HHS Public Access
Author manuscript
Pediatr Obes. Author manuscript; available in PMC 2016 August 01.

Published in final edited form as:
Pediatr Obes. 2015 August ; 10(4): 305–310. doi:10.1111/ijpo.262.

Is gestational weight gain associated with offspring obesity at 36 months?

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Abstract

Objective—We examined the association between gestational weight gain (GWG) and offspring obesity at age 36 months.

Methods—Mother-infant dyads (n=609) were followed from a first study visit (mean (standard deviation): 18.8 (2.7) weeks gestation) to 36 months postpartum. Total GWG over the entire pregnancy was defined as excessive or non-excessive according to the 2009 Institute of Medicine guidelines. Four mutually exclusive categories of excessive or non-excessive GWG across early (conception to first study visit) and late (first study visit to delivery) pregnancy defined GWG pattern. Body mass index (BMI) z-scores ≥95th percentile of the 2000 CDC references defined offspring obesity at 36 months. Multivariable log-binomial models adjusted for prepregnancy BMI and breastfeeding were used to estimate the association between GWG and childhood obesity risk.

Results—Nearly half of the women had total excessive GWG. Of these, 46% gained excessively during both early and late pregnancy while 22% gained excessively early and non-excessively late, and the remaining 32% gained non-excess weight early and excessively later. Thirteen percent of all children were obese at 36 months. Excessive total GWG was associated with more than twice the risk of child obesity [adjusted risk ratio (95% CI): 2.20 (1.35, 3.61)] compared with

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Conflict of interest statement: The authors declare that they have no conflicts of interest

overall non-excessive GWG. Compared with a pattern of non-excessive GWG in both early and late pregnancy, excessive GWG in both periods was associated with an increased risk of obesity [2.39 (1.13, 5.08)].

Conclusions—Excessive GWG is a potentially modifiable factor that may influence obesity development in early childhood.

Keywords

Weight Gain; Pediatric Obesity; Maternal Nutritional Physiological Phenomena; Prenatal Exposure Delayed Effects; Pregnancy Trimesters

Introduction

Pediatric obesity is one of the most important public health concerns in the United States. From 1971 to 2000, obesity prevalence rates more than doubled for preschoolers and adolescents, more than tripled for children 6 to 11 years (1), and have since plateaued for all age groups (2), except among 2 to 5 year-olds, for whom obesity rates have declined by 43% in the last 10 years (3). Childhood obesity has been associated with a variety of immediate and long-term comorbidities, such as insulin resistance, diabetes mellitus, hypertension, asthma, altered pubertal timing, depression, unhealthy eating behaviors, and substance use (4). Moreover, obese children are also more likely to be obese adults (5). Given that obesity is resistant to treatment, research efforts focused on modifiable factors to prevent obesity are essential.

Gestational weight gain (GWG) may influence offspring obesity risk in early life. A recent meta-analysis suggested that excessive total GWG may be associated with offspring weight in early childhood (6), though studies among young children have been inconsistent (7–11). Moreover, evidence suggests that fetal programming may be time-sensitive. Thus, the timing of maternal weight gain may be linked to offspring body size and fat mass, with early GWG exerting greater influence than later gain (12). Use of an overall measure of GWG across the entirety of pregnancy may contribute to inconsistent results because it is a heterogeneous measure, mixing periods of excessive gain which may or may not result in a total excessive weight gain.

Our objective was to estimate the risk of obesity in early childhood in relation to total GWG as well as patterns of early and late GWG.

Methods

The study sample included mother and child pairs participating in the Maternal Health Practices and Child Development project. Comprehensive descriptions of study design and methods are available elsewhere (13). Briefly, from 1982 to 1985, women <26 weeks pregnant and attending a prenatal clinic at Magee-Womens Hospital in Pittsburgh, PA were recruited for a study of the effects of prenatal substance use. Two cohorts were selected: (1) the alcohol cohort consisted of women who drank three or more alcoholic drinks per week in the first trimester and a random sample women who drank less often and (2) the marijuana cohort consisted of women who used two or more joints per month in the first trimester and a random sample of those who reported using less often. Women could be in either or both cohorts; we studied the combined cohort (n=829). The Institutional Review Boards of Magee-Womens Hospital and University of Pittsburgh approved the original study and written, informed consent was obtained at each study phase.

