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Gestational weight gain and child adiposity at age 3 years

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Abstract

OBJECTIVE— The purpose of this study was to examine the associations of gestational weight gain with child adiposity.

STUDY DESIGN— Using multivariable regression, we studied associations of total gestational weight gain and weight gain according to 1990 Institute of Medicine guidelines with child outcomes among 1044 mother-child pairs in Project Viva.

RESULTS— Greater weight gain was associated with higher child body mass index z-score (0.13 units per 5 kg [95% CI, 0.08, 0.19]), sum of subscapular and triceps skinfold thicknesses (0.26 mm [95% CI, 0.02, 0.51]), and systolic blood pressure (0.60 mm Hg [95% CI, 0.06, 1.13]). Compared with inadequate weight gain (0.17 units [95% CI, 0.01, 0.33]), women with adequate or excessive weight gain had children with higher body mass index z-scores (0.47 [95% CI, 0.37, 0.57] and 0.52 [95% CI, 0.44, 0.61], respectively) and risk of overweight (odds ratios, 3.77 [95% CI: 1.38, 10.27] and 4.35 [95% CI: 1.69, 11.24]).

CONCLUSION— New recommendations for gestational weight gain may be required in this era of epidemic obesity.

Keywords

adiposity; blood pressure; overweight; pregnancy; weight gain

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Maternal weight gain during pregnancy is an important determinant of birth outcomes. In 1990, the Institute of Medicine published guidelines for gestational weight gain, motivated by evidence that low weight gain may cause fetal growth restriction and increased perinatal mortality rates.[1,2] These guidelines call for smaller gains in mothers with higher body mass index (BMI) and generally permit greater gains than previous recommendations. However, many women gain outside of the recommended amount, and excessive gains have become more common.[3,4]

Gestational weight gain is directly associated with birthweight adjusted for gestation length (fetal growth).[1,5] Fetal growth is directly associated with offspring BMI.[6,7] By alteration of the intra-uterine environment, the amount of weight gained during pregnancy not only influences fetal growth but also may result in persistent programming of child weight, as has been shown previously with other intrauterine exposures such as maternal smoking and diabetes mellitus.8,9

However, most studies of perinatal predictors of later obesity have not considered gestational weight gain.[6,10,11] The few published studies of gestational weight gain and offspring obesity are limited by retrospective data, lack of information on potential confounding factors, and pregnancies that occurred before the current epidemic of obesity.[12-14] In the present study, we used data from an ongoing prebirth cohort study to determine whether maternal weight gain during pregnancy programs child adiposity. In addition, to inform health policy recommendations, we studied whether weight gain within or above the recommended range increased the risk for child overweight, compared with lower gains.

Methods

Population and study design

Study subjects were participants in Project Viva, a prospective cohort study of pregnant women and their children. We previously reported the recruitment protocols.[8] Mothers provided informed consent. The human subjects committee of Harvard Pilgrim Health Care approved all study protocols.

Of 2128 women who delivered a live singleton infant, 1585 women enrolled for continuation beyond 6 months after delivery. At the time of this analysis, 1110 children had completed the study visit at age 3 years. We excluded participants for whom information was missing on prepregnancy weight, parental BMI, or infant birthweight, or who did not have a weight recorded within 4 weeks preceding delivery; therefore, 1044 mother-child pairs were included in the study. The 1084 mothers who were not included in this analysis were more likely to be black (22% vs 11%) or Hispanic (9% vs 6%), to be not married (11% vs 6%), and to have a slightly higher mean prepregnancy BMI (25.2 vs 24.6 kg/m^2), but they were similar in mean gestational weight gain (15.4 vs 15.6 kg) and rates of inadequate (16% vs 14%) and excessive (50% vs 51%) gain.

