Maternal and Child Health Journal (2019) 23:925–933
https://doi.org/10.1007/s10995-018-02719-8

Relationship Between Prepregnancy Overweight, Obesity, and Preterm Birth in Puerto Rico

Stephanie M. Eick[1] · **Michael Welton**[1] · **José F. Cordero**[1]

Published online: 7 January 2019

Abstract
Objectives We examined the association between prepregnancy body mass index (PP-BMI) and preterm birth (PTB) among women in Puerto Rico (PR) as a potentially modifiable risk factor. *Methods* We conducted a retrospective study using the birth certificate data files from 2005 to 2012 developed by the PR Department of Health to examine the relationship between PP-BMI and PTB. Logistic regression was used to determine crude and adjusted odds ratios (OR) and 95% confidence intervals (CI) for the categories of PP-BMI of overweight (25–29.9 kg/m^2), obesity ($\geq$ 30 kg/m^2), and overweight and obesity together ($\geq$ 25 kg/m^2) and PTB. Stratified analysis explored the associations between PP-BMI and PTB by region within PR and year. *Results* Following exclusions of birth records with missing data, 343,508 births were included in our analysis. The percentage of PTB decreased from 18.6 to 15.2 during our study period. Statistically significant differences were observed between preterm and full term births across all covariates. Overweight (OR 1.08, 95% CI 1.06, 1.11), obesity (OR 1.17, 95% CI 1.14, 1.20), and overweight and obesity together (OR 1.11, 95% CI 1.09, 1.14) were significantly associated with increased odds of PTB after adjusting for confounders. The associations between PP-BMI and PTB persisted across all regions and years. *Conclusions for Practice* PP-BMI is associated with increased odds of PTB among women in PR and the associations were consistent in exploratory analyses. Future research should examine the relationship between PP-BMI and PTB among other Hispanic subgroups and among Puerto Ricans in the mainland United States.

Keywords Preterm birth · Body mass index · Epidemiology · Puerto Rico · Health disparities · Pre-pregnancy weight

Significance

"What is already known about the paper" Prepregnancy body mass index (PP-BMI) is a known risk factor for preterm birth (PTB). Puerto Ricans have unexplained higher rates of PTB compared to other Hispanic subgroups and non-Hispanic whites.

"What this study adds" After adjusting for confounders, overweight and obesity prior to pregnancy are risk factors for PTB among women giving birth in Puerto Rico. These associations were consistent over time and by region despite varying rates of PTB across years and location.

✉ Stephanie M. Eick
eick.steph@gmail.com

[1] Department of Epidemiology and Biostatistics, College of Public Health, University of Georgia, Health Sciences Campus 101 Buck Road, Athens, GA 30605, USA

Introduction

Preterm birth (PTB) is a serious public health issue in the United States (U.S.) and globally. Babies born prior to 37 weeks of gestation are a higher risk of serious neonatal complications that can result in life long disability. PTB is the leading cause of neonatal mortality in most developed countries and a major contributor to health care cost, with an estimated 16 billion per year in the U.S. alone (Behrman and Butler 2007). Preterm infants are at risk for adverse health outcomes, both at birth and later in life (Behrman and Butler 2007). Reducing the PTB rates may help lower the infant mortality rate and help foster a healthier next generation. Infants born preterm are more likely to develop cerebral palsy, mental retardation, attention deficit-hyperactivity disorder and many other health challenges (Behrman and Butler 2007).

Most causes and risk factors of PTB are not well understood but maternal conditions, such as maternal hypertension and eclampsia, account for some of the pathways

contributing to medically indicated PTB and early elective delivery. The causes of spontaneous PTB are not well known and require greater study. Many risk factors can affect gestational length and birth weight. For example, a meta-analysis concluded that women who are short stature are at increased risk for delivering preterm and low birth weight (Han et al. 2012). Whereas tall women have a decreased risk of having a PTB and low birth weight infant (Derraik et al. 2016; Han et al. 2012). These relationships are consistent within categories of body mass index, where tall overweight and obese women are at a reduced risk for PTB and overweight and obese short women are at increased risk for delivering preterm (Shachar et al. 2015).

The prevalence of overweight and obesity varies greatly by race, ethnicity and geographical location and is higher among Hispanic populations in the U.S., with 72.5% classified as overweight or obese, compared to 63.3% among non-Hispanic Whites (Wang and Beydoun 2007). Importantly variation among Hispanic subgroups also exists, with overweight and obesity being more common among Puerto Ricans (Aponte 2009) than other Hispanic groups such as Cubans, Mexicans and Central and South American. A small cohort study of pregnant women in Puerto Rico, PROTECT, found that 44% had a prepregnancy body mass index (PP-BMI) that is overweight or obese (Guilloty et al. 2015). Among 12 year olds in Puerto Rico in 2010–2011, the prevalence of overweight and obesity, respectively which may be a predictor of obesity as young adults, was 18.8% and 24.3% (Elías-Boneta et al. 2015). Furthermore, children enrolled in private schools in Puerto Rico are more likely to be obese than children attending public school (Elías-Boneta et al. 2015). Puerto Ricans residing in the Continental U.S. also exhibit faster increases in BMI from adolescence to adulthood relative to other Hispanic subgroups (Albrecht and Gordon-Larsen 2013). Among a representative group of U.S. based Puerto Rican adolescents (ages 12–14), the mean BMI increased by 8.5 kg/m^2 between ages 12 and 33 (Albrecht and Gordon-Larsen 2013). In comparison, the mean BMI increased by 5.4 kg/m^2 among Hispanics of Cubans descent living in the U.S. and 6.7 kg/m^2 for Central and South Americans during that same time (Albrecht and Gordon-Larsen 2013).

