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Maternal Obesity and Risk of Preterm Birth and Low Birthweight in Hawaii PRAMS, 2000–2011

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Abstract
Objective Maternal obesity is a risk factor for preterm birth, a leading cause of infant morbidity and mortality. Native Hawaiian and other Pacific Islanders (NHOPI) have high rates of poor birth outcomes. Despite the high rates of obesity in NHOPI in Hawaii, the association with preterm birth has not been examined in this population. *Methods* We performed a retrospective cohort study of 20,061 women using data collected by Hawaii's Pregnancy Risk Assessment Monitoring System (PRAMS) from 2000 to 2011. We investigated the contribution of maternal age, pre-pregnancy BMI, gestational diabetes, hypertension, race, socioeconomic status, and smoking to our primary outcomes of preterm birth and low birthweight using multivariable logistic regression, stratified by NHOPI versus non-NHOPI race. *Results* Pre-pregnancy obesity was more common in NHOPI than non-NHOPI women (23.9 and 10.5%, respectively; $p < 0.01$). Overall, the risk for preterm birth increased with maternal obesity (BMI ≥ 30.0; aOR = 1.24, 95% CI 1.06–1.45, $p < 0.01$), compared with normal weight women. Among NHOPI women, the prevalence of preterm birth was elevated compared with non-NHOPI women although the prevalence of low birth weight was lower. After adjusting for confounders, risk for preterm birth and low birth weight were elevated in NHOPI women compared with White women. Maternal obesity did not significantly affect the risk of prematurity within the NHOPI group. *Conclusions for Practice* Our study demonstrates an association between maternal pre-pregnancy obesity and preterm deliveries in Hawaii. NHOPI have high rates of pre-pregnancy obesity as well as increased risk of both preterm delivery and low birthweight when compared to White women. Further data are needed to assess interactions between race, maternal health, and neonatal morbidity, and to identify ways to improve birth outcomes for minority populations in the state of Hawaii.

Keywords Obesity · Hawaii · Native Hawaiian · Prematurity · Preterm birth · Low birthweight · PRAMS

Abbreviations

PRAMS	Pregnancy Risk Assessment Monitoring System
NHOPI	Native Hawaiian and Other Pacific Islander
LBW	Low birthweight

Significance

What is already known on this subject? Obesity is a significant health issue in the state of Hawaii, particularly in the Native Hawaiian and other Pacific Islander (NHOPI) population. Maternal obesity is a known risk factor for multiple complications in pregnancy including premature delivery.

What this study adds? This study characterizes the prevalence of maternal obesity and associated comorbidities in the state of Hawaii with a focus on NHOPI women. Prevalence of preterm birth is elevated among NHOPI women while low birth weight is lower. However, risk for both are elevated in NHOPI women after adjusting for confounders underlining the importance of further studies to characterize risk. Risk factors associated with prematurity and low birthweight are different for NHOPI women than non-NHOPI women, highlighting a need for research into the health disparities affecting this population.

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Introduction

Obesity is a major public health issue throughout the United States, and represents a major challenge in the state of Hawaii (Moy et al. 2010; Madan et al. 2012). Nationwide, almost two-thirds of US adults are overweight or obese (Flegal et al. 2012) and estimates for obesity among pregnant women range from 18.5 to 38.3% (Yogev and Catalano 2009). Among Native Hawaiians and other Pacific Islander adults in the state of Hawaii, the prevalence of overweight and obesity is 73.4% (CDC 2013).

Maternal obesity before and during pregnancy is a known risk factor for a wide range of poor pregnancy outcomes, including miscarriage (Lo et al. 2012), fetal anomalies (Nodine and Hastings-Tolsma 2012), gestational diabetes (Aviram et al. 2011), preeclampsia (Kulie et al. 2011), delivery complications (Blomberg 2013), and obesity and metabolic syndrome in childhood (Simmons 2011). A comprehensive review (McDonald et al. 2010) examined evidence for an association between maternal obesity and adverse child outcomes and found an increased risk of preterm birth in overweight and obese women. The high rates of obesity in Hawaiian women pose a significant risk during pregnancy and may contribute to greater adverse perinatal outcomes compared with non-Hispanic Whites (Schempf et al. 2010).

Previous studies looking at pregnancy-associated risk factors for neonatal morbidity in Hawaii have examined predictors of exclusive breastfeeding (Hayes et al. 2014), reporting on post-partum depression (Hayes et al. 2010), and the prevalence of gestational diabetes and its association with macrosomia in different racial groups (Tsai et al. 2013), but little is known about the role of maternal obesity in relation to prematurity and low birthweight (LBW) in the population consisting of Native Hawaiian and other Pacific Islanders (NHOPI). The goals of this study were to evaluate the effect of maternal obesity and associated co-morbidities including hypertension and gestational diabetes on prematurity and LBW in the state of Hawaii, and to examine the characteristics associated with these birth outcomes in NHOPI women, using a large, population-based dataset, the Hawaii Pregnancy Risk Assessment Monitoring System (PRAMS).

