, at birth, of those who are at highest risk to become obese preschoolers.

The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) provides an ideal setting for identifying newborns who are at highest risk for later obesity and for subsequently developing an approach to preventing the development of obesity in preschoolers. WIC is a federal program that provides supplemental food and nutrition counseling to low-income pregnant and postpartum mothers and to their children from birth until 60 months of age. Almost half of US children are enrolled in WIC at some point during infancy, and almost 1 in 4 US children are enrolled at 2 to 4 years of age.[18]

It was established long ago in cross-sectional studies that obesity aggregates within families and that obese mothers are more likely to have obese children.[19,20] However, no study has ever examined the probability of obesity in preschoolers according to maternal weight during early pregnancy. This study tested the hypothesis that newborns whose mothers are obese in the first trimester of pregnancy are at an increased risk of being obese at 2 to 4 years of age.

METHODS

Overview

This retrospective cohort study involved a sample of children from Ohio WIC. These were children who were born in the years 1992–1996 and for whom clinical data were available from their first trimester of gestation until 24 to 59 months of age. Clinical data that are routinely available at birth were used to predict obesity in the preschool years. The study data were assembled by linking children's height and weight measurements, obtained in WIC, to their birth certificate data and to the height and weight measurements collected on their mothers in WIC during the first trimester of pregnancy.

A mother or a child can meet the income eligibility criteria for WIC when their household income is ≤185% of the federal poverty level (≤$34 040 per year for a family of 4 in 2003).[21] However, children can also meet the income eligibility criteria when they are enrolled in Medicaid. During the time of this study, the cut point for Ohio Medicaid eligibility was as high as 309% of the federal poverty level.[22]

Height and weight measurements on mothers and children are obtained as part of the nutritional assessment to determine eligibility for WIC. For pregnant women, these measurements occur at the time of WIC enrollment. For children, they occur at enrollment and at 6-month intervals when recertification visits are required. These height and weight data are recorded in a computerized database.

Through computerized record linkage, WIC anthropometric data were combined with birth certificate data, and this process also allowed the joining of the anthropometric data on mothers and children, a linkage not otherwise possible within the Ohio WIC database. The Ohio WIC database included visit records for the period January 1, 1994, through June 30, 2001, but it also included visit data from before 1994 on any mother or child who was enrolled in WIC on January 1, 1994. Children in the WIC database were linked to birth certificate data from the years 1992–1996. The Institutional Review Boards of Cincinnati Children's Hospital Medical Center and the Ohio Department of Health approved this study, and each waived the requirement for individual subject consent for the analyses of these administrative data.

Data Linkage

All linkages between the WIC and birth certificate databases were accomplished using 9 data fields contained in each database: the child's full name (first, middle initial, and last), birth date, and gender along with the mother's full name (first, middle initial, and last) and birth date. First, all records in WIC for each child were linked using the child's name, gender, and birth date. Therefore, children who had breaks in WIC enrollment, entered foster or adoptive care, or made moves within the state had all of their WIC data consolidated even when they were assigned different WIC identification numbers over time. Maternal WIC visit records were also linked using not only the mother's name and birth date but also the mother's social security number. Because mothers in the WIC database often used maiden names and/or multiple married names, records with the same social security number, birth date, first name, and middle initial were considered to be from the same woman even when the last names did not match. This process consolidated maternal WIC data across multiple pregnancies in which mothers may have been enrolled using different WIC identification numbers and/or last names.

Child WIC data were linked to maternal WIC data in a 2-step process. All children in WIC were first linked to their birth certificate, and then the name of the child's mother, obtained from the birth certificate, was used to link the child to the mother's WIC data. The link of WIC children to their birth certificates was made only when there was a complete match on name (first, middle initial, and last), gender, and birth date. This reduced the possibility of linking a child in WIC to the incorrect birth certificate data and, in turn, to the WIC data of the wrong mother. The mother's birth date, first name, middle initial, and both married and maiden last names on the birth certificate were used to link the child to the mother's WIC records, if available. When a mother in WIC used >1 last name, a linkage was attempted to any of the last names that she used in WIC.