PTB is also an important public health challenge in Puerto Rico. In the 1990s the percentage of PTB in Puerto Rico was close to that of Hispanics residing in the U.S. In 1990, the PTB percentage in Puerto Rico was 11.6%, lower than Puerto Rican women delivering in the U.S. mainland, 13.3%. A decade later, in the year 2000, the percentage of PTB among women in the island was 15%, compared to Puerto Rican women delivering in the U.S. mainland with a percentage of 13.4% (Centers for Disease Control and Prevention 2003). The percentage of PTB increased in Puerto Rico and reached 19.9% in 2006 (Martin et al. 2006). The reasons of this increase are not well known, but it appears that clinical factors such as prenatal care, maternal age, or maternal education cannot explain the observed increase. In the recent years the rate of PTB has declined. More recently, the percentage continues to decline and in 2016, the preliminary percentage is 11.5% a slight increase from 2015, when 11.4% of babies were born preterm (Martin et al. 2017).

Although many studies have examined associations between PP-BMI and PTB (Behrman and Butler 2007; Torloni et al. 2009), these associations have not been studied in Puerto Rico. As such, it is important to understand how the association between PP-BMI and PTB may vary across cultures and regions to successfully tailor interventions aimed at reducing PTB in different populations. Puerto Ricans represent a unique and understudied population because they are one of the largest Hispanic subgroups, they are American citizens, and they are not a minority group on the island. Historically, the rate of PTB in Puerto Rico has been one of the highest both in the U.S. and globally. Although the rate of PTB has declined in recent years, it remains high relative to the mainland U.S. (March of Dimes 2017). The birth rate in Puerto Rico has also been declining from nearly 60,000 births per years in the 1990s compared to approximately 31,000 livebirths in 2015 (Martin et al. 2017). This trend appears to continue with an average decline of about 2000 births. At the same time, the rate of obesity and PP-BMI appear to increase over time. In the present study, we examined the association between PP-BMI and PTB in Puerto Rico using data from birth certificates from 2005 to 2012, the most currently available at the time of this analysis.

Methods

Data for this analysis was obtained from the Vital Statistics Office of the Puerto Rico Department of Health. The Puerto Rico birth data contains demographic and clinical information from all the Puerto Rico birth certificates from 2005 to 2012. We restricted our analysis to singleton births because multiple births are a known risk factor for preterm delivery. We also limited the analysis to women who were Puerto Rico residents at time of birth. Infants who had an implausible or extreme gestational age (<20 weeks gestation and >45 weeks gestation) were excluded from the analysis. The University of Georgia's Institutional Review Board's approval was not needed for this project because the University of Georgia was not engaged in human subjects research.

Maternal prepregnancy weight was recorded in pounds and was converted to kilograms (kg) and the recorded height recorded in feet and inches was converted to meters (m). Prepregnancy weight is generally defined as weight prior to the first prenatal visit and is often based on self-report. However, due to the nature of data collection on the birth

certificate, we are unable to determine the percentage of women self-reporting prepregnancy weight. PP-BMI was calculated by dividing prepregnancy weight in kg by height in m^2. We categorized PP-BMI into underweight (< 18.5 kg/m^2), normal (18.5–24.9 kg/m^2), overweight (25–29.9 kg/m^2), and obese (≥ 30 kg/m^2). We considered overweight (25–29.9 kg/m^2), obesity (PP-BMI ≥ 30 kg/m^2), and overweight and obesity together (PP-BMI ≥ 25 kg/m^2) as our main exposure.

PTB was our outcome and gestational age was obtained as reported on the birth certificate and was dichotomized into preterm (≤ 37 weeks gestation) and full term (> 37 weeks gestation). PTB was further categorized into late (34 weeks to 36 and 6 days), moderately (32 weeks to 33 weeks and 6 days), and very preterm (< 32 weeks) (World Health Organization 2017). If a birth was missing gestational age, we calculated it by subtracting the date of last menstrual period (LMP) by date of birth when these measures were available. If day of LMP was missing, we used the midpoint of the month in gestational age calculations. Gestational weight gain was calculated by subtracting prepregnancy weight from maternal weight at delivery and was categorized as either low, adequate, or high for each category of maternal PP-BMI (American College of Obstetricians and Gynecologists 2013). Adequate weight gain was defined as being within the target range for each category of PP-BMI (28–40 lbs for underweight; 25–35 lbs for normal weight; 15–25 lbs for overweight; 11–20 lbs for obese). Low weight gain was defined as below the target range, and high as weight gain above the target range for each category of PP-BMI. Birth weight for gestational age was categorized into small for gestational age (SGA; growth measurement < 10th percentile for gestational age), large for gestational age (LGA; growth measurement > 90th percentile for gestational age), and adequate for gestational age (AGA; growth measurement between 10th and 90th percentile for gestational age) based on standardized categorizations that have been corrected for implausible estimates (Talge et al. 2014). Covariates in our analyses included gestational weight gain, maternal age (years), marital status (married or living together, single), maternal education (< high school completion, high school completion, >high school completion), insurance status (public, private, other), region of maternal residence (Arecibo, Bayamon, Caguas, Fajardo, Mayaguez/Aguadilla, Metro, Ponce) and year of birth (2005 to 2012).