Methods

PRAMS Survey

We performed a cross-sectional retrospective cohort study using data from Hawaii PRAMS 2000–2011. PRAMS is a population-based surveillance system by the Centers for Disease Control and Prevention (CDC) and state health departments in 40 states with the goal of monitoring maternal behaviors and risk factors to determine links to infant morbidity and mortality. It is a cross-sectional survey that collects maternal self-reported information on health issues in pregnancy including self reported smoking frequency as well as hypertension and diabetes during pregnancy. This information is then supplemented by linked birth certificate data including birthweight, maternal pregnancy complications and maternal exposure in pregnancy including smoking in pregnancy.

Hawaii PRAMS began officially collecting data in 2000 and remains active in 2014. At the time this study was conducted, data was available for Phases 4–6, which represented mothers surveyed in Hawaii between 2000 and 2011. The data are stratified using a sampling weight to each respondent based on birth weight, geographic location, and ethnicity. Nonresponse adjustment factors are used to account for lower response rates within certain strata (such as lower educational level) based on multivariate analysis. Noncoverage weights are used to account for any missing records that are clustered geographically or temporally. This study took this complex survey design into account by using the overall analysis weight produced by the sampling, nonresponse, and noncoverage components of the weight. The full methodology of PRAMS is described by Shulman et al. (2006).

For our analysis, smoking in pregnancy was used from the birth certificate in lieu of self-reported data as the birth certificate question is binary (did the mother smoke in pregnancy) while the PRAMS questions asked about smoking in the last 3 months of pregnancy and the last 3 months before being pregnant, without having a question about smoking during the duration of the pregnancy. Additionally, birthweight and gestational age were also extracted from the birth certificate instead of using the self-reported measures from the PRAMS questionnaire.

Data Analysis

The two major outcomes of interest in this study were preterm birth (defined as gestational age less than 37 weeks) and LBW (defined as under 2500 g). For the state of Hawaii, gestational age is measured based on clinical estimate of gestational age (Hayes et al. 2010).

Given the high prevalence of obesity and other health issues faced by the Native Hawaiian and other Pacific Islander population, we conducted a separate analysis of risk factors for our outcomes of interest in NHOPI mothers to better understand the causes of these health disparities, initially by using chi-squared tests to test for differences in baseline characteristics and then by running NHOPI subgroup specific logistic regression and multivariable logistic

regression analyses. We conducted a similar approach in the non-NHOPI sub-groups as well as the overall cohort (NHOPI and non-NHOPI mothers). We followed the analytic approach of Schempf et al. (2010) that grouped Native Hawaiian with other Pacific Islander groups (e.g. Samoan, Tongan, Guamanian) and analyzed Filipino as a separate Asian group (Hayes et al. 2014).

Risk factors for prematurity and LBW (including maternal age, ethnicity, education level, marital status, socioeconomic status as indicated by income level, smoking during pregnancy, pre-pregnancy body mass index (BMI)) and health status in pregnancy were assessed using logistic regression models. We subsequently adjusted all outcomes for maternal age, education level, participation in the Special Supplemental Nutrition Program for Women, Infants and Children (WIC), pre-pregnancy BMI and smoking status in multivariable models. All birth weights including infants with high birthweight (HBW) (> 4000 g) were included in the reference group for LBW analysis. Additionally, the LBW analysis did not adjust or account for gestational age or prematurity. We subsequently investigated the differential impact of hypertension and similarly diabetes during pregnancy in relation to prematurity and low birth weight in NHOPI and non-NHOPI population groups by conducting stratified analyses and by including an interaction term in multivariable models. Lastly we assessed the role of obesity in relation to hypertension and gestational diabetes on the impact of risk for LBW and prematurity through stratified analysis in our cohort and by including interaction terms in multivariable models.

All data analysis used Stata 13.1 using "svy" estimation to account for the analysis weight provided by PRAMS to adjust for survey stratification.

Results

The total number of women surveyed as part of Hawaii PRAMS between 2000 and 2011 was 22,449. Of these, 20,061 women (89.4%) had data for maternal demographics, birthweight, and gestational age and were included in this study. The mean (SD) age of the women included was 28.0 (7.1) years with a mean BMI of 24.7 (6.5) kg/m^2. The prevalence of pre-pregnancy obesity in this cohort (defined as BMI 30.0–39.9) was 12.9% (95% CI 12.4–13.4), and was higher for NHOPI women at 20.3% (95% CI 19.2–21.4) than non-NHOPI women at 9.2% (95% CI 8.7–9.9) ($p < 0.01$; Table 1). For extreme obesity (defined as