Objective: This study aimed to evaluate the association between prepregnancy body mass index (BMI), gestational weight gain (GWG), and cesarean delivery in Hispanics.

Methods: We examined these associations among 1,215 participants in Proyecto Buena Salud, a prospective cohort of Hispanic women studied from 2006 to 2011. Prepregnancy BMI, GWG, and the mode of delivery were abstracted from medical records.

Results: A quarter of the participants entered pregnancy with obesity, 23% delivered via cesarean, and 52% exceeded the Institute of Medicine guidelines for GWG. After adjusting for age, women with obesity had 2.03 times the odds of cesarean delivery compared with women with normal BMI (95% confidence interval [CI]: 1.46-2.82); findings remained significant after adjusting for GWG. Women with excessive total GWG had 1.49 times the odds of cesarean delivery (95% CI: 1.06-2.10) compared with women who gained within guidelines. An excessive rate of third trimester GWG (standard deviation [SD] change in GWG per week) increased the odds of cesarean delivery (odds ratio = 1.66; 95% CI: 1.05-2.62), while an excessive rate of first and third trimester GWG was not associated with increased odds.

Conclusions: Obesity prior to pregnancy was associated with increased odds of cesarean delivery among Hispanics. Excessive GWG across pregnancy and an excessive rate of third trimester GWG were also associated with increased odds.

Introduction

Cesarean deliveries are associated with an increased risk of maternal and fetal morbidity and mortality compared with vaginal deliveries (1,2). Infants born via cesarean are at an increased risk for neonatal respiratory morbidity and hypoglycemia (2,3). Women who have had a previous cesarean are more likely to deliver subsequent pregnancies via cesarean (4).

While rates of cesarean delivery in the United States have increased from 22.3% to more than 32% in the past 15 years, they have recently stabilized among non-Hispanic black and white women at approximately 32.2% (5,6). Among Hispanics, rates vary substantially by Hispanic subgroup, with women of Puerto Rican and Dominican descent having 1.3 times the rate of cesarean delivery as compared with non-Hispanic whites, while Mexican Americans have 1.15 times the rate (7). Among Hispanic women, Puerto Rican women are one of the only subgroups with increasing rather than decreasing rates of cesarean (5). This is important as Hispanics are the largest minority group in the United States, with the highest birth rates of any minority group (8,9). Puerto Ricans are the second largest Hispanic subgroup in the United States (10,11) and the predominant subgroup in the Northeast (12).

Women who have overweight or obesity may experience an increased risk of cesarean delivery as a consequence of excess pelvic soft tissue, which can lead to a relative obstruction of the birth canal. In addition, decreased rates of cervical dilation after labor has begun and a subsequent increased rate of inductions (“failure to progress”) after labor has started have been observed among women with obesity, thereby also increasing their risk of cesarean delivery (13). Hispanic women are more likely to begin their pregnancies with overweight or obesity compared with non-Hispanic white women, with almost half entering pregnancy in these categories (14,15). The number of Hispanic women with both elevated BMI and excessive gestational weight gain (GWG) has been increasing over time (16).

Prior studies have tended to observe that prepregnancy overweight and obesity increase the risk of cesarean delivery (14). These obesity-related risks may vary by race or ethnicity, with Hispanic
and black women with obesity being more likely to have adverse outcomes than white women with obesity (17-19). In one of the few studies to examine racial or ethnic differences, Steinfeld et al. found that Hispanic gravidas with obesity were significantly more likely to deliver by cesarean than non-Hispanic whites with obesity (25.7% vs. 4.2%; \( P = 0.03 \)) (17). However, a meta-analysis of cohort studies found no differences in the association across ethnic groups, although data were not presented for Hispanics (20). Indeed, to our knowledge, no prior studies of prepregnancy BMI and cesarean delivery have focused on a Hispanic-only population. In addition, prior studies have often used nonstandard BMI categorizations (20) and have not excluded women with chronic diseases or preexisting conditions (21).

The role of GWG in cesarean delivery remains less clear. Excessive GWG may contribute to the risk of cesarean delivery via an increase in child birth weight, macrosomia, and an increased rate of preeclampsia independent of prepregnancy BMI (13). Prior studies have not typically considered trimester-specific measures of GWG (e.g., rate of GWG in the first, second, and third trimesters). This is important as weight gained during specific trimesters and the rate of such gain may have distinct and independent associations with cesarean delivery. In addition, older studies have not relied upon the most recent Institute of Medicine (IOM) guidelines for GWG (14). Finally, the majority of prior studies have not included Hispanic women.