Statistical analysis

Means, standard deviations, frequencies, and counts were used to describe our study population. Logistic regression was used to calculate crude and adjusted odds ratios (OR), and 95% confidence intervals (CI) for the association between PTB and overweight and obesity using normal BMI as the referent group. We also calculated ORs and 95% CIs for associations between PTB overweight and obesity together (≥ 25 kg/m^2) using separate models. Underweight women were excluded from models examining associations between overweight, obesity, and overweight and obesity together. All covariates were assessed as potential confounders in separate models. These covariates were chosen due to their association with PTB shown in the literature. Model selection was done using the forward selection estimate approach. If the OR for any category of PP-BMI (overweight, obesity, or overweight and obesity together) changed by greater than 5% when the covariate was added, it was retained in the full model. We assessed for collinearity was assessed by examining condition indices and variance decomposition proportions using the cut-points of > 30 and > 0.5, respectively. We found no evidence of multicollinearity between any variables eligible for inclusion in our final adjusted models.

Due to significant differences in PTB rates by time and geographic region we conducted exploratory analysis to examine any differences in the crude and adjusted associations between PP-BMI and PTB stratified by year and region separately. All model covariates were maintained from the previous logistic regression models.

P-values were considered statistically significant at alpha of < 0.05. All analysis was done using SAS 9.4 (Cary, NC).

Results

Between 2005 and 2012, 358,973 births occurred in Puerto Rico. We excluded 742 births because the woman's residence at the time of birth was outside the island, 7105 births because they were twins or greater gestations, and 7642 births due to implausible or missing gestational age, leaving 343,508 births included in our analysis. Among all resident singleton births, 59,817 (17.4%) were born preterm and among them, 45,890 (13.1%) were late preterm, whereas 6501 (1.9%) were moderately preterm and 7426 (2.1%) were very preterm. The number of preterm births per year differs significantly, declining over time, from 18.6% in 2005 to 15.2% in 2012. The percentage of births occurring preterm, averaged across all years, varied across region ranging from 18.1% in Caguas and Fajardo to 16.0% in Bayamon (Table 1).

Women delivering preterm were more likely to be married or living together (64.3%), have less than a high school education (22.3%), and have public insurance (71.4%) compared to women delivering at term. Over 40% of our study population were either overweight (23.8%) or obese (17.1%) and 33% had high gestational weight gain (Table 2). Demographic characteristics among women who were excluded were similar to women retained in our analysis.

Table 1 Description of number of births by year of birth and region of birth; Puerto Rico, 2005–2012

Characteristics	Total N (%)	Preterm N (%)	Full term N (%)	P
Year of birth				**< 0.01**
2005	49,456 (14.4)	9197 (18.6)	40,259 (81.2)	
2006	47,613 (13.9)	8889 (18.7)	38,724 (81.2)	
2007	45,633 (13.3)	8298 (18.2)	37,335 (81.7)	
2008	44,451 (13.0)	8153 (18.3)	36,388 (81.6)	
2009	42,562 (12.4)	7080 (16.2)	35,482 (80.9)	
2010	39,584 (11.5)	6175 (14.9)	33,409 (80.8)	
2011	37,730 (11.0)	6249 (15.5)	31,481 (78.2)	
2012	36,389 (10.6)	5766 (15.2)	30,623 (80.5)	
Region				**< 0.01**
Arecibo	41,847 (12.2)	7210 (16.8)	34,637 (80.5)	
Bayamon	57,913 (16.9)	9534 (16.0)	48,379 (81.0)	
Caguas	55,714 (16.2)	10,194 (18.1)	45,520 (80.9)	
Fajardo	12,808 (3.7)	23,943 (18.2)	10,415 (79.1)	
Mayaguez/Aguadilla	45,889 (13.4)	8109 (17.4)	37,780 (80.9)	
San Juan/Metro	72,416 (21.0)	12,291 (16.5)	60,125 (80.5)	
Ponce	56,921 (16.6)	10,086 (17.5)	46,835 (81.5)	

Bold indicated statistical significance; p values calculated from Chi square tests and indicate change in the number of births

P, p value

After adjusting for covariates (maternal age, gestational weight gain, education, and year of birth), overweight, obesity, and overweight and obesity together were significantly associated with increased odds of PTB, the strongest association was observed among obese women (OR 1.17, 95% CI 1.14, 1.20), followed by overweight and obesity together (OR 1.11, 95% CI 1.09, 1.14) and overweight women (OR 1.08, 95% CI 1.06, 1.11). Compared to women married or living with a partner, being single was associated with decreased odds of PTB (OR 0.91, 95% CI: 0.89, 0.93). Having less than a high school education and having public insurance were associated with increased odds of PTB compared to reference groups (OR 1.19, 95% CI 1.16, 1.22 and OR 1.13, 95% CI 1.10, 1.22, respectively). Infants born SGA were less likely be preterm (OR 0.60, 95% CI 0.58, 0.61) compared to AGA infants (Table 3).