There were 763 women with live, singleton births that were eligible for follow-up evaluations at 8, 18, and 36 postnatal months. At the 36 month follow-up visit, n=56 dyads were excluded because the child died, or was adopted, or the family moved more than 150 miles away. Among the remaining 707 dyads, 35 refused or were lost to follow-up, resulting in n=672 interviewed at 36 months. We further excluded dyads for whom maternal prepregnancy BMI (self-reported pregravid weight (kilograms) divided by height (meters) squared) or GWG data were missing (n=24), those with missing child weight or height data at 36 months (n=31), those where the mother's first study visit was ≥26 weeks (n=6), and those with implausible child weight-for-age or BMI-for-age z-scores (n=2), resulting in a total of 609 mother-child dyads for analysis.

Our primary exposure was GWG relative to the 2009 Institute of Medicine recommendations. Women self-reported the amount of weight they gained from conception to the first prenatal visit [mean: 18.8 (standard deviation (SD), 2.7) weeks gestation] and from conception to delivery. We studied total GWG (conception to delivery) as well as pattern of weight gain during early pregnancy (conception to first prenatal visit) and late pregnancy (first prenatal visit to delivery). We evaluated total GWG as well as early- and late-pregnancy GWG by comparing it to the recommended GWG, based on prepregnancy BMI-specific first-trimester weight gain and the range of recommended rate of gain in the 2nd and 3rd trimesters (14). We classified GWG in each period as excessive if it was greater than the upper limit of recommended GWG and non-excessive otherwise. Then for pattern of GWG, we created four mutually exclusive groups based on excessive and non-excessive gain during early and late pregnancy. To determine the sensitivity of our findings to residual confounding by gestational age, we additionally calculated GWG z-scores for total GWG (15).

Our primary outcome was offspring obesity at 36 months, defined as a BMI z-score ≥95th percentile on sex and age-adjusted CDC growth charts (16). Child's weight and length at 36 months were measured using a calibrated scale operated by trained pediatric study nurses.

Covariates including race, marital status, employment status, monthly household income, education level, parity, mental health, and substance use were ascertained via maternal interview at the first visit. The frequency of tobacco, alcohol, and marijuana use during the first trimester (13) as well as patterns over the course of pregnancy (abstained throughout pregnancy; abstained after first trimester; did not abstain after first trimester) and the postpartum period (≥1 packs/day at 8, 18, or 36 months; ≥1 drinks/day at 8, 18, or 36 months; ≥1 joint/day at 8, 18, or 36 months) was calculated based on interview data. Elevated maternal depressive symptoms and trait anxiety at the first visit were defined as scores ≥75th percentile on the Center for Epidemiologic Studies Depression Scale (17) and on the State-Trait Personality Inventory (18), respectively, and low social support was a score <25th percentile of a factor score (19). Gestational age at delivery and infant weight at birth were abstracted from medical records. Preterm birth was classified as the delivery of a liveborn infant at <37 weeks. Babies were classified as small- or large-for-gestational age (<10th percentile, >90th percentile, respectively) based on birth weight for gestational age z-scores (20). At 18 months, mothers reported having ever breastfed the child and the age at which solid foods were introduced to her child's diet (<6 months; ≥6 months). At 36 months, mothers recalled the usual frequency of child's fruit, vegetable, sugared drink, and soda consumption using a simple questionnaire designed for the study.

Statistical Analysis

Pearson chi-square tests were used to study the bivariate associations between maternal characteristics at the first visit and category of total and pattern GWG, and with childhood obesity. Multivariable log-binomial regression models were used to estimate the relative risks (RR) of childhood obesity at 36 months by categories of total and pattern GWG after adjusting for confounders. We also ran these models among a subset of children who were not obese at the previous study visit at 18 months (BMI at 18 months <95th percentile on age and sex-adjusted WHO growth charts (2006)) to estimate whether associations were observed after the critical period of infant growth. GWG was classified as excessive or non-excessive, grouping women who gained inadequately and adequately together because of the similarity in their adjusted risk ratio. In sensitivity analyses, we examined continuous total GWG z-score and considered nonlinearity using restricted cubic splines as well as tertiles based on the distribution.