In light of the elevated risks for obesity, GWG, and cesarean delivery among women of Puerto Rican ethnicity, we chose to evaluate these associations among participants in Proyecto Buena Salud, a study of Hispanic women of Puerto Rican and Dominican descent. We hypothesized that: (1) higher prepregnancy BMI, (2) exceeding IOM guidelines for GWG, and (3) excessive rate of GWG in the first, second, and third trimesters would lead to increased odds of cesarean delivery at term.

**Methods**

**Study design**

Proyecto Buena Salud was a prospective cohort study of Hispanic prenatal care patients in Western Massachusetts conducted from January 2006 through October 2011 (22). Bilingual interviewers recruited patients at a prenatal care visit prior to 18 weeks gestation. Women were informed of the aims and procedures of the study and provided written informed consent approved by the Institutional Review Boards of the University of Massachusetts Amherst and Baystate Medical Center. The study consisted of interviews in early, mid-, and late pregnancy in Spanish or English (telephone or in person) involving interviewer administration of semiquantitative questionnaires. After delivery, medical records were abstracted for clinical characteristics of the pregnancy and medical history.

Women were eligible if they were of Puerto Rican or Dominican heritage, meaning they were born in the Caribbean islands or had a parent or two grandparents born in the Caribbean islands. Exclusion criteria included (1) taking medications that adversely influence glucose tolerance, (2) multiple gestation (e.g., twins, triplets), (3) preconception history of diabetes, hypertension, heart disease, or chronic renal disease, and (4) <16 or >40 years of age. For the purpose of the current analysis, women were excluded if information on GWG was missing or if they had a spontaneous or therapeutic abortion, a stillbirth, a preterm birth (<37 weeks gestation), or a late-term birth (>42 weeks gestation), as their GWG and mode of delivery would likely not be comparable with women who delivered a live infant at term.

**Prepregnancy BMI**

Prepregnancy BMI was categorized according to the National Institutes of Health guidelines (23). A clinical weight was recorded at each prenatal care visit and at delivery. Prepregnancy weight was either self-reported to the interviewer at the time of recruitment (85.0%) or self-reported to the practitioner at the first prenatal care visit (mean = 12.5 [standard deviation, SD = 3.2] weeks gestation) and recorded in the medical record (13.0%). If prepregnancy weight was not available from either source, it was based on measured weight at the first prenatal care visit (1.6%) or from a prepregnancy clinical visit (0.4%). The validity of self-reported prepregnancy weight is high, particularly if collected in early pregnancy (24). A recent study found a strong correlation (\( r = 0.95; \ P = 0.0001 \)) between self-reported prepregnancy weight and physician-measured weight with a mean discrepancy of 0.5 ± 3.0 kg and no significant (\( P = 0.64 \)) differences between women who had normal weight versus overweight or obesity (25).

**GWG**

Total GWG was calculated by subtracting prepregnancy weight from weight at delivery and was evaluated continuously and categorized as “inadequate,” “within guidelines,” or “excessive” based on the IOM’s 2009 guidelines for prepregnancy BMI-specific GWG (14). GWG in the first trimester was calculated by subtracting prepregnancy weight from weight measured at the prenatal care visit closest to 13 weeks gestation (mean = 13.0 weeks gestation; SD = 1.3). The rate of GWG in each trimester was calculated by dividing the GWG during each trimester by the corresponding number of gestational weeks. We evaluated the impact of a 1-pound change in the rate of GWG as well as a 1 SD change in the rate of GWG. The rate of GWG was also categorized as “inadequate,” “within guidelines,” or “excessive” based on IOM guidelines (14).

In the case of missing weight values at trimester cut points, linear interpolation was used in the manner of Herring et al. (26) to calculate missing values. Linear interpolation is a method of imputing values within a range of values in a time series (27). Given that each participant has multiple values of measured weights over a pregnancy, and that weight gain is assumed to be linear for most of pregnancy gain (1), linear interpolation is considered an acceptable method of imputing missing weight at a specific time point within this time series (26).