After adjusting for covariates, overweight, obesity, and overweight and obesity together were significantly associated with increased odds of PTB across nearly all regions and years (Tables 4, 5). Among obesity and overweight and obesity together, the only exception was in Arecibo where the associations between overweight and overweight and obesity together and PTB was not statistically significant, however the magnitude of association was similar across all regions. The strength of association between PP-BMI and PTB persisted, with no significant differences, across all regions and years for each PP-BMI category.

Discussion

Among women in Puerto Rico, overweight and obesity are risk factors for PTB. The associations between PP-BMI and PTB persisted across all regions and years. These associations became more pronounced after controlling for confounders, indicating that the relationship is independent of other factors. We observed greater OR estimates in obese women compared to overweight, which may suggest a stronger relationship between obesity and PTB which has been shown in other studies (Cnattingius et al. 2013). To the best of our knowledge, our results cannot be attributed to changes in the medical system that occurred during the timeframe of our study.

Many risk factors for PTB have been identified, among them gestational weight gain, young maternal age (< 18 years of age), stress, alcohol use, and diet (Behrman and Butler 2007). Our results show PP-BMI may be a contributor to PTB among Puerto Rican women. A study among overweight and obese women in Puerto Rico showed that they are more likely to have excessive gestational weight gain relative to underweight and normal weight women (Guilloty et al. 2015), this finding was observed in our dataset and may be contributing to the PTB rate.

Previous literature suggests that women who are overweight or obese prior to pregnancy are more likely to have more antenatal, intrapartum, and neonatal complications (Doherty et al. 2006), which may or may not result in labor

Table 2 Description of study population; Puerto Rico, 2005–2012

	Total N (%)	Preterm N (%)
	343,508 (100)	59,817 (17.4)
Characteristics		
Maternal age (years)		
Mean (SD)	25.3 (5.97)	25.3 (6.24)
Missing	74 (0.00)	19 (0.03)
Pre-pregnancy BMI[a]		
Underweight	25,943 (7.55)	5183 (46.6)
Normal	163,897 (47.7)	27,877 (22.5)
Overweight	81,684 (23.8)	13,445 (17.5)
Obese	58,772 (17.1)	10,445 (55.3)
Missing	13,212 (3.85)	2867 (4.79)
Gestational weight gain (lbs)[b]		
Low	97,264 (28.3)	21,488 (21.6)
Adequate	116,573 (33.9)	18,740 (31.3)
High	113,153 (32.9)	16,133 (27.0)
Missing	16,518 (1.02)	3456 (5.78)
Marital status		
Single	130,463 (38.0)	21,336 (35.7)
Married/living together	213,004 (62.0)	38,479 (64.3)
Missing	41 (0.01)	2 (0.00)
Education		
< High School	65,112 (22.3)	13,354 (22.3)
High School	112,159 (33.2)	19,834 (33.2)
> High School	165,649 (44.3)	26,496 (44.3)
Missing	588 (0.17)	133 (0.22)
Insurance status[c]		
Public	236,356 (68.8)	42,722 (71.4)
Private	102,677 (29.9)	16,424 (27.5)
Other	3546 (1.03)	506 (0.85)
Missing	929 (0.27)	165 (0.28)
Infant weight for gestational age[d]		
Small for gestational age	54,893 (16.0)	6713 (11.2)
Normal weight	227,828 (66.3)	40,223 (67.2)
Large for gestational age	60,679 (17.7)	12,845 (21.5)
Missing	108 (0.03)	36 (0.06)

BMI body mass index

[a]Underweight < 18.5 kg/m^2, Normal 18.5–24.9 kg/m^2, Overweight 25-29.9 kg/m^2, Obese > 30 kg/m^2

[b]Underweight BMI, Low < 28 pounds, Normal 28–40 pounds, High > 40 pounds; Normal BMI, Low < 18.5 pounds, Normal 18.5–24.9 pounds, High > 25 pounds; Overweight BMI, Low < 15 pounds, Normal 15–25 pounds, High > 25 pounds; Obese BMI, Low < 11 pounds, Normal 11–20 pounds, High > 20 pounds

[c]Other includes private, out of pocket, charity, and other

[d]SGA birth < 10th percentile for gestational age; LGA birth > 90th percentile for gestational age

induction prior to 39 weeks. Some of these complications, including gestational diabetes, hypertension, and preeclampsia are linked to maternal weight gain (Doherty et al. 2006). Infants born to obese women may also be at increased risk for adverse neurodevelopmental outcomes, although data are limited (Van Lieshout et al. 2011).

Future studies should consider additional maternal and child health outcomes, such as infant mortality and other developmental measures, and their relationship with PP-BMI. Our results point in this direction based on our significant associations between our covariates, specifically gestational weight gain and PTB. Furthermore, our results changed significantly after controlling for confounders, indicating that other factors and interactions may be at play and should be further explored. We found that SGA infants were at decreased risk of being preterm. These infants may be less to be preterm because of other factors that may make them less likely to gain weight but are unrelated to PTB (Heaman et al. 2013).

Our results are consistent with some previous literature showing that overweight and obesity are risk factors for PTB (Cnattingius et al. 2013; McDonald et al. 2010). Different to our findings, a prior meta-analysis showed that being overweight or slightly obese did not increase the risk for overall PTB (Torloni et al. 2009). Despite the overall null association, authors showed that obese women have increased odds for medically indicated PTB prior to 37 weeks (Torloni et al. 2009). We are unable to differentiate between subtypes of PTB and increased odds for medically indicated PTB may be what we are seeing in our analysis. The same review also showed that the risk of PTB increases with increasing BMI, which is consistent with our results. Among Puerto Ricans in Puerto Rico, PP-BMI remains a modifiable risk factor because it can be addressed by preconception care and weight reduction prior to pregnancy.