Study Measures

Anthropometric Data

Ohio WIC used the recommend protocols, developed by the Centers for Disease Control and Prevention, for obtaining height and weight measurements.[23–25] Both mothers and children were evaluated while wearing light clothing and no shoes. Weight was obtained with an electronic or balance-beam scale, and stature was obtained using a stadiometer (usually wall mounted). Measurements were recorded to the nearest quarter of a pound (0.1 kg) and quarter of an inch (0.6 cm).

Study Covariates From the Birth Certificates

The child's birth certificate provided the following variables: the child's birth weight, gestational age, gender, birth year, and birth plurality (singleton vs multiple birth) plus the mother's race/ethnicity, parity, cigarette use in pregnancy (yes/no), education (years), pregnancy weight gain, and marital status. Because there were so few mothers in Ohio of Hispanic origin, all mothers who reported Hispanic origin on the birth certificate, regardless of race, were combined and 4 separate maternal race/ethnicity groups were used in the analysis: white (non-Hispanic), black (non-Hispanic), Hispanic, and "other." I used no paternal data because paternal information was not recorded on ~20% of birth certificates and no information on paternal height or weight was recorded in the WIC database.

Children were placed into 3 categories of birth weight for gestational age—small (<10th percentile), appropriate (10th–89th percentile), and large (≥ 90th percentile)—using separate gender- and maternal parity-specific percentiles for non-Hispanic whites (used for whites and "others"),[26] Mexican Americans (used for Hispanics),[26] and blacks.[27] The clinical gestational age was used rather than the gestational age calculated from the date of the last menstrual period. This choice was made because the date of the last menstrual period was missing in 23% of the WIC children who linked to their birth certificates and because the distribution of birth weight among children <35 weeks' gestation was less skewed when using the clinical gestational age measure.[27] Birth weights <400 g or >7000 g and gestational ages <23 weeks or >43 weeks were considered implausible and set to missing. Pregnancy weight gain was computed as the net rate of weight gain (kilograms/week) by subtracting the birth weight from the self-reported pregnancy weight gain and then dividing the result by the number of weeks of gestation.

Cleaning of Anthropometric Data and Calculation of Body Mass Index

Child Data

Between January 1, 1994, and June 30, 2001, a total of 203 788 unique children visited an Ohio WIC clinic and were 24 to 59 months of age at the visit and had been born in the years 1992–1996. The weight-for-height z score (WHZ) for each child's available paired height and weight measurement was calculated using the 2000 Centers for Disease Control and Prevention growth reference.[28] Paired measurements were excluded when the height was outside the range used to calculate WHZ in the growth reference (77–121.5 cm) or when the WHZ was biologically implausible[29] (WHZ <-4 or >5). The remaining paired measurements were converted to a body mass index (BMI) value (kg/m^2), the preferred method for assessing childhood fatness on the basis of weight and height measures,[30] leaving at least 1 BMI value on 203 345 children.

Maternal Data

From all of the measured height values available on each mother in the WIC database, the median was selected. After maternal weight values that were considered implausible were removed (<50 pounds or >500 pounds), weights that were obtained during the child's first trimester of gestation were selected after the pregnancy was dated using the child's birth date and gestational age. This first-trimester weight served as the proxy for the maternal weight at conception because measured maternal prepregnancy weight is rarely available, self-reported prepregnancy weight varies by sociodemographic factors, and, despite individual variations, the weight gain in the first trimester of pregnancy is small (1–2 kg).[31,32] For each child, the mother's first-trimester BMI was computed from her median height and her earliest recorded first-trimester weight.

Data Analysis

Of the 203 345 children with at least 1 valid BMI measure, 110 343 could be linked the their birth certificate, and, of these, 51 542 could be linked to their mother's WIC records. The final study sample was reduced to 8494 children who also had data available on their mother's BMI during the first trimester of gestation and who were singleton births. Analyses were conducted separately on 3 subsamples of these children: those with at least 1 BMI measurement at 1) 2 years of age (24–35 months; $n = 7188$), 2) 3 years of age (36–47 months; $n = 6438$), and 3) 4 years of age (48–59 months; $n = 5401$). Each child did not contribute BMI data at each age interval. Of the 8494 children studied, 4230 had data in all 3 age intervals, 2073 in 2 age intervals, and 2191 in only 1 age interval. The entire analysis was not restricted to the smaller sample of children with data in all 3 age intervals because doing so would have increased the variance in the estimates, at each age, of the risk of childhood obesity associated with maternal obesity. When a child had >1 valid BMI measurement in a given age interval, 1 BMI measurement in that interval was randomly selected for the analysis. There were no siblings within each age group.