**Mode of delivery**

The mode of delivery was analyzed as a dichotomous variable (i.e., vaginal or cesarean). For multiparous women, the mode of delivery is highly correlated with the prior mode of delivery; about 90% of women who deliver via cesarean will have a planned (“scheduled”) cesarean delivery for subsequent pregnancies (28). Furthermore, the risk profile of planned cesareans is different than unplanned cesarean deliveries that occur after an unsuccessful labor. Therefore, we
abstracted information regarding the presence of labor during delivery from medical records as a proxy for planned versus unplanned cesareans, as have others (1,29).

Covariates
Interviewers collected sociodemographic factors, smoking and alcohol consumption during early pregnancy, generation in the United States, and acculturation (measured via the Psychological Acculturation Scale) (30). Physical activity (metabolic equivalent hours per week) was measured via the Pregnancy Physical Activity Questionnaire (31) at early, mid-, and late pregnancy. Total energy intake was measured during midpregnancy via two 24-hour diet recalls.

Nutrient intakes were assessed in the University of Minnesota Nutrition Data System by linking the food data file to the Minnesota Nutrient Data file (Minnesota Nutrition Data System software; food database version 10A, nutrient database version 25; Nutrition Coordinating Center, University of Minnesota). Total energy intake was calculated directly by summing kilocalories from each food reported as consumed based on its portion size. Gravity, parity, age, infant birth weight, gestational age at delivery, presence of labor, and history of macrosomia were abstracted from medical records.

Statistical analyses
The distribution of participant characteristics according to the mode of delivery was computed by using $\chi^2$ tests and Fisher exact tests. Unadjusted and multivariable logistic regressions were used to evaluate the association between GWG, prepregnancy BMI, and the odds of cesarean delivery. We assessed the linearity of each continuous GWG variable before including them in the models (32). The rate of GWG in the first, second, and third trimesters met the criteria for linearity and therefore were included in models as continuous variables.

A priori, we chose to include age in our multivariable models with prepregnancy BMI as the primary exposure variable. We also included covariates in the final model if they changed the estimate for the primary exposure by 10% or more (33). Based on this method, no additional covariates were included in our BMI models.

We then repeated the analysis adjusting for GWG to estimate the independent effect of prepregnancy BMI over and above weight gain. Covariates were included in the final model with a missing indicator level, so no participants were excluded because of missing covariate data.

We followed a similar model-building approach for our multivariable models with GWG as the primary exposure variable, a priori including age and prepregnancy BMI. Then, by using the change-inestimate approach, physical activity in mid- and late pregnancy, number of children in the household, and generation in the United States met the criteria for inclusion.

We then evaluated whether the association between GWG and cesarean delivery differed according to BMI and parity (i.e., multiplicative interaction) by including an interaction term in the models and assessing its statistical significance. We also evaluated the presence of additive interaction by using the technique for logistic regression models by Kalilani et al. (34).

We conducted several sensitivity analyses. First, we restricted the analysis of first trimester GWG and cesarean delivery to women with a weight gain measure within 1 week of the 13-week cut point. We also repeated the GWG and cesarean delivery analyses excluding women who developed gestational diabetes mellitus and preeclampsia, both of which can impact GWG and cesarean delivery. Finally, we repeated the analyses only among women who labored before their cesarean (as a proxy for an unplanned cesarean delivery). Analyses were performed by using SAS software version 9.4 (SAS Institute Inc., Cary, North Carolina).

Results
A total of 1,583 participants were recruited. We excluded 211 women who did not deliver at Baystate, 18 women missing GWG, 15 women who had a stillbirth, 123 women who had a preterm birth, and 1 woman who had a late-term birth, for a final sample of 1,215 Hispanic women.

Nearly three-quarters of the women had a vaginal delivery ($n = 937$; 77%). Of the 23% of women who delivered via cesarean ($n = 278$), 61% ($n = 169$) labored before the delivery. The majority of participants were young and unmarried. Most reported low levels of acculturation, with 46% being born in Puerto Rico or the Dominican Republic. Cesarean delivery was more common among older women and those with obesity ($P < 0.001$) (Table 1).

Nearly half of the women (48%) had overweight or obesity before pregnancy, while 6% had underweight (Table 2). The average total GWG was 31.1 pounds (SD = 16.1) and 52% had excessive GWG, while 19% gained less than recommended. More than half of the women exceeded the recommended rate of GWG in the first, second, and third trimesters (Table 2). The correlation between the first and second trimester GWG was 0.23 ($P < 0.001$), between the second and third trimester was 0.48 ($P < 0.001$), and between the first and third trimester was 0.08 ($P = 0.005$).