Future analysis should be conducted in Puerto Rico and in other Hispanic populations and should consider Hispanic subgroups separately. The rates of PTB are notably higher in Puerto Ricans relative to other Hispanic subgroups within the U.S., including Mexicans and Cubans who have PTB rates comparable to non-Hispanic white women (Hamilton et al. 2015). Failure to differentiate between subgroups may be overlooking substantial heterogeneity seen among Hispanic populations. Puerto Rico is a unique population relative to other Hispanic subgroups because they are native U.S. citizens. Thus, the experiences of Puerto Ricans in Puerto Rico and Puerto Ricans coming to the mainland U.S. might be different relative to other Latin subgroups. Puerto Ricans born in Puerto Rico have worse birth outcomes, including PTB and lower birth weight, than those born in the mainland U.S. (Kaufman et al. 2011).

While our study presents significant results from a large population of women, encompassing 94% of all births

Table 3 Crude and adjusted associations between covariates and preterm birth; Puerto Rico Birth Files, 2005–2012

Characteristics	Crude		Adjusted[a]	
	N	OR (95% CI)	N	OR (95% CI)
Prepregnancy Body Mass Index[b]	218,393		215,878	
Normal weight		Ref		Ref
Overweight		**0.96 (0.94,0.98)**		**1.08 (1.06, 1.11)**
Overweight and obesity		1.00 (0.98, 1.02)		**1.11 (1.09, 1.14)**
Obesity		**1.06 (1.03, 1.08)**		**1.17 (1.14, 1.20)**
Maternal age (years)	336,794	1.00 (0.98, 1.02)	336,742	**1.01 (1.01, 1.01)**
Gestational weight gain (lbs)[c]	320,695		320,194	
Low		**1.48 (1.44, 1.51)**		**1.68 (1.64, 1.72)**
Adequate		Ref		Ref
High		**0.87 (0.85, 0.89)**		**1.15 (1.12, 1.18)**
Marital status	336,793		320,162	
Married/living together		Ref		Ref
Single		**0.89 (0.87, 0.90)**		**0.91 (0.89, 0.93)**
Education	336,258		320,194	
> High School		Ref		Ref
High School		**1.20 (1.17, 1.23)**		**1.19 (1.16, 1.22)**
< High School		**0.89 (0.87, 0.90)**		**0.85 (0.84, 0.87)**
Insurance status[d]	335,927		319,349	
Private		Ref		Ref
Public		**1.16 (1.14, 1.18)**		**1.13 (1.10, 1.15)**
Other		**0.87 (0.79, 0.96)**		**0.79 (0.71, 0.87)**
Infant weight for gestational age[e]	336,742		320,113	
Average for gestational age		Ref		Ref
Small for gestational age		**1.54 (1.50, 1.58)**		**0.63 (0.61, 0.65)**
Large for gestational age		**0.80 (0.78, 0.82)**		**1.27 (1.24, 1.31)**

Bold indicated statistical signifance

OR odds ratio, *CI* confidence interval; Ref, reference

[a]Logistic regression models adjusted for maternal age, gestational weight gain, education, and year of birth

[b]Normal 18.5–24.9 kg/m^2, Overweight 25–29.9 kg/m^2, Obese > 30 kg/m^2, Overweight and obesity > 25 kg/m^2

[c]Underweight BMI, Low < 28 pounds, Normal 28–40 pounds, High > 40 pounds; Normal BMI, Low < 18.5 pounds, Normal 18.5–24.9 pounds, High > 25 pounds; Overweight BMI, Low < 15 pounds, Normal 15–25 pounds, High > 25 pounds; Obese BMI, Low < 11 pounds, Normal 11–20 pounds, High > 20 pounds

[d]Other includes private, out of pocket, charity, and other

[e]SGA birth < 10th percentile for gestational age; LGA birth > 90th percentile for gestational age

occurring on the island during our study period, we acknowledge our limitations. First, our findings may be attributable to our large sample size. However, given that our study population-based, any increase in odds of PTB attributed to PP-BMI, a modifiable risk factor, does represent a substantial proportion of women. Second, we were unable to differentiate between spontaneous PTB and medically indicated PTB and the causal pathways are different between the two (Ananth et al. 2006).

Other maternal health complications, such as gestational hypertension, preexisting diabetes mellitus, chronic hypertension, and preeclampsia may lead to a medically indicated PTB. This may be due to inflammation, as both obesity and pregnancy contribute to chronic inflammation (Madan et al. 2010). Had we been able to differentiate between PTB pathways, we may have seen that odds of medically indicated PTB were higher among overweight and obese women due to maternal complications.