All variables were reported categorically to facilitate clinical interpretation and application. The primary outcome variable was obesity (BMI ≥95th percentile) at 2, 3, and 4 years of age, and the main predictor variable was the maternal first-trimester BMI level, categorized according to the 5 levels established by the World Health Organization.[29] Maternal BMI was also examined as a dichotomous variable, and mothers with a BMI ≥30 kg/m² were considered obese. χ^2 tests were used to evaluate the bivariate association of childhood obesity with maternal BMI categories and with the levels of each covariate. To assess the possible interaction between maternal obesity and several covariates (the child's gender and birth weight and the mother's race/ethnicity, smoking status, age, and pregnancy weight gain), I calculated the relative risk of childhood obesity associated with maternal obesity at each level of the covariate (eg, relative risks in each of the 3 birth weight groups). The relative risks were compared across these levels using the Mantel-Haenszel test of homogeneity to identify significant differences in relative risks (eg, across the 3 birth weight groups, comparing the relative risk of child obesity associated with maternal obesity). To examine the independent association of maternal first-trimester BMI level with childhood obesity, I conducted multivariate logistic regression analyses to adjust for covariates such as birth weight. Covariates were placed in the regression models when they were significantly ($P \leq .05$) associated with childhood obesity in at least 1 age group in bivariate analyses and/or had been shown in previous studies to be associated with childhood obesity.

TABLE 1. Characteristics of 8494 Children at Birth

	n*	%
Maternal BMI†		
<18.5 kg/m²	430	5.1
18.5–24.9 kg/m²	3476	40.9
25–29.9 kg/m²	2016	23.7
30–39.9 kg/m²	2037	24.0
≥40 kg/m²	535	6.3
Birth weight		
<2500 g	651	7.7
2500–3999 g	7015	82.7
≥4000 g	821	9.7
Birth weight for gestational age		
Small (<10th percentile)	1067	12.6
Appropriate (10–89th percentile)	6704	78.3
Large (≥90th percentile)	688	8.1
Child gender		
Female	4289	50.5
Male	4205	49.5
Maternal race/ethnicity‡		
White	6754	79.5
Black	1475	17.4
Hispanic	207	2.4
Other	58	0.7
Parity		
First-born child	4116	48.6
Not a first-born child	4356	51.4
Smoking in pregnancy		
No	5690	67.1
Yes	2785	32.9
Birth year		
1992	70	0.8
1993	1440	17.0
1994	2031	23.9
1995	2481	29.2
1996	2472	29.1
Maternal education		
<High school	224	2.6
Some high school	2519	29.7
High school	4327	51.1
Some college	1231	14.5
College or beyond	171	2.0
Marital status		
Married	3817	44.9
Not married	4677	55.1
Maternal age		
<18 y	726	8.5
18–24 y	4693	55.3
25–29 y	1695	20.0
≥30 y	1380	16.2

* Children have missing values where total does not equal 8494.
† Measured in the first trimester of child's gestation.
‡ Mutually exclusive categories where the "Hispanic" category includes those of any race listing "Hispanic" ethnicity.