We first examined the association between prepregnancy BMI and the odds of cesarean delivery (Table 3). In age-adjusted analyses, each kilogram per meter squared increase in prepregnancy BMI was associated with increased odds of cesarean delivery ($RR = 1.06$; 95% confidence interval [CI]: 1.04-1.08). After adjusting for total GWG, findings were virtually unchanged. In age-adjusted analyses, women who had obesity prior to pregnancy had 2.03 times increased odds of cesarean delivery compared with women with normal prepregnancy BMI (95% CI: 1.46-2.82). These odds increased to 2.46 (95% CI: 1.72-3.51) after adjustment for GWG (Table 3).

We then examined the association between GWG and the odds of cesarean delivery (Table 4). Women with excessive total GWG had 46% increased odds of cesarean delivery compared with women gaining within guidelines (95% CI: 1.04-2.05). This increase in odds remained after adjusting for prepregnancy BMI, physical activity in mid- and late pregnancy, number of children in the household, and generation in the United States (odds ratio [OR] = 1.49; 95% CI: 1.06-2.10).

We then examined the association between the rate of GWG in each trimester of pregnancy (SD change in GWG per week) and the odds
| Demographics | Total sample \(^a\) \((N = 1,215)\) | Vaginal \((n = 937)\) | Cesarean \((n = 278)\) | \(P\) value |
|--------------|-------------------------------|-------------------|-------------------|----------|
| Age (y)      | \(n\) | %       | \(n\) | %       | \(n\) | %       |        |
| 16-19        | 370 | 30.5    | 334 | 36.1    | 37 | 22.7    | \(< 0.001\) |
| 20-24        | 488 | 40.2    | 415 | 45.2    | 331 | 20.6    |
| 25-29        | 212 | 17.5    | 159 | 17.2    | 23 | 22.7    |
| \(\geq 30\)  | 143 | 11.8    | 92  | 33.4    | 301 | 20.6    |
| Marital status |       |         |     |         |     |         | 0.947 |
| Single/separated/divorced/widowed | 954 | 87.5  | 876 | 87.4  | 93 | 87.4 |
| Married      | 112 | 10.3    | 103 | 10.3    | 12 | 10.3    |
| Refused      | 24  | 2.2     | 2.2 | 2.4     | 2.4 |
| Education    |       |         |     |         |     |         | 0.487 |
| Less than high school | 528 | 48.0 | 483 | 47.0 | 45 | 47.0 |
| High school graduate or GED | 361 | 32.8 | 333 | 31.2 | 28 | 28.3 |
| Post high school | 211 | 19.2 | 184 | 21.7 | 17 | 17.7 |
| Number of adults in household\(^b\) |       |         |     |         |     |         | 0.228 |