PP-BMI was based on what was recorded in the birth certificate, which can be filled out by a nurse or doctor. Some may have some direct measurements from prenatal visits and others are based on self-report. We are unable to determine the source of the data for PP-BMI. Self-reported measures could introduce social desirability bias, since women may be more likely to report lower weight (Visscher et al. 2006). Approximately 17% of our study sample was born preterm,

Table 4 Adjusted associations between overweight, obesity, and preterm birth by region; Puerto Rico, 2005–2012

	Crude		Adjusted[a]	
	N	OR (95% CI)	N	OR (95% CI)
Arecibo	35,800		35,427	
Overweight		0.93 (0.87, 1.00)		1.04 (0.97, 1.12)
Overweight and obese		0.96 (0.91, 1.02)		1.05 (0.99, 1.12)
Obese		1.01 (0.94, 1.10)		**1.10 (1.01, 1.19)**
Bayamon	50,418		49,860	
Overweight		**0.92 (0.87, 0.97)**		1.03 (0.97, 1.09)
Overweight and obese		0.96 (0.92, 1.01)		**1.07 (1.02, 1.13)**
Obese		1.02 (0.96, 1.09)		**1.13 (1.06, 1.20)**
Caguas	48,633		48,087	
Overweight		0.97 (0.92, 1.02)		**1.07 (1.01, 1.14)**
Overweight and obese		1.03 (0.98, 1.08)		**1.13 (1.08, 1.19)**
Obese		**1.11 (1.05, 1.18)**		**1.22 (1.14, 1.30)**
Fajardo	11,093		10,967	
Overweight		1.00 (0.89, 1.12)		1.11 (0.99, 1.25)
Overweight and obese		1.05 (0.95, 1.15)		**1.15 (1.04, 1.27)**
Obese		1.09 (0.97, 1.23)		**1.20 (1.06, 1.36)**
Mayaguez/Aguadilla	39,864		39,544	
Overweight		0.96 (0.91, 1.02)		**1.08 (1.01, 1.15)**
Overweight and obese		1.04 (0.95, 1.14)		**1.12 (1.06, 1.19)**
Obese		**1.09 (1.02, 1.17)**		**1.19 (1.11, 1.28)**
San Juan/Metro	62,933		62,019	
Overweight		1.01 (0.96, 1.06)		**1.16 (1.10, 1.22)**
Overweight and obese		1.04 (0.99, 1.08)		**1.18 (1.13, 1.23)**
Obese		**1.07 (1.01, 1.13)**		**1.20 (1.13, 1.27)**
Ponce	49,680		49,201	
Overweight		0.94 (0.89, 1.00)		1.05 (0.99, 1.11)
Overweight and obese		0.97 (0.92, 1.01)		**1.07 (1.01, 1.12)**
Obese		1.01 (0.94, 1.06)		**1.09 (1.03, 1.16)**

Bold indicated statistical signifance; Normal BMI (18.5–24.9 kg/m^2) is the reference group for all models

Overweight 25–29.9 kg/m^2, Obese > 30 kg/m^2, Overweight and Obesity > 25 kg/m^2

OR odds ratio, *CI* confidence interval

[a]Logistic regression models adjusted for maternal age, gestational weight gain, education, and year of birth

which is high relative to other populations (Blencowe et al. 2013), our sample does not include more recent years with lower rates of PTB. However, our high rates of PTB are consistent with other estimates of PTB among Puerto Ricans during this time (Martin et al. 2012). We looked at trends over time and did not see any suggestion of changing temporal trends in association, giving us confidence in our results. Different ways exist to measure gestational age, including LMP and best obstetrical estimate. Systematic biases are often observed between the two, with LMP being inaccurate by about one week (Harland et al. 2012). Due to the way data was reported, we do not know which measure was used for each pregnancy. Data was collected for legal, not research purposes, and data for some pregnancies was incomplete; however missing data was less than 6% for each measure included in our study. Lastly, our results are from Puerto Rican women, living in Puerto Rico at the time of birth and may not be generalizable to other populations.

Conclusions

We conclude that maternal overweight and obesity are risk factors for PTB in Puerto Rico. Interventions targeting reduction of obesity and overweight among women of child bearing age may help to reduce the PTB rate. However, PP-BMI does not explain all the heterogeneity seen in PTB in this population, this is evident by the significant relationships observed between PTB and covariates in our study. Future research in this population should examine other risk factors for PTB in combination with BMI, such as dietary intake, gestational weight gain, and

Table 5 Crude and adjusted associations between overweight, obesity, and preterm birth by year; Puerto Rico, 2005–2012