RESULTS

The majority of the 8494 children were born to mothers who were either white or black (Table 1). One third were born to mothers who smoked during pregnancy, and one third were born to mothers who had not finished high school. Delivery occurred before 37 weeks' gestation for 8.7% of children and before 33 weeks for 1.8%. The prevalence of childhood obesity was 9.5%, 12.5%, and 14.8% at 2, 3, and 4 years of age, respectively. On the basis of the BMI value at each child's oldest age of measurement (mean age: 48.2 months), the prevalence of obesity was 13.2%, and the prevalence was 13.1%, 13.4%, and 15.0% ($P = .72$) in the children of white, black, and Hispanic mothers, respectively. Maternal BMI was measured, on average, at 9.3 weeks' gestation, and the mean (±standard deviation) BMI was 27.3 ± 7.2 kg/m². More than 30% of the children had a mother who was obese, and almost 1 in 15 had a mother with a BMI ≥40 kg/m² (Table 1). The rates of maternal prepregnancy obesity did not differ significantly according to the year of measurement (data not shown) but did differ by maternal race/ethnicity (29.4% in whites, 35.5% in blacks, 23.7% in Hispanics; $P <$ .001).

Obesity during the preschool years was strongly associated with the prepregnancy BMI level of the mother (Table 2). Among children whose mothers were obese in the first trimester of pregnancy (BMI ≥30 kg/m²), the prevalence of obesity at ages 2, 3, and 4 years was 15.1%, 20.6%, and 24.1%, respectively, which was 2.4 to 2.7 times the prevalence of obesity among children who were born to normal-

TABLE 2. Relationship Between Characteristics of Children at Birth and the Percentage of Children Obese (BMI ≥95th Percentile) at Various Preschool Ages

Characteristic at Birth	2-Year-Olds (24–35 Months; n = 7188)		3-Year-Olds (36–47 Months; n = 6438)		4-Year Olds (48–59 Months; n = 5401)	
	% Obese	P Value*	% Obese	P Value*	% Obese	P Value*
Maternal BMI†		<.001		<.001		<.001
<18.5 kg/m²	2.5		4.4		4.7	
18.5–24.9 kg/m²	6.4		7.5		9.0	
25–29.9 kg/m²	9.0		12.0		14.5	
30–39.9 kg/m²	13.9		19.7		22.8	
≥40 kg/m²	19.4		24.0		28.8	
Birth weight for gestational age		<.001		<.001		<.001
Small (<10th percentile)	5.2		6.5		8.7	
Appropriate (10–89th percentile)	9.1		12.6		14.7	
Large (≥90th percentile)	20.5		21.2		25.6	
Gender		.15		<.001		.002
Female	9.0		10.7		13.3	
Male	10.0		14.4		16.3	
Race/ethnicity (mother)‡		.03		.08		.59
White	9.4		12.7		14.6	
Black	9.2		11.1		15.2	
Hispanic	15.6		17.9		17.8	
Other	14.8		10.5		9.7	
Parity		.12		.013		.10
First-born child	10.1		13.6		15.6	
Not a first-born child	9.0		11.5		14.0	
Smoking in pregnancy		.03		.28		.51
No	9.0		12.2		14.6	
Yes	10.6		13.2		15.3	
Pregnancy weight gain§		.003		.001		0.15
Quartile 1 (lowest)	11.2		14.4		15.9	
Quartile 2	7.5		10.4		12.9	
Quartile 3	9.5		11.0		14.3	
Quartile 4 (highest)	9.6		13.6		15.2	
Birth year		.06		.10		.24
1992–1993	9.4		11.8		13.3	
1994	8.0		11.6		14.1	
1995	10.2		12.1		14.9	
1996	10.3		14.1		16.1	
Maternal education		.47		.23		.08
<High school	9.6		14.4		14.2	
Some high school	9.4		11.7		13.5	
High school	10.0		13.3		15.9	
Some college	8.4		11.0		13.2	
College or beyond	7.2		13.6		19.8	
Marital status		.64		.58		.53
Married	9.4		12.3		14.4	
Not married	9.7		12.7		15.1	
Maternal age		.08		.05		.05
<18 y	7.1		9.3		11.6	
18–24 y	9.3		12.3		14.4	
25–29 y	10.6		13.9		16.7	
≥30 y	10.0		13.1		15.4	
Total	9.5		12.5		14.6	

* P value for χ^2 test.
† Measured in the first trimester of child's gestation.
‡ Mutually exclusive categories where the "Hispanic" category includes those of any race listing "Hispanic" ethnicity.
§ Net rate of pregnancy weight gain (maternal weight gain − birth weight/length of gestation).

weight mothers (BMI ≥18.5 and <25 kg/m²). Among those who were born to obese mothers, the prevalence of BMI ≥85th percentile at ages 2, 3, and 4 years was 28.4%, 36.9%, and 41.2%, respectively.