| 1            | 288 | 26.4    | 258 | 28.6    | 22| 22.6 |
| 2            | 524 | 48.1    | 475 | 50.0    | 28| 28.9 |
| \(\geq 3\)  | 278 | 25.5    | 26.7| 21.4    | 21| 21.5 |
| Number of children in household\(^b\) |       |         |     |         |     |         | 0.974 |
| 0            | 209 | 19.5    | 194 | 19.8    | 19| 19.8 |
| 1            | 391 | 36.4    | 364 | 36.7    | 36| 36.7 |
| 2            | 263 | 24.5    | 244 | 25.0    | 24| 24.7 |
| \(\geq 3\)  | 210 | 19.6    | 199 | 18.6    | 21| 21.2 |
| Acculturation\(^c\) |       |         |     |         |     |         | 0.126 |
| Low (1 to \(< 3\)) | 822 | 78.7  | 79.8| 75.2    | 79| 75.2 |
| High (\(\geq 3\)) | 222 | 21.3    | 20.2| 24.8    | 21| 24.8 |
| Generation in United States |       |         |     |         |     |         | 0.139 |
| Born in PR/DR | 544 | 46.3  | 45.7| 48.5    | 45| 48.5 |
| Parent born in PR/DR | 561 | 47.7 | 47.7| 48.1    | 47| 48.1 |
| Grandparent born in PR/DR | 70  | 6.0   | 6.7 | 3.4     | 7 | 3.4 |
| Behavioral characteristics |       |         |     |         |     |         | 0.887 |
| Smoking during early pregnancy |       |         |     |         |     |         | 0.155 |
| None         | 667 | 86.5    | 866 | 86.2    | 662| 86.2 |
| \(\leq 10\)  cigarettes/d | 93  | 12.1   | 12.1| 12.1    | 93 | 12.1 |
| \(> 10\)  cigarettes/d | 11  | 1.4    | 1.3 | 1.7     | 11 | 1.7 |
| Physical activity, mid-late pregnancy |       |         |     |         |     |         | 0.033 |
| Low (10.0-119.7 METS/wk) | 329 | 33.3 | 32.1| 37.2    | 32| 37.2 |
| Medium (119.8-191.5 METS/wk) | 330 | 33.4 | 34.9| 28.3    | 30| 28.3 |
| High (191.6-1,143.3 METS/wk) | 330 | 33.4 | 33.0| 34.5    | 30| 34.5 |
| Characteristics of pregnancy |       |         |     |         |     |         | 0.033 |
| Infant birth weight (g), mean (SD) | 1,203 | 3,291.6 (421.7) | 3,358.3 (554.4) | 0.033 |
| Gesational age of infant at delivery (wk), mean (SD) | 1,214 | 39.6 (1.3) | 39.4 (1.5) |
| Medical history |       |         |     |         |     |         | <0.001 |
| Prepregnancy BMI (kg/m\(^2\)) |       |         |     |         |     |         | 0.033 |
| \(< 18.5\)  | 71  | 5.9    | 6.7 | 3.3     | 3.3 |
| \(18.5 \leq < 25\) | 555 | 45.9 | 48.6| 36.8    | 36.8 |
| \(25 \leq < 30\) | 283 | 23.4 | 23.6| 22.7    | 22.7 |
| \(\geq 30\)  | 301 | 24.9    | 21.2| 37.2    | 37.2 |
TABLE 1. (continued).