	Crude		Adjusted[a]	
	N	OR (95% CI)	N	OR (95% CI)
2005	43,177		42,706	
Overweight		0.96 (0.91, 1.02)		**1.07 (1.01, 1.14)**
Overweight and obese		1.02 (0.97, 1.07)		**1.12 (1.07, 1.18)**
Obese		**1.10 (1.03, 1.08)**		**1.20 (1.13, 1.29)**
2006	41,812		41,339	
Overweight		0.92 (0.87, 0.98)		1.02 (0.96, 1.08)
Overweight and obese		0.97 (0.93, 1.02)		**1.06 (1.01, 1.12)**
Obese		1.05 (0.99, 1.12)		**1.14 (1.06, 1.22)**
2007	39,856		39,391	
Overweight		0.98 (0.92, 1.04)		**1.08 (1.01, 1.15)**
Overweight and obese		1.00 (0.95, 1.05)		**1.10 (1.04, 1.16)**
Obese		1.04 (0.97, 1.11)		**1.13 (1.06, 1.22)**
2008	38,627		38,189	
Overweight		0.93 (0.88, 0.99)		1.05 (0.98, 1.12)
Overweight and obese		0.99 (0.94, 1.04)		**1.10 (1.04, 1.17)**
Obese		**1.07 (1.00, 1.15)**		**1.18 (1.10, 1.26)**
2009	36,667		36,265	
Overweight		1.00 (0.93, 1.06)		**1.11 (1.03, 1.18)**
Overweight and obese		1.02 (0.96, 1.07)		**1.11 (1.05, 1.18)**
Obese		1.03 (0.96, 1.11)		**1.12 (1.04, 1.20)**
2010	34,201		33,804	
Overweight		0.98 (0.92, 1.05)		**1.10 (1.03, 1.19)**
Overweight and obese		1.01 (0.95, 1.07)		**1.12 (1.06, 1.20)**
Obese		1.04 (0.96, 1.12)		**1.15 (1.06, 1.25)**
2011	32,521		32,160	
Overweight		1.02 (0.95, 1.09)		**1.15 (1.07, 1.23)**
Overweight and obese		1.02 (0.96, 1.08)		**1.14 (1.07, 1.21)**
Obese		1.02 (0.94, 1.10)		**1.12 (1.04, 1.22)**
2012	31,560		31,251	
Overweight		0.94 (0.88, 1.02)		**1.09 (1.01, 1.72)**
Overweight and obese		1.03 (0.97, 1.09)		**1.17 (1.09, 1.24)**
Obese		**1.14 (1.06, 1.23)**		**1.27 (1.17, 1.37)**

Bold indicated statistical signifance; Normal BMI (18.5–24.9 kg/m^2) is the reference group for all models

Overweight 25-29.9 kg/m^2, Obese > 30 kg/m^2, Overweight and Obesity > 25 kg/m^2

OR odds ratio, *CI* confidence interval

[a]Logistic regression models adjusted for maternal age, gestational weight gain, education, and year of birth

stress. Furthermore, future research should differentiate between spontaneous and medically indicated PTB. Future research should investigate the association between BMI and PTB in other Hispanic populations, including mainland Puerto Ricans, to explore the persistence and strength of association.

Compliance with Ethical Standards

Conflicts of interest The authors declare that they have no conflicts of interest and did not receive any funding for this study.

References

Albrecht, S. S., & Gordon-Larsen, P. (2013). Ethnic differences in body mass index trajectories from adolescence to adulthood: A focus on Hispanic and Asian subgroups in the United States. *PLoS ONE, 8*(9), e72983. https://doi.org/10.1371/journal.pone.0072983.

American College of Obstetricians and Gynecologists. (2013). ACOG Committee opinion no. 548: Weight gain during pregnancy. *Obstetrics & Gynecology. 121*(1), 210–212. https://doi.org/10.1097/01.AOG.0000425668.87506.4c.

Ananth, C. V., Getahun, D., Peltier, M. R., Salihu, H. M., & Vintzileos, A. M. (2006). Recurrence of spontaneous versus medically indicated preterm birth. *American Journal of Obstetrics and Gynecology, 195*(3), 643–650. https://doi.org/10.1016/j.ajog.2006.05.022.

Aponte, J. (2009). Diabetes-related risk factors across Hispanic subgroups in the Hispanic health and nutritional examination survey (1982–1984). *Public Health Nursing, 26*(1), 23–38. https://doi.org/10.1111/j.1525-1446.2008.00741.x.

Behrman, R. E., & Butler, A. S. (2007). Preterm birth: Causes, consequences, and preventionassuring healthy, outcomes. In R. E. Behrman & A. S. Butler (Eds.), *Institute of Medicine (US) Committee on Understanding Premature Birth and Assuring Healthy Outcome*. Washington (DC): National Academies Press (US) National Academy of Sciences.

Blencowe, H., Cousens, S., Chou, D., Oestergaard, M., Say, L., Moller, A.-B., et al. (2013). Born Too Soon: The global epidemiology of 15 million preterm births. *Reproductive Health, 10*(Suppl 1), S2–S2. https://doi.org/10.1186/1742-4755-10-S1-S2.

Centers for Disease Control and Prevention. (2003). Infant health among Puerto Ricans–Puerto Rico and U.S. mainland, 1989–2000. *Morbidity and Mortality Weekly Report, 52*(42), 1012–1016.

Cnattingius, S., Villamor, E., Johansson, S., Edstedt Bonamy, A. K., Persson, M., Wikstrom, A. K., & Granath, F. (2013). Maternal obesity and risk of preterm delivery. *Jama, 309*(22), 2362–2370. https://doi.org/10.1001/jama.2013.6295.

Derraik, J. G., Lundgren, M., Cutfield, W. S., & Ahlsson, F. (2016). Maternal height and preterm birth: A study on 192,432 Swedish Women. *PLoS ONE, 11*(4), e0154304. https://doi.org/10.1371/journal.pone.0154304.

Doherty, D. A., Magann, E. F., Francis, J., Morrison, J. C., & Newnham, J. P. (2006). Pre-pregnancy body mass index and pregnancy outcomes. *International Journal of Gynecology & Obstetrics, 95*(3), 242–247. https://doi.org/10.1016/j.ijgo.2006.06.021.

Elías-Boneta, A. R., Toro, M. J., Garcia, O., Torres, R., & Palacios, C. (2015). High prevalence of overweight and obesity among a representative sample of Puerto Rican children. *BMC Public Health, 15*(1), 219. https://doi.org/10.1186/s12889-015-1549-0.