Measures of gestational weight gain

We calculated total gestational weight gain as the difference between the last weight recorded before delivery and self-reported prepregnancy weight. We also categorized women as having gained inadequate, adequate, or excessive weight according to Institute of Medicine guidelines.[1] These guidelines recommend that women with a “normal” prepregnancy BMI (19.8–26.0 kg/m^2) should gain 11.5–16 kg, that women with a BMI of <19.8 kg/m^2 should gain 12.5–18 kg, that women with a BMI of 26.0–29.0 kg/m^2 should gain 7–11.5 kg, and that women with a BMI of <29.0 kg/m^2 should gain at least 6.0 kg. We set an upper limit of 11.5 kg for these heaviest women.[4] We defined *net gain* as infant birthweight subtracted from total gestational weight gain. For analysis of preterm birth as an outcome, we used the rate of weight gain after the first trimester (kilograms gained after week 12 divided by the weeks of gestation after week 12).

We performed a validation study that compared self-reported prepregnancy weight with clinically measured weights among 170 study participants who had weight recorded in the medical record within 3 months before their last menstrual period. The association between self-reported and clinically measured weight was linear. Correlation coefficients (r = 0.99 overall) and mean underreporting of weight (approximately 1 kg) did not differ by race/ ethnicity, gestational age at study enrollment, or weight itself.

Assessment of child anthropometry

We measured child height and weight using a calibrated stadiometer (Shorr Productions, Olney, MD) and scale (Seca model 881; Seca Corporation, Hanover, MD). We calculated age- and sex-specific BMI percentiles and z-scores with 2000 CDC reference data.[15] We defined *child overweight* as a BMI of ≥95th percentile. We also measured subscapular and triceps skinfold thicknesses using Holtain calipers (Holtain LTD, Cross-well, UK) and calculated the sum and ratio of the 2 thicknesses. Research assistants followed standardized techniques[16] and participated in biannual in-service training (Shorr Productions). Inter- and intrarater measurement error was within published reference ranges.[17] Using biannually calibrated Dinamap Pro-100 oscillometric automated monitors (GE Medical Services, Tampa, FL), research assistants measured child blood pressure up to 5 times at 1-minute intervals and recorded measurement conditions that included order of readings, cuff size, limb, child position, and activity state.

Assessment of covariates

Using interviews and questionnaires we collected self-reported maternal race/ ethnicity, age, education, parity, household income, prepregnancy weight and height, and paternal weight and height, from which we calculated BMI (kg/m^2). We obtained prenatal glucose tolerance test results and child sex, birthweight and delivery date from the medical record. We calculated gestation length from the last menstrual period, or from the second trimester ultrasound if the two estimates differed by > 10 days. We determined birthweight for gestational age z-value ("fetal growth") based on US national reference data.[18] We defined small for gestational age as < 10th percentile for sex, and large for gestational age as > 90th percentile. At 6 months postpartum, we measured infant weight and height. Mothers reported duration of breastfeeding on postpartum questionnaires. At 3 years postpartum, mothers reported their child's television viewing habits and frequency of consumption of fast food and sugar-sweetened beverages.

Statistical analysis

We used multinomial logistic regression[19] to examine associations of gestational weight gain with child BMI percentile in the categories <50th, 50th to 84th, 85th to 94th, and ≥ 95th percentile. This method includes all observations with available data and calculates the odds of being in each outcome category compared with the reference group, which we classified as BMI < 50th percentile. We chose this reference group based on evidence that even a "normal" BMI above the median in childhood is associated with later obesity.[20]

We used linear regression to examine associations of gestational weight gain with child BMI z-score and the sum and ratio of subscapular and triceps skinfold thicknesses. We generated estimated BMI z-score means and standard errors within weight gain categories using means and proportions of participant characteristics. For systolic blood pressure, we used mixed-effect regression models, incorporating each of the up to 5 measurements per child as repeated outcome measures.[21] We additionally studied associations of weight gain with small and large for gestational age birth, cesarean section, and preterm delivery as outcomes, using multivariable logistic regression.