| Parity               | Total sample\(^a\) \((N = 1,215)\) | Vaginal \((n = 937)\) | Cesarean \((n = 278)\) | \(P\) value |
|----------------------|--------------------------------------|------------------------|------------------------|-------------|
| 0 live births        | 501 (41.3)                           | 421 (42.1)             | 388 (38.8)             | 0.600       |
| 1 live birth         | 367 (30.3)                           | 300 (30.0)             | 312 (31.2)             |             |
| \(\geq 2\) live births | 344 (28.4)                           | 279 (27.9)             | 301 (30.1)             |             |

\(^a\)N may not total to 1,215 because of missing data.
\(^b\)Including the participant as appropriate: if < 18 years, included as a child; if > 18 years, included as an adult.
\(^c\)Acculturation is measured by the Psychological Acculturation Scale and ranges from 1 to 5.

DR, Dominican Republic; METS, metabolic equivalents; PR, Puerto Rico.

TABLE 2 Distribution of prepregnancy BMI and GWG variables: Proyecto Buena Salud, 2006-2011

| BMI                  | \(n\) | \(\%\) | Mean | SD  |
|----------------------|-------|--------|------|-----|
| Prepregnancy (kg/m\(^2\), continuous) | 1,210 | 26.3%  | 6.7  |     |
| Prepregnancy (categories) |       |        |      |     |
| Underweight (BMI < 18.5 kg/m\(^2\)) | 71    | 5.9%   |      |     |
| Normal weight (BMI 18.5 to < 25.0 kg/m\(^2\)) | 555   | 45.9%  |      |     |
| Overweight (BMI 25.0 to < 30.0 kg/m\(^2\)) | 283   | 23.4%  |      |     |
| Obesity (BMI 30.0 kg/m\(^2\)) | 301   | 24.9%  |      |     |
| GWG (lb)              |       |        |      |     |
| Total pregnancy (lb)  | 1,184 | 31.1%  | 16.1 |     |
| Adherence to IOM guidelines |       |        |      |     |
| Inadequate            | 227   | 19.4%  |      |     |
| Within guidelines     | 335   | 28.7%  |      |     |
| Excessive             | 606   | 51.9%  |      |     |
| First trimester (lb)  | 1,208 | 4.8%   | 7.9  |     |
| Adherence to IOM guidelines |       |        |      |     |
| Inadequate            | 377   | 31.2%  |      |     |
| Within guidelines     | 223   | 18.5%  |      |     |
| Excessive             | 608   | 50.3%  |      |     |
| Rate of GWG (lb/wk)   |       |        |      |     |
| First trimester (lb/wk) | 1,208 | 0.4%   | 0.6  |     |
| Adherence to IOM guidelines |       |        |      |     |
| Inadequate            | 377   | 31.2%  |      |     |
| Within guidelines     | 223   | 18.5%  |      |     |
| Excessive             | 608   | 50.3%  |      |     |
| Second trimester (lb/wk) | 1,215 | 1.0%   | 0.6  |     |
| Adherence to IOM guidelines |       |        |      |     |
| Inadequate            | 339   | 28.0%  |      |     |
| Within guidelines     | 178   | 14.7%  |      |     |
| Excessive             | 693   | 57.3%  |      |     |
| Third trimester (lb/wk) | 1,187 | 1.0%   | 0.6  |     |
| Adherence to IOM guidelines for rate |       |        |      |     |
| Inadequate            | 303   | 25.6%  |      |     |
| Within guidelines     | 176   | 14.9%  |      |     |
| Excessive             | 704   | 59.5%  |      |     |

IOM, Institute of Medicine.
of cesarean delivery (Table 4). In fully adjusted models, the rate of GWG in the first trimester (OR = 1.13; 95% CI: 0.98-1.31) and the rate of GWG in the second trimester (OR = 1.08; 95% CI: 0.94-1.25) were not significantly associated with the odds of cesarean delivery. However, the rate of GWG in the third trimester was associated with 24% increased odds of cesarean delivery (95% CI: 1.06-1.44) (Table 4). Similarly, exceeding IOM recommendations for the rate of GWG in the first and second trimesters was not associated with the odds of cesarean delivery, while an excessive rate of GWG in the third trimester was associated with 66% increased odds (95% CI: 1.05-2.62).

### TABLE 3
Cesarean delivery according to prepregnancy BMI: Proyecto Buena Salud, 2006-2011

| Prepregnancy BMI (kg/m²), continuous | Total sample | Unadjusted | Adjusted for age | Adjusted for age and total GWG |
|--------------------------------------|-------------|------------|-----------------|-------------------------------|
|                                      |            | OR 95% CI  | OR 95% CI       | OR 95% CI                     |
| Prepregnancy (BMI [kg/m²], continuous) | 1,210       | 1.06 1.04-1.08 | 1.06 1.04-1.08   | 1.07 1.05-1.09               |
| Prepregnancy (categories)            |            |            |                 |                               |
| Underweight (BMI < 18.5 kg/m²)       | 71          | 0.65 0.31-1.34 | 0.67 0.32-1.40   | 0.76 0.35-1.67               |
| Normal weight (BMI 18.5 to < 25.0 kg/m²) | 555        | 1.00 referent | 1.00 referent    | 1.00 referent                |
| Overweight (BMI 25.0 to < 30.0 kg/m²) | 283         | 1.27 0.89-1.81 | 1.13 0.79-1.62   | 1.22 0.85-1.77               |
| Obesity (BMI 30.0 kg/m²)             | 301         | 2.31 1.68-3.18 | 2.03 1.46-2.82   | 2.46 1.72-3.51               |