Guilloty, N. I., Soto, R., Anzalota, L., Rosario, Z., Cordero, J. F., & Palacios, C. (2015). Diet, pre-pregnancy BMI, and gestational weight gain in Puerto Rican women. *Maternal and Child Health Journal, 19*(11), 2453–2461. https://doi.org/10.1007/s10995-015-1764-4.

Hamilton, B. E., Martin, J. A., Osterman, M. J., Curtin, S. C., & Matthews, T. J. (2015). Births: Final data for 2014. *National Vital Statistics Reports, 64*(12), 1–64.

Han, Z., Lutsiv, O., Mulla, S., & McDonald, S. D. (2012). Maternal height and the risk of preterm birth and low birth weight: A systematic review and meta-analyses. *Journal of Obstetrics and Gynaecology Canada, 34*(8), 721–746. https://doi.org/10.1016/s1701-2163(16)35337-3.

Harland, K. K., Saftlas, A. F., Wallis, A. B., Yankowitz, J., Triche, E. W., & Zimmerman, M. B. (2012). Correction of systematic bias in ultrasound dating in studies of small-for-gestational-age birth: An example from the Iowa Health in Pregnancy Study. *American Journal of Epidemiology, 176*(5), 443–455. https://doi.org/10.1093/aje/kws120.

Heaman, M., Kingston, D., Chalmers, B., Sauve, R., Lee, L., & Young, D. (2013). Risk factors for preterm birth and small-for-gestational-age births among Canadian women. *Paediatric and Perinatal Epidemiology, 27*(1), 54–61. https://doi.org/10.1111/ppe.12016.

Kaufman, J. S., MacLehose, R. F., Torrone, E. A., & Savitz, D. A. (2011). A flexible Bayesian hierarchical model of preterm birth risk among US Hispanic subgroups in relation to maternal nativity and education. *BMC Medical Research Methodology, 11*(1), 51. https://doi.org/10.1186/1471-2288-11-51.

Madan, J., Chen, M., Goodman, E., Davis, J., Allan, W., & Dammann, O. (2010). Maternal obesity, gestational hypertension, and preterm delivery. *The Journal of Maternal-Fetal & Neonatal Medicine, 23*(1), 82–88. https://doi.org/10.3109/14767050903258738.

March of Dimes. (2017). Born Too Soon. Retrieved from http://www.marchofdimes.org/mission/global-preterm.aspx#tabs-1.

Martin, J. A., Hamilton, B. E., Osterman, M. J., Driscoll, A. K., & Mathews, T. J. (2017). Births: Final data for 2015. *National Vital Statistics Reports, 66*(1), 1.

Martin, J. A., Hamilton, B. E., Sutton, P. D., Ventura, S. J., Menacker, F., Kirmeyer, S., et al. (2006). Births: Final data for 2006. *National Vital Statistics Reports, 57*(7), 1–102.

Martin, J. A., Hamilton, B. E., Ventura, S. J., Osterman, M. J., Wilson, E. C., & Mathews, T. J. (2012). Births: Final data for 2010. *National Vital Statistics Reports, 61*(1), 1–72.

McDonald, S. D., Han, Z., Mulla, S., & Beyene, J. (2010). Overweight and obesity in mothers and risk of preterm birth and low birth weight infants: Systematic review and meta-analyses. *Bmj, 341*, c3428. https://doi.org/10.1136/bmj.c3428.

Shachar, B. Z., Mayo, J. A., Lee, H. C., Carmichael, S. L., Stevenson, D. K., Shaw, G. M., & Gould, J. B. (2015). Effects of race/ethnicity and BMI on the association between height and risk for spontaneous preterm birth. *American Journal of Obstetrics and Gynecology, 213*(5), 700.e701–700.e709. https://doi.org/10.1016/j.ajog.2015.07.005.

Talge, N. M., Mudd, L. M., Sikorskii, A., & Basso, O. (2014). United States birth weight reference corrected for implausible gestational age estimates. *Pediatrics*. https://doi.org/10.1542/peds.2013-3285.

Torloni, M. R., Betran, A. P., Daher, S., Widmer, M., Dolan, S. M., Menon, R., et al. (2009). Maternal BMI and preterm birth: A systematic review of the literature with meta-analysis. *Journal of Maternal-Fetal and Neonatal Medicine, 22*(11), 957–970. https://doi.org/10.3109/14767050903042561.

Van Lieshout, R. J., Taylor, V. H., & Boyle, M. H. (2011). Pre-pregnancy and pregnancy obesity and neurodevelopmental outcomes in offspring: A systematic review. *Obesity Reviews, 12*(5), e548–e559. https://doi.org/10.1111/j.1467-789X.2010.00850.x.

Visscher, T. L., Viet, A. L., Kroesbergen, I. H., & Seidell, J. C. (2006). Underreporting of BMI in adults and its effect on obesity prevalence estimations in the period 1998 to 2001. *Obesity (Silver Spring), 14*(11), 2054–2063. https://doi.org/10.1038/oby.2006.240.

Wang, Y., & Beydoun, M. A. (2007). The obesity epidemic in the United States—gender, age, socioeconomic, racial/ethnic, and geographic characteristics: A systematic review and meta-regression analysis. *Epidemiology Reviews, 29*, 6–28. https://doi.org/10.1093/epirev/mxm007.

World Health Organization. (2017). Preterm birth. Retrieved from http://www.who.int/mediacentre/factsheets/fs363/en/.