In the final multivariable models, we included only those covariates that were of a priori interest, were independent predictors of the outcome, or confounded associations of gestational weight gain with child size. Included covariates were maternal prepregnancy BMI, prenatal smoking, race/ethnicity, household income, marital status, glucose tolerance, duration of any breast-feeding, paternal BMI; and child sex, fetal growth, and gestation length. We additionally adjusted blood pressure models for measurement conditions (cuff size, limb, child position, and activity state). By use of "missing" categories we included participants missing information on glucose tolerance (1%), smoking (3%), and breastfeeding duration (13%). Adjustment for maternal age, education, parity, time between the last pregnancy weight and delivery, newborn length, and child diet and television viewing did not appreciably change estimates, so we did not include these factors in our final models. In the subset of children who were weighed at 6 months of age, we additionally adjusted estimates for the change in weight-for-age z-score from birth to 6 months of age.

We performed all analyses using SAS version 8.2 (SAS Institute, Cary, NC).

Results

Mean (SD) maternal prepregnancy BMI was 24.6 kg/m^2 (5.0), and total gestational weight gain was 15.6 kg (5.4). Approximately one-third (29%) of mothers had a prepregnancy BMI > 26.0 kg/m^2. According to the 1990 Institute of Medicine recommendations, 51% of women gained excessive weight, 35% gained adequate weight, and 14% gained inadequate weight (Table 1). Mean (SD) child BMI z-score was 0.45 units (1.01), and 9% of children were overweight (BMI ≥ 95th percentile for age and sex).

On bivariate analysis, gestational weight gain was directly associated with child overweight (OR 1.30, 95% CI: 1.04, 1.62 for each 5 kg). Adjustment for sociodemographic factors, breastfeeding duration, glucose tolerance, and gestation length did not markedly change estimates (Table 2), but adjustment for maternal and paternal BMI strengthened the association (OR 1.66, 95% CI: 1.31, 2.12) (Table 2). Additional adjustment for fetal growth, which is likely in the pathway between gestational weight gain and child size, slightly attenuated estimates (OR 1.52, 95% CI: 1.19, 1.94). When we instead used BMI < 85th percentile as a reference group, gestational weight gain remained associated with a risk of BMI ≥ 95th percentile (OR 1.44, 94% CI: 1.17, 1.79).

Total gestational weight gain was associated with child BMI z-score (0.13 units, 95% CI: 0.08, 0.19 per 5 kg) as well as the sum of subscapular and triceps skinfold thicknesses (0.26 mm, 95% CI: 0.02, 0.51) (Table 2), but not with the ratio of subscapular to triceps skinfolds, a measure of truncal obesity (0.003, 95% CI: −0.01, 0.01). The association of net weight gain with child adiposity (0.12 BMI z-score units, 95% CI: 0.07, 0.18, per 5 kg) was similar to that for total weight gain. Additional adjustment for children's television viewing habits and consumption of fast food and sugar-sweetened beverages did not appreciably alter results (0.13 BMI z-score units, 95% CI: 0.07, 0.19, per 5 kg).

Children of mothers in all Institute of Medicine weight gain groups, even those with inadequate gain, had mean BMI z-scores above the median of the 2000 CDC growth curves,[15] which were primarily based upon US children in the 1970s.[22] Compared with children exposed to inadequate gestational weight gain, who had an adjusted mean BMI z-score of 0.17 (95% CI: 0.01, 0.33), children exposed to adequate (0.47 units, 95% CI: 0.37, 0.57) or excessive (0.52 units, 95% CI: 0.44, 0.61) gain had higher BMI z-scores (Figure 1). Women with adequate or excessive gain had approximately a 4-fold increased odds of having an overweight child (odds ratios 3.77, 95% CI: 1.38, 10.27, and 4.35, 95% CI: 1.68, 11.24, respectively), compared with inadequate gain (Table 3).