Theory-based causal diagrams (21) were used to select potential confounders (maternal prepregnancy BMI, age, race, parity, first trimester income, education, substance use, child's sex, and dietary characteristics). Parsimonious models were generated by removing potential confounders from the full model based on a change in the main-effect estimate by ≥10%. Only prepregnancy BMI and ever-breastfed met our definition of confounding and were retained in our final models. Gestational age at delivery and birth weight were considered potential mediators on the causal path from GWG to child weight and were not included in models (22). Effect modification on the additive scale was evaluated by prepregnancy overweight, race, maternal depression, anxiety, prenatal substance use, and child's sex using the synergy index (23). Finally, we applied inverse probability sample weights (24) to reweight the study sample to reflect the original prenatal clinic sample from which the cohort was selected. Stata Software, version 11 (College Station, TX) was used for analysis.

Results

Most women (62%) in the study had a normal prepregnancy BMI (Table 1). Women tended to be young (mean 23.1 years of age), unmarried (67%), have at least a high-school education (86%), and have a monthly household income <$400 (62%). A majority of women drank alcohol in the first trimester (65%), half smoked tobacco (53%), and two in five women used marijuana. Black mothers and nulliparous mothers made up approximately half of the sample. Children were light at birth [mean (SD) birth weight for gestational age z-score −0.36 (0.94)] and born at term [39.1 (2.18)].

A majority of women had total non-excessive GWG (55%), of which, 36% had total inadequate GWG and 64% had total adequate GWG. For the 45% of women with total excessive GWG, half had excessive GWG in both early and late pregnancy, while the remainder gained excessively in only one of these periods (Table 2). Mothers who had a higher prepregnancy BMI and more years of education tended to gain excessive weight during both early and late pregnancy as compared to lean women and women who were less educated, respectively (online supplement). There were no significant differences in pattern of GWG by maternal race/ethnicity, income, prenatal substance use, sex, or infant ever breastfed status.

Thirteen percent of children were obese at 36 months. Of these, approximately half were already obese prior to their 18-month study visit, while the remainder developed obesity between 18 and 36 months of age. Women who were heavier at the start of pregnancy were more likely to have an obese child at 36 months, but there were no differences in other maternal or child characteristics by child obesity status at 36 months (Table 3).

Women who had total excessive GWG were more likely than women with total non–excessive GWG to have an obese child at 36 months (Table 4). In models adjusted for prepregnancy BMI and ever breastfed status, total excessive GWG was associated with a higher risk of childhood obesity at 36 months. Similarly, among the subset of children who were not obese at 18 months (n=392), total excessive GWG remained associated with increased obesity risk at 36 months (adjusted RR (95% CI): 2.51 (1.23, 5.11)).

Compared with women whose GWG pattern was non-excessive in both early and late pregnancy, women who had excess GWG in both periods were more than twice as likely to have an obese child at 36 months after adjustment (Table 4). Compared with the same referent, a pattern of early excessive gain and late non-excessive gain was associated with a higher risk of child obesity in crude models, but the effect was attenuated after adjustment. In contrast, a gain pattern of early non-excessive and late excessive was unassociated with obesity risk in crude or adjusted models. There was no interaction between early and late GWG for the risk of child obesity.

In a series of sensitivity analyses, none of the results changed meaningfully when we applied inverse probability sample weights; excluded heavy alcohol or marijuana users (≥1 drink or ≥1 joint per day in the first trimester) or those who continued prenatal use of alcohol or marijuana; or used GWG z-scores to classify GWG. Our findings of GWG z-scores supported a positive non-linear association between GWG and risk of child obesity at 36 months, confirming our findings for excessive GWG. We did not find evidence of effect modification on the additive scale by prepregnancy BMI, maternal depression, anxiety, alcohol use, marijuana use, tobacco cigarette use, race, or child sex in any of the models.

Discussion

In a sample of predominantly low-income mothers, women who gained more weight during pregnancy than is recommended by the 2009 IOM Committee (14) had children with an increased risk of obesity at 36 months as compared with women with non-excessive gain.

This link between excessive GWG and childhood obesity appeared to be limited to women who gained excessively during both early and late periods of their pregnancy and was not evident in women with excessive gain only in either early or late pregnancy. This association remained after adjustment for confounders.