Children of obese mothers were twice as likely as those of nonobese mothers to be large for gestational age at birth (12.4% vs 6.3%; $P < .001$). Children who were large for gestational age were also more likely to be obese preschoolers (Table 2). No other covariates had nearly as strong or consistent an association with preschooler obesity, but some patterns of association were present. For example, newborns who were male, were first born, or had a mother of Hispanic ethnicity tended to have a higher prevalence of obesity as preschoolers. There was also a trend for children who were born in later birth years or to mothers who were older to have a higher prevalence of obesity. Although mothers who smoked during pregnancy were more likely than nonsmokers to have children who were small for gestational age (20.2% vs 8.9%; $P < .001$), they tended to have children who were more likely to be obese as preschoolers. There was no definite pattern of bivariate association between becoming obese as a preschooler and the mother's education level, marital status, or weight gain during pregnancy. When interactions were evaluated, there were no significant ($P > .05$) differences in the association between maternal obesity and preschooler obesity according to child gender or birth weight category or maternal age, race/ethnicity, smoking status, or pregnancy weight gain. For example, the relative risks of child obesity at 4 years of age associated with maternal obesity were 1.8, 2.2, and 2.2 in small-, appropriate-, and large-for-gestational-age infants, respectively (other data not shown).

After adjusting for all covariates, including birth weight category, the association between the mother's BMI level in the first trimester of pregnancy and the child's obesity at all preschool ages was strong and increased with increasing maternal BMI (Table 3). In the multivariate regression models for each preschool age (Table 3), large birth weight for gestational age, being first born, and having a mother who smoked during pregnancy all were independently associated with higher obesity risk. Boys were at higher risk at 3 and 4 years of age but not at 2 years of age.

In these same multivariate models (Table 3), when maternal BMI was entered as a dichotomous variable

TABLE 3. Logistic Regression Models Showing Adjusted Odds* of Obesity (BMI ≥95th Percentile) at Various Preschool Ages

Characteristic at birth	2-Year-Olds (24–35 Months; n = 6764†)		3-Year-Olds (36–47 Months; n = 6063†)		4-Year Olds (48–59 Months; n = 5089†)	
	OR	95% CI	OR	95% CI	OR	95% CI
Maternal BMI‡						
<18.5 kg/m²	0.41	0.21–0.81	0.63	0.36–1.10	0.56	0.31–1.00
18.5–24.9 kg/m²	1.00§		1.00		1.00	
25–29.9 kg/m²	1.42	1.13–1.79	1.69	1.35–2.10	1.75	1.40–2.18
30–39.9 kg/m²	2.28	1.84–2.83	3.06	2.49–3.76	3.07	2.48–3.79
≥40 kg/m²	3.05	2.22–4.18	3.82	2.8–5.19	4.31	3.17–5.87
Birth weight for gestational age						
Small (<10th percentile)	0.55	0.39–0.76	0.49	0.35–0.67	0.61	0.45–0.83
Appropriate (10–89th percentile)	1.00		1.00		1.00	
Large (≥90th percentile)	2.33	1.84–2.96	1.59	1.25–2.03	1.69	1.32–2.17
Gender						
Female	1.00		1.00		1.00	
Male	1.10	0.93–1.30	1.41	1.21–1.66	1.27	1.08–1.49
Race/ethnicity (mother)‖						
White	1.00		1.00		1.00	
Black	0.99	0.78–1.25	0.82	0.65–1.03	1.02	0.81–1.27
Hispanic	1.87	1.17–3.00	1.47	0.94–2.31	1.20	0.75–1.94
Other	2.67	1.21–5.93	1.11	0.38–3.28	0.83	0.24–2.86
Parity						
First-born child	1.33	1.09–1.62	1.42	1.17–1.70	1.34	1.11–1.62
Not a first-born child	1.00		1.00		1.00	
Smoking in pregnancy						
No	1.00		1.00		1.00	
Yes	1.43	1.19–1.72	1.25	1.05–1.49	1.21	1.01–1.45
Pregnancy weight gain¶						
Quartile 1 (lowest)	1.00		1.00		1.00	
Quartile 2	0.79	0.62–1.00	0.84	0.67–1.05	0.95	0.76–1.20
Quartile 3	1.00	0.79–1.26	0.95	0.75–1.20	1.12	0.89–1.42
Quartile 4 (highest)	0.92	0.72–1.16	1.07	0.86–1.34	1.09	0.87–1.37
Birth year						
1992/1993	1.00		1.00		1.00	
1994	0.82	0.63–1.08	0.96	0.74–1.25	1.13	0.86–1.48
1995	1.12	0.87–1.43	0.99	0.78–1.27	1.19	0.92–1.53
1996	1.05	0.82–1.35	1.16	0.91–1.48	1.26	0.98–1.63
Maternal education						
<High school	1.23	0.72–2.11	1.40	0.86–2.27	1.10	0.66–1.84
Some high school	1.12	0.9–1.38	1.00	0.82–1.22	0.94	0.77–1.16
High school	1.00		1.00		1.00	
Some college	0.74	0.57–0.97	0.76	0.59–0.97	0.76	0.59–0.97
College or beyond	0.67	0.34–1.31	1.05	0.60–1.84	1.14	0.64–2.03
Marital status						
Married	1.00		1.00		1.00	
Not married	1.02	0.85–1.22	1.11	0.94–1.32	1.06	0.89–1.27
Maternal age						
<18 y	0.76	0.52–1.11	0.79	0.55–1.12	0.93	0.66–1.32
18–24 y	1.00		1.00		1.00	
25–29 y	1.21	0.97–1.52	1.23	0.99–1.52	1.20	0.96–1.49
≥30 y	1.09	0.85–1.40	1.13	0.89–1.44	1.06	0.83–1.35