We next performed additional analyses to explore whether observed associations differed by selected maternal and child characteristics. Gestational weight gain was similarly associated with child BMI z-score among children of mothers with prepregnancy BMI 19.8 to 26.0 kg/m^2 (0.12 units, 95% CI: 0.04, 0.20 per 5 kg) and BMI >26.0 kg/m^2 (0.16 units, 95% CI: 0.06, 0.25 per 5 kg). Accordingly, we saw no evidence for a multiplicative interaction between pre-pregnancy BMI and gestational weight gain (*P* value = .51). Among the 787 children weighed at age 6 months, additional adjustment for change in weight-for-age z score from birth to 6 months did not diminish the estimated effect of gestational weight gain on child BMI z-score

(0.14 units, 95% CI: 0.08, 0.21 per 5 kg). Gestational weight gain remained directly associated with child BMI z-score when we limited the analysis to the 859 mothers with normal glucose tolerance during pregnancy (0.14 units, 95% CI: 0.07, 0.20 per 5 kg) and when we excluded the 67 children born before 37 completed weeks of gestation (0.13, 95% CI: 0.08, 0.19 per 5 kg).

We had blood pressure information for 970 children. Mean (SD) systolic blood pressure was 92.1 mm Hg (10.9). After multivariable adjustment (Table 2), systolic blood pressure was an estimated 0.60 mm Hg (95% CI: 0.06, 1.13) higher per 5 kg of gestational weight gain. This effect was partially accounted for by the association of gestational weight gain with child size, a major determinant of blood pressure, and was reduced to 0.34 mm Hg (95% CI: −0.19, 0.87 per 5 kg) after additional adjustment for child BMI.

Because recommendations for gestational weight gain historically have been based on relationships with birth outcomes, we also studied associations with outcomes at birth. Compared with inadequate gain, women with adequate gain did not have a different risk of small or large for gestational age or caesarean birth (Table 3). Women with excessive gain had an increased risk of having a large for gestational age baby and a possible reduction in small for gestational age, but no difference in cesarean section rates (Table 3). The mean (SD) rate of weight gain after the first trimester was 0.51 (0.18) kg/week. This rate was not associated with risk of preterm birth (adjusted OR 0.98, 95% CI: 0.85, 1.14 per 0.1 kg/wk). Five (19%) of the 27 women with an extremely low rate of gain (de-fined as < 1 kg/month after the first trimester for those with prepregnancy BMI ≤ 26.0, or < 0.5 kg/month for pre-pregnancy BMI > 26.0)[1] had preterm births (adjusted OR of preterm birth 3.49, 95% CI: 1.14, 10.67), although none had a small for gestational age infant.

Comment

In this prospective study of over 1000 mother-child pairs, we found that mothers with greater gestational weight gain had children with more adiposity at 3 years of age, measured by skinfold thickness as well as by BMI. This association was independent of parental BMI, maternal glucose tolerance, breastfeeding duration, fetal and infant growth, and child behaviors. Children of mothers who gained more weight also had somewhat higher systolic blood pressure, a cardiovascular risk factor related to adiposity even in young children. Similar to the US population as a whole,[23] many mothers and their children in this cohort were overweight, and a majority of mothers gained more weight than is currently recommended by the Institute of Medicine.[3,24,25] Compared with mothers who had inadequate gestational weight gain, even mothers with so-called adequate gain had a substantially higher risk of having children who were overweight, with no difference in risk of undesirable birth outcomes such as small or large for gestational age birth or cesarean section. Preterm birth was more common among mothers with an extremely low rate of gain.

The 1990 Institute of Medicine report "Nutrition during Pregnancy" [1] remains the standard for clinical recommendations regarding gestational weight gain. This report followed decades of evidence that weight gain during pregnancy influences birth outcomes, in particular fetal growth. However, some have questioned whether evidence is sufficient that greater gains promote better birth outcomes in modern developed nations.[2] Higher gestational weight gain may cause undesirable birth outcomes such as increased rates of macrosomia and cesarean sections,[24,26,27] and is associated with higher postpartum weight retention and later risk for obesity in the mother.[28,29]

The current study is one of few that have examined associations of weight gain during pregnancy with offspring outcomes after birth. In 1 study of children born in the 1960s, gestational weight gain was approximately 1 kg higher among mothers of children above the 95th percentile of weight for height compared with those below the 5th percentile, although this analysis was not adjusted for any parental or child characteristics.[12] Gestational weight gain was not associated with child weight in several more recent studies,[13,14,30] although in these papers weight gain was not the primary predictor of interest, and thus its association with child overweight was not explored in depth. Three additional studies published to date as abstracts only have supported an association between gestational weight gain and offspring overweight,[31-33] although 2 include data on pregnancies that occurred over 30 years ago to mothers who were generally not overweight.[32,33] No published study has reported on direct measures of adiposity such as skinfold thickness or physiologic sequelae of excess adiposity such as blood pressure, or has categorized weight gain according to the currently used Institute of Medicine guidelines.