Studies on total GWG and BMI in children aged approximately 2 to 5 years are mixed (7, 9–11, 25, 26). We reported a positive relationship, consistent with those (9, 11, 25, 26) that classified total GWG according to guidelines that account for strong confounding by prepregnancy BMI (14). Although we lacked child anthropometric indicators of body composition other than child BMI, others have found that total excessive GWG is associated with offspring higher summed triceps and subscapular skinfold thickness at 36 months (9), waist circumference, and DEXA-measured fat mass at 4 and 5 years (8, 25).

Studies of pattern of GWG and childhood weight tend to suggest that higher GWG in early pregnancy has a stronger influence on childhood anthropometric indicators of body composition than later-pregnancy weight gain (27). In contrast, we found that the increased risk of childhood obesity was statistically significant only among women who gained excessively in both early and late pregnancy. Unlike our study, von Kries and colleagues used data from a large Bavarian retrospective cohort and found that regardless of GWG at <14 weeks or 14 to <26 weeks, GWG ≥26 weeks may contribute to the risk of childhood obesity (28).

In both our study and von Kries' study, GWG at <26 weeks was the earliest period of pregnancy studied, yet gain in earlier periods may be more relevant to fetal programming. Higher early maternal weight gain may reflect an increase in maternal fat (14), which may influence biological processes that promote offspring fat accrual. Early pregnancy overnutrition may program developing fetal tissues to function suboptimally, ultimately impacting body composition. Maternal weight gain in later pregnancy is attributed to rapid fetal growth (14); thus, overnourishment in late gestation may influence overall body composition. Thus, children of women with excess weight gain throughout pregnancy may indeed have an elevated risk for later obesity.

Our analysis has several limitations. Substance use in this cohort was common during pregnancy, which may limit generalizability. Nevertheless, our results were similar when we eliminated heavy substance users from our analysis. We used self-reported GWG data, perhaps resulting in GWG misclassification. However, the reporting of weight occurred shortly after the patient was weighed at a prenatal visit or delivery, perhaps reducing the likelihood of major bias. Like previous reports (8, 9, 27, 28), we did not find evidence that the effect of total GWG on childhood obesity varied by prepregnancy BMI, or that the effect of early excessive GWG was modified by late GWG, but our sample size may have been too small to detect these effects.

Unmeasured confounding by shared family characteristics of mothers and children remains possible. We tested a number of child dietary characteristics, such as ever breastfed and regular intake of sugared drinks and fruits and vegetables as confounders in our model, and the results did not change. However, these factors were not measured with validated instruments and residual confounding may exist. In a study of GWG across two pregnancies in the same mother, and a positive association between GWG and childhood obesity was eliminated after accounting for shared factors in the sibling analysis (7). More research is needed to evaluate the causality of these associations.

Excessive GWG is common in U.S. mothers (14), and our study adds to the growing body of evidence linking excessive weight gain during pregnancy to offspring obesity. If randomized trials prove that this is a casual relationship, then interventions to reduce excessive GWG may serve not only to improve the health of mothers but to break the intergenerational link between excess adiposity in mothers and their children.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

NIH/NICHD grant: R01 HD072008 (L.B.)

NIH/NIAAA grant: AA06666 (N.D.)

NIH/NIDA grant: DA03874 (N.D.)

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Table 1

Characteristics of the study sample, n=609.

	%
Prepregnancy body mass index (kg/m^2)	
Underweight (<18.5)	12
Normal weight (18.5–24.9)	60
Overweight (25.9–29.9)	18
Obese (≥30.0)	10
Maternal race/ethnicity	
White	48
Black	52
Maternal age (years)	
<20	18
20–24	51
25–29	25
≥30	6
Maternal education (years)	
<12	27
=12	60
>12	13
Marital status	
Unmarried	68
Married	32
Employment	
Working or in school	25
Not working or in school	75
Income Level ($/month)	
<400	62
≥400	38
Parity	
Nulliparous	45
Multiparous	55
Prenatal smoking	
None	47
<0.5 packs/day	22
0.5 to <1 packs/day	18
≥1 packs/day	14
Prenatal alcohol use	
None	35
>0 to <1.5 drinks/week	21
1.5 drink/week to <1 drinks/day	25
≥1 drinks/day	19