### TABLE 4
Cesarean delivery according to GWG variables: Proyecto Buena Salud, 2006–2011

| Overall pregnancy | Cases | Unadjusted | Adjusted for age and prepregnancy BMI | Full modela |
|-------------------|-------|------------|--------------------------------------|-------------|
|                   | n     | %          | OR 95% CI                             | OR 95% CI   | OR 95% CI |
| GWG compliance with IOM guidelines | | | | |
| Inadequate | 42  | 18.7%  | 0.99 0.64-1.52 | 0.98 0.63-1.53 | 0.98 0.63-1.54 |
| Within guidelines | 63   | 18.9%  | 1.00 referent | 1.00 referent | 1.00 referent |
| Excessive | 161  | 26.6%  | 1.56 1.12-2.17 | 1.46 1.04-2.05 | 1.49 1.06-2.10 |
| First trimester | | | | |
| Rate of GWG (SD change in GWG/wk) | 275  | 22.8%  | 1.12 0.98-1.28 | 1.13 0.98-1.30 | 1.13 0.98-1.31 |
| GWG in first trimester: compliance with IOM guidelines | | | | |
| Inadequate | 82  | 21.8%  | 0.91 0.62-1.36 | 0.82 0.54-1.23 | 0.82 0.54-1.23 |
| Within guidelines | 52   | 23.3%  | 1.00 referent | 1.00 referent | 1.00 referent |
| Excessive | 141  | 23.2%  | 0.99 0.69-1.43 | 0.95 0.65-1.37 | 0.96 0.66-1.39 |
| Second trimester | | | | |
| Rate of GWG (SD change in GWG/wk) | 277  | 22.9%  | 1.13 0.98-1.29 | 1.08 0.93-1.24 | 1.08 0.94-1.25 |
| Rate of GWG: compliance with IOM guidelines | | | | |
| Inadequate | 79  | 23.3%  | 1.44 0.91-2.29 | 1.18 0.73-1.90 | 1.2 0.74-1.94 |
| Within guidelines | 31   | 17.4%  | 1.00 referent | 1.00 referent | 1.00 referent |
| Excessive | 167  | 24.1%  | 1.51 0.98-2.30 | 1.26 0.81-1.95 | 1.28 0.83-1.99 |
| Third trimester | | | | |
| Rate of GWG (SD change in GWG/wk) | 268  | 22.7%  | 1.24 1.07-1.43 | 1.23 1.05-1.43 | 1.24 1.06-1.44 |
| Rate of GWG: compliance with IOM guidelines | | | | |
| Inadequate | 62  | 20.5%  | 1.36 0.83-2.22 | 1.16 0.70-1.93 | 1.14 0.69-1.89 |
| Within guidelines | 28   | 15.9%  | 1.00 referent | 1.00 referent | 1.00 referent |
| Excessive | 178  | 25.3%  | 1.79 1.15-2.77 | 1.66 1.05-2.61 | 1.66 1.05-2.62 |

aAdjusting for age, prepregnancy BMI, physical activity in mid-late pregnancy, number of children in household, and generation in the United States.
We found no presence of multiplicative or additive interaction for the association between GWG and cesarean delivery according to prepregnancy BMI or parity. After restricting the analysis of first trimester GWG and cesarean delivery to women with a visit within 1 week of the 13-week cut point, findings were essentially unchanged. Similarly, there were no substantive changes to our results when women with preeclampsia (n = 22) and gestational diabetes mellitus (n = 49) were excluded. Finally, findings were unchanged when the sample was restricted to women who went into labor before cesarean delivery.

**Discussion**

In summary, in this prospective cohort of Hispanic women, after adjusting for important risk factors, we found that an excessive total GWG and an excessive rate of GWG in the third trimester were associated with increased odds of cesarean delivery. After adjusting for age, women who had obesity before pregnancy had twofold increased odds of cesarean delivery compared with women who had normal weight. These findings were strengthened after additional adjustment for GWG, indicating that GWG was masking some of the impact of BMI on cesarean delivery.

Our finding that excessive total GWG was associated with increased odds of cesarean delivery is consistent with prior research. A retrospective cohort by Yee et al. (35) among 2,310 women, including a significant proportion of Mexican American women, found that excessive total GWG according to 2009 IOM guidelines was associated with 47% increased odds of cesarean delivery (95% CI: 1.03-2.10) (35). In a retrospective cohort study in California (10% Latina), Stotland et al. found that excessive total GWG was associated with 40% increased odds (95% CI: 1.22-1.59) (36). Similarly, we found that excessive total GWG was associated with 49% increased odds of cesarean delivery (95% CI: 1.06-2.10).

Only two prior studies to our knowledge examined the association between the rate of GWG in each trimester independently and the risk of cesarean delivery. In a population-based prospective cohort study of 6,959 women in the Netherlands, Gaillard et al. found that the first trimester rate of GWG (SD change in GWG per week) was associated with a 1.19 odds of cesarean delivery (95% CI: 1.10-1.29) (37). The rate of second (OR = 1.05; 95% CI: 0.96-1.15) and third trimester (OR = 1.00; 95% CI: 0.90-1.20) GWG was not associated with cesarean delivery. In a retrospective cohort study among American Samoan women, Hawley et al. found that GWG in the second trimester (SD change in GWG z score) was associated with a 1.40 odds of cesarean delivery (95% CI: 1.08-1.83), while GWG in the third trimester was not (38). In the current study, we found that the third trimester rate of GWG was significantly associated with cesarean delivery (OR = 1.24; 95% CI: 1.06-1.44). Differences in findings may be due to differences in the study populations; in addition, 53% of women in the Gaillard study were missing information on first trimester GWG, and the Hawley study lacked a measure of prepregnancy weight. Conflicting findings highlight the fact that this is an area that needs more exploration to be clinically meaningful.