Gestational weight gain may be linked with child adiposity through several potential pathways. Mothers who gain weight readily because of genetic, dietary, or other behavioral factors may have children who also are more likely to gain weight. Adjustment for maternal and paternal BMI as well child behaviors minimizes some of the effect of shared genes and extrauterine environment. Alternatively, weight gain during pregnancy may program offspring size by modifying the intrauterine environment of the fetus. The search for potential mechanisms by which intrauterine nutrition may program offspring health remains an area of active investigation.[34]

The population we studied was generally insured and well educated, and results may not be generalizable to other populations, especially those with a low prevalence of obesity. However, the frequencies of inadequate and excessive weight gain were similar to those reported in lower income US populations.[35] Prepregnancy weight was self-reported and may be underestimated, and thus gestational weight gain may be overestimated. However, our validation study indicated that ranking of individuals is likely preserved. Although the time between the last measured weight and delivery varied by up to 4 weeks, we saw no evidence that adjustment for the difference influenced our analyses. Breastfeeding duration did not differ according to gestational weight gain; in other populations women with both inadequate and excessive weight gain have tended to breastfeed for a shorter duration.[36] Strengths of the present study include the prospective design, the large number of sociodemographic, behavioral, and pathway variables that we considered, and the research standards used to measure childhood outcomes.

In conclusion, mothers who gained more weight during pregnancy had children at higher risk for overweight in early childhood. Because childhood obesity is increasing in prevalence and effective treatment remains elusive, prevention remains critical. The Institute of Medicine may need to reevaluate its recommendations for gestational weight gain, considering not only birth outcomes but also risk of obesity for both mother and child. Efforts to moderate weight gain during pregnancy may help to stem the rising tide of childhood obesity.

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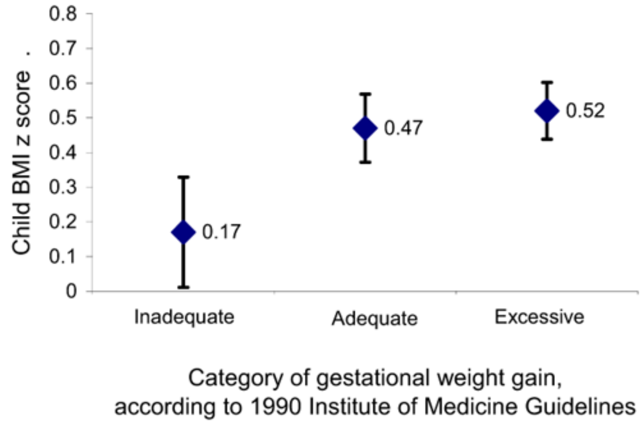

FIGURE.
Child BMI z-score at age 3 years, according to the maternal gestational weight gain category recommended by the Institute of Medicine[1]
Estimates and 95% CIs are from multivariable linear regression models with the use of means and proportions of participant characteristics that have been adjusted for sociode-mographic variables, maternal and paternal body size, glucose tolerance, breastfeeding duration, gestation length, and child age and sex.