CI indicates confidence interval.
* Each column in the table represents a single model with all ORs adjusted for all other variables in the column.
† Sample size is reduced because some cases had missing data on variables included in the regression model.
‡ Measured in the first trimester of child's gestation.
§ OR of 1.0 indicates the referent category for each variable.
‖ Mutually exclusive categories where the "Hispanic" category includes those of any race listing "Hispanic" ethnicity.
¶ Net rate of pregnancy weight gain (maternal weight gain − birth weight/length of gestation).

(obese, BMI ≥30 kg/m^2, and nonobese, BMI <30 kg/m^2) rather than as 5 BMI levels, the adjusted odds (95% confidence intervals) of obesity at 2, 3, and 4 years of age associated with maternal obesity were 2.2 (1.8–2.6), 2.6 (2.2–3.1), and 2.6 (2.2–3.1), respectively. These odds ratios (ORs) did not change when birth weight, pregnancy weight gain, and maternal age at delivery were entered in the model as continuous variables (data not shown). When only maternal obesity was entered in the model, the addition of birth weight for gestational age modestly altered the value of the regression coefficient associated with the maternal obesity (8% change at 2 years of age and 5% at ages 3 and 4 years). When the ORs for maternal obesity were converted to relative risks[33] to account for the high prevalence of childhood obesity in children of nonobese mothers (8%–9%), the adjusted relative risks of childhood obesity associated with maternal obesity were 2.0 (1.7–2.3), 2.3 (2.0–2.6), and 2.3 (2.0–2.6) at 2, 3, and 4 years of age, respectively.

DISCUSSION

In this sample of almost 8500 low-income preschool children enrolled in Ohio WIC between 1994 and 2001, >30% of their mothers were obese in the first trimester of pregnancy. Even after controlling for birth weight, newborns whose mothers were obese in early pregnancy were more than twice as likely to be obese preschoolers. By 4 years of age, obesity was present in almost 1 in 4 of the children who were born to obese mothers compared with <1 in 10 of children who were born to normal-weight mothers. Obesity during the preschool years was also associated with other clinical factors easily assessed at birth, such as high birth weight, being first born, and having a mother who smoked in pregnancy. However, in multivariate models that contained a number of risk factors, maternal obesity in early pregnancy emerged as the risk factor with the largest OR.