	%
Prenatal marijuana use	
None	58
>0 to <0.5 joint/day	21
0.5 to <1 joints/day	7
≥1 joints/day	13
Prenatal smoking pattern	
Never used in pregnancy	43
First trimester use only	5
Second and/or third trimester use	52
Prenatal alcohol use pattern	
Never used in pregnancy	30
First trimester use only	38
Second and/or third trimester use	32
Prenatal marijuana use pattern	
Never used in pregnancy	58
First trimester use only	24
Second and/or third trimester use	18
Gestational age at delivery (weeks)	
<37 weeks	9
≥37 weeks	91
Birth weight for gestational age z-score *	
Small for age (<10th percentile)	16
Appropriate for age (10th to 90th percentile)	80
Large for age (>90th percentile)	4
Infant sex	
Female	50
Male	50
Ever breastfed infant	
Yes	22
No	78

*Reference for birth weight for gestational age z-score (20)

Table 2

Gestational weight gain (GWG) pattern by overall GWG.

GWG Pattern †	Overall sample	2009 IOM Overall GWG Category	
		Not Excessive	Excessive
	n (%)	n (%)	n (%)
Early non-excessive; late non-excessive	148 (24)	148 (44)	0 (0)
Early non-excessive; late excessive	166 (27)	79 (24)	87 (32)
Early excessive; late non-excessive	170 (28)	109 (32)	61 (22)
Early excessive; late excessive	125 (21)	0 (0)	125 (46)

†Pearson chi-square test $p<0.001$

Table 3

Childhood obesity at 36 months by characteristics of the sample.

	Obesity at 36 months (N=609)	
	Not Obese	**Obese**
Prepregnancy body mass index (kg/m^2), % †		
Underweight (<18.5)	96	4
Normal weight (18.5–24.9)	88	12
Overweight (25.9–29.9)	81	19
Obese (≥30.0)	82	18
Maternal race/ethnicity, %		
White	85	15
Black	90	10
Income level ($/month), %		
<400	88	12
≥400	86	14
Parity, %		
Nulliparous	85	15
Multiparous	89	11
Prenatal smoking, %		
None	88	12
<0.5 packs/day	86	13
0.5 to <1 packs/day	95	5
≥1 packs/day	82	19
Prenatal alcohol use, %		
None	85	15
>0 to <1.5 drinks/week	92	8
1.5 drink/week to <1 drinks/day	90	10
≥1 drinks/day	8	17
Prenatal marijuana use, %		
None	88	12
>0 to <0.5 joint/day	89	11
0.5 to <1 joints/day	85	15
≥1 joints/day	85	15
Gestational age at delivery (weeks), %		
<37 weeks	93	7
≥37 weeks	87	13
Birth weight for gestational age z-score, % *		
Small for age (<10th percentile)	90	10
Appropriate for age (10th to 90th percentile)	87	13
Large for age (>90th percentile)	82	18
Infant sex, %		

	Obesity at 36 months (N=609)	
	Not Obese	**Obese**
Female	89	11
Male	86	14
Ever breastfed infant, %		
Yes	85	15
No	88	12

†Pearson chi-square test $p<0.05$

*Reference for birth weight for gestational age z-score (20)

Table 4

Association between measures of gestational weight gain (GWG) and childhood obesity at 36 months (n=609).

	Obesity Status at 36 months		Unadjusted RR	Adjusted RR‡
	Not Obese	Obese	(95% CI)	(95% CI)
Overall GWG, n (%) †				
overall Non-excessive	313 (93)	23 (7)	1.0 (ref)	1.0 (ref)
overall Excessive	219 (80)	54 (20)	2.89 (1.82, 4.58)	2.20 (1.35, 3.61)
GWG Pattern, n (%) †				
Early non-excessive; late non-excessive	139 (94)	9 (6)	1.0 (ref)	1.0 (ref)
Early non-excessive; late excessive	148 (89)	18 (11)	1.78 (0.83, 3.85)	1.35 (0.62, 2.97)
early excessive; late non-excessive	148 (87)	22 (13)	2.13 (1.01, 4.45)	1.86 (0.88, 3.93)
early excessive; late excessive	97 (78)	28 (22)	3.68 (1.81, 7.51)	2.39 (1.13, 5.08)

†Pearson chi-square test $p<0.05$

‡Adjusted for prepregnancy body mass index and ever breastfed infant