TABLE 1

Participant characteristics and their associations with gestational weight gain among 1044 mother-child pairs in Project Viva

Characteristic	Subjects n (%)	Total gestational weight gain in kilograms (mean ± SD)	Gestational weight gain per Institute of Medicine recommendations n (%)		
			Inadequate	Adequate	Excessive
Maternal					
Study population	1044 (100%)	15.6 ± 5.4	108 (14%)	279 (35%)	400 (51%)
Age at enrollment (y)					
15–24	66 (6%)	15.0 ± 6.1	19 (29%)	17 (26%)	30 (45%)
25–34	648 (62%)	16.0 ± 5.3	75 (12%)	216 (33%)	357 (55%)
35–44	330 (32%)	15.0 ± 5.3	49 (15%)	136 (41%)	145 (44%)
Race/ethnicity					
Black	112 (11%)	14.7 ± 5.8	19 (17%)	46 (41%)	47 (42%)
Hispanic	60 (6%)	14.5 ± 5.5	9 (15%)	24 (40%)	27 (45%)
White	772 (74%)	15.9 3 5.3	100 (13%)	261 (34%)	411 (53%)
Other	100 (10%)	15.2 ± 5.1	15 (15%)	38 (38%)	47 (47%)
Prepregnancy BMI (kg/m^2)[1]					
<19.8	124 (12%)	15.7 ± 4.5	30 (24%)	64 (52%)	30 (24%)
19.8–26.0	622 (60%)	16.4 ± 4.8	79 (13%)	240 (39%)	303 (49%)
26.1–29.0	134 (13%)	15.3 ± 5.3	7 (5%)	24 (18%)	103 (77%)
>29.0	164 (16%)	13.1 ± 7.1	27 (16%)	41 (25%)	96 (59%)
Smoking[*]					
Never	703 (67%)	15.4 ± 5.1	99 (14%)	268 (38%)	336 (48%)
Quit before pregnancy	211 (20%)	15.9 ± 5.5	28 (13%)	68 (32%)	115 (55%)
Smoked in early pregnancy	102 (10%)	17.2 ± 6.5	13 (13%)	23 (23%)	66 (65%)
Marital status					
Married/cohabiting	984 (94%)	15.7 ± 5.3	131 (13%)	346 (35%)	507 (52%)
Single/divorced/widowed	60 (6%)	15.0 ± 6.4	12 (20%)	23 (38%)	25 (42%)
Parity					
Nulliparous	505 (48%)	16.3 ± 5.3	55 (11%)	176 (35%)	274 (54%)
Parous	539 (52%)	15.0 ± 5.4	88 (16%)	193 (36%)	258 (48%)
Glucose tolerance test result[†]					
Gestational diabetes mellitus	46 (4%)	11.6 ± 6.2	16 (35%)	13 (28%)	17 (37%)
Impaired glucose tolerance	127 (12%)	14.9 ± 5.7	16 (13%)	44 (35%)	67 (53%)
Normal	859 (82%)	15.9 ± 5.3	108 (13%)	311 (36%)	440 (51%)
Delivery					
Caesarean section	242 (23%)	15.6 ± 6.0	29 (12%)	84 (35%)	128 (53%)
Vaginal	802 (77%)	15.7 ± 5.2	114 (14%)	284 (35%)	404 (50%)
Paternal BMI (kg/m^2)					
<25	374 (36%)	15.7 ± 5.0	53 (14%)	147 (39%)	174 (46%)
≥25	670 (64%)	15.6 ± 5.6	90 (13%)	222 (33%)	358 (53%)
Child					
Male	530 (51%)	16.1 ± 5.3	61 (12%)	180 (34%)	289 (55%)
Female	514 (49%)	15.2 ± 5.4	82 (16%)	189 (37%)	243 (47%)
Birthweight for gestational age percentile					
Small (<10th)	50 (5%)	14.4 ± 3.9	11 (22%)	25 (50%)	14 (28%)
Appropriate (10th-90th)	857 (82%)	15.4 ± 5.3	122 (14%)	308 (36%)	427 (50%)
Large (<90th)	137 (13%)	17.6 3 5.7	10 (7%)	36 (26%)	91 (66%)
Duration of any breastfeeding (mo)[‡]					
<1	157 (15%)	15.4 ± 6.1	26 (14%)	43 (33%)	88 (53%)
1–6	320 (31%)	15.8 ± 5.3	41 (13%)	115 (36%)	164 (51%)
7–11	181 (17%)	15.7 ± 4.9	27 (15%)	63 (35%)	91 (50%)
≥12	249 (24%)	15.7 ± 5.0	35 (14%)	93 (37%)	121 (49%)
BMI at age 3 y (percentile)					
<50th	321 (31%)	15.0 ± 5.1	64 (20%)	114 (35%)	143 (45%)
50th–84th	449 (43%)	15.8 ± 5.4	53 (12%)	162 (36%)	234 (52%)
85th–94th	182 (17%)	15.9 ± 5.5	19 (10%)	64 (35%)	99 (54%)
≥95th	92 (9%)	16.5 ± 5.9	7 (7%)	29 (32%)	56 (61%)

[*] Information missing (28; 3%).

[†] Information missing (12; 1%).

[‡] Information missing (137; 13%).

TABLE 2

Associations of maternal gestational weight gain with child adiposity-related outcomes at age 3 years, before and after adjustment for potential confounding and pathway variables

Model covariate	Odds ratio: BMI* ≥95th percentile vs <50th percentile (95% CI)	BMI z-score* units (95% CI)	Sum of subscapular and triceps skinfold thicknesses in millimeters (95% CI)	Systolic blood pressure in millimeters of mercury† (95% CI)
0 (unadjusted)	1.30 (1.04, 1.62)	0.10 (0.04, 0.16)	0.18 (−0.06, 0.42)	0.33 (−0.17, 0.83)
1 (model 0 + covariates)‡	1.34 (1.07, 1.69)	0.09 (0.03, 0.14)	0.18 (−0.07, 0.42)	0.51 (−0.01, 1.04)
2 (model 1 + parental BMI)	1.66 (1.31, 2.12)	0.13 (0.08, 0.19)	0.26 (0.02, 0.51)	0.60 (0.06, 1.13)
3 (model 2 + fetal growth)§	1.52 (1.19, 1.94)	0.11 (0.05, 0.17)	0.25 (0.00, 0.50)	0.56 (0.01, 1.10)

Effect estimates are for a 5-kg increment in total weight gain.

*BMI for age and sex as compared with US national reference population[17]; odds ratios from multinomial logistic regression analysis of the entire study cohort.

†All blood pressure analyses are adjusted additionally for blood pressure measurement conditions and child age and sex.

‡Maternal prenatal smoking, race/ethnicity, household income, marital status, glucose tolerance, gestation length, breastfeeding duration, and child's sex.

§Defined as birthweight for gestational age z-value, by sex.[20]

TABLE 3

Adjusted odds* of child outcomes according to Institute of Medicine categories of maternal gestational weight gain

Child BMI at age 3 y†	**N (%)**	**Odds ratio: Institute of Medicine category of weight gain (95% CI)**		
		Inadequate	**Adequate**	**Excessive**
Percentile				
50th–84th	449 (43)	1.0	1.85 (1.17, 2.92)	1.84 (1.17, 2.88)
85th–94th	182 (17)	1.0	2.09 (1.12, 3.92)	2.03 (1.11, 3.72)
≥95th	92 (9)	1.0	3.77 (1.38, 10.27)	4.35 (1.69, 11.24)
Fetal growth‡				
Small for gestational age	50 (5)	1.0	1.13 (0.51, 2.52)	0.53 (0.22, 1.32)
Large for gestational age	137 (13)	1.0	1.42 (0.66, 3.06)	2.17 (1.06, 4.44)
Cesarean section	242 (23)	1.0	1.27 (0.77, 2.09)	1.31 (0.81, 2.11)

*All odds ratios adjusted for maternal prepregnancy BMI, prenatal smoking, race/ethnicity, household income and marital status, glucose tolerance, paternal BMI, gestation length, and child's sex.

†BMI percentiles for age and sex compared with US national reference population[17]; all groups are compared with BMI <50th percentile by multinomial logistic regression; odds ratios for BMI are adjusted additionally for breastfeeding duration.

‡*Small-for-gestational age* defined as birthweight for gestational age <10th percentile; *large-for-gestational age* defined as >90th percentile, by sex.[20]