The study was limited to children in a single-state WIC program, and it evaluated only children whose mothers had BMI measured in WIC during the first trimester of the pregnancy. However, the rates of childhood obesity[18] and maternal obesity[34] were similar to those described in the WIC population as a whole during this period. The internal validity of these findings is enhanced by several aspects of the study method: the measurement of both maternal and child BMI, the application of a high-specificity data linkage algorithm, and the adjustment for a variety of other clinical variables that might confound the association between maternal and child obesity. Although BMI data on fathers might have further enhanced the prediction of early childhood obesity, these data were unavailable for analysis, just as they are often unavailable in clinical practice.

It has previously been shown that prepregnancy BMI in mothers is associated with obesity in young adulthood,[35–37] but it has not been clear how early in life children who are born to obese mothers begin to express their risk of obesity. Stunkard et al[38] suggested that this risk relationship does not emerge until at least 3 to 4 years of age, but the results here show that children who were born to obese mothers were twice as likely to be obese by 2 years of age.

There are many mechanisms by which a mother's obesity in early pregnancy might confer risk of obesity to her child, including the child's inheritance of genes that confer susceptibility to obesity,[39] the effects of maternal obesity on the intrauterine environment,[40,41] and the maternal role in shaping the child's postnatal eating and activity environment. This study cannot distinguish among those possibilities. Although obese mothers delivered children with higher birth weights, the odds of preschooler obesity associated with maternal obesity changed little with the addition of the child's birth weight to the regression models. This suggests that effect of the mother's obesity on the child's obesity was not primarily mediated by those intrauterine influences that are expressed in higher birth weight.[42] Indeed, by adulthood, the association of birth weight with adult fatness is no longer present after controlling for maternal prepregnancy weight.[35,37]

In addition to this study, at least 4 others have now shown an association between maternal smoking in pregnancy and obesity in children.[43–46] The mechanism for this association remains unclear, and the association is a paradoxical one given that maternal smoking reduces birth weight and that lower birth weight is associated with lower BMI later in life.[40,41] One explanation may be that maternal smoking in pregnancy is a proxy for the child's postnatal environment in terms of diet and activity behaviors that are difficult to measure and that smoking during pregnancy does not, in itself, cause obesity in children. It is also plausible, however, that smoking affects the appetite regulation system in the developing brain.[47,48] Regardless of the mechanism linking maternal prenatal smoking and offspring obesity, the finding may be of clinical importance because there is emerging evidence that risk of obesity-related morbidity is higher in children who become obese after being born at low birth weight than in children who become obese after being born at normal or high birth weight.[49–51]

The findings of this study highlight the impact of maternal and child health on the current obesity epidemic. The population-level burden now imposed by obesity is likely to worsen even while obesity receives increasing attention as a public health problem. This is likely in consideration of the following: half of infants in the United States are living in households that meet the income-eligibility criteria for WIC, nearly one third of mothers in WIC are already obese when they conceive, one quarter of all children who are born to obese mothers are already obese by 4 years of age, and obese 4-year-olds who have obese mothers are 3 times more likely to be obese in young adulthood.[52]

Viewed more optimistically, however, the period before a mother conceives, during her pregnancy, and in the early years of her child's life may provide important opportunities to prevent obesity by affecting an intergenerational cycle that promotes obesity. In this regard, WIC is potentially well suited to have a role in obesity prevention because WIC reaches pregnant mothers and young children and is focused on nutrition-related health outcomes. Childhood obesity has now become the most significant nutritional problem facing the WIC population, and obesity-prevention strategies are being actively addressed by WIC. The data reported here strongly support the programmatic step recently taken by WIC to implement a new nutrition risk criterion, entitled "at risk for overweight." This criterion now permits income-eligible children to be certified for WIC if they are born to mothers who were obese in pregnancy. Although we still do not understand the best way to prevent childhood obesity, these data suggest that where the resources to address this problem are necessarily limited, we should consider focusing on children who are born to obese mothers, and we should try to develop interventions that begin at or before the birth of the child.

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