In a retrospective cohort study in New York State (39), Durie et al. found that women (<7% Hispanic) with an excessive rate of GWG in the second or third trimesters had ORs ranging from 1.38 (95% CI: 1.26-1.51) for women with normal BMI to 1.45 (95% CI: 1.23-1.71) for women who were overweight. We similarly found that an excessive third trimester rate of GWG was associated with increased odds of cesarean delivery (OR = 1.66; 95% CI: 1.05-2.62), while an excessive second trimester rate of GWG was not significantly associated (OR = 1.28; 95% CI: 0.83-1.99).

Our findings that women with obesity had increased odds of cesarean delivery are consistent with the prior literature, which has focused on non-Hispanic white populations. A meta-analysis calculated pooled ORs (n = 11 studies) for cesarean delivery of 1.53 (95% CI: 1.48-1.58) in women with overweight and 2.26 (95% CI: 2.04-2.51) in women with obesity (20). Similarly, we found that women with overweight and obesity had statistically significant increased odds of cesarean delivery of 2.03 and 2.46, respectively.

Our study faced several limitations. First, we were unable to adjust for confounding by history of cesarean delivery, which is positively associated with subsequent cesarean and may be positively associated with GWG (14). However, if GWG was an indication for the prior cesarean, then adjusting for previous cesarean could lead to overadjustment. To address this concern, we repeated our analysis among nulliparous women only; findings were unchanged.

Mid- and late pregnancy physical activity was identified as a potential confounder but served, in part, as a marker of activity prior to pregnancy with correlations of 0.46 (P < 0.001). Therefore, the adjusted model indicates the indirect impact of GWG on cesarean delivery above and beyond the impact of physical activity.

We relied primarily upon self-reported prepregnancy weight as recorded by health professionals. A clinically measured weight has the benefit of being more objective than self-reported weight. However, self-reported prepregnancy weight is commonly used in epidemiologic studies because preconception weight measures typically do not exist in medical record data, and the IOM presents it as a practical method for this purpose (14).

We did not have information on indication for cesarean. A recent study noted that Hispanic women were at significantly higher odds of cesarean delivery for failure to progress and at lower odds of cesarean for malpresentation as compared with non-Hispanic white women (40). To the extent that these factors were also associated with GWG, this may have led to confounding. Lastly, there were too few women with forceps delivery and vacuum extraction delivery to evaluate the association between GWG and operative vaginal delivery.

The biological mechanism linking GWG to the mode of delivery may not vary by racial or ethnic group, but racial or ethnic differences exist in indications for cesarean delivery (40), and health care utilization and access also vary by racial or ethnic group. Therefore, our findings may be generalized to pregnant women from Puerto Rico and the Dominican Republic, but care should be taken in generalizing to other Hispanic subgroups or non-Hispanic populations.

**Conclusion**

In summary, we found that obesity prior to pregnancy, excessive total GWG, and an excessive third trimester rate of GWG were associated with increased odds of cesarean delivery. These findings
in a population of Hispanic women are consistent with those observed in primarily non-Hispanic white and black populations. Our results indicate that intervention efforts to reduce the odds of cesarean delivery should focus on helping women enter pregnancy with a normal BMI and avoid exceeding IOM guidelines for GWG. A healthy rate of weight gain during pregnancy may be critical to avoid cesarean delivery and suggests a target for public health intervention studies. Such interventions should be culturally specific and ideally begin early in pregnancy to avoid entrenched behaviors in late pregnancy. For example, given observed correlations between prepregnancy physical activity and mid- and late pregnancy, such interventions could focus on early pregnancy lifestyle behaviors. Future studies should also evaluate the trimester-specific effects of GWG on cesarean delivery and focus on the understudied, high-risk Hispanic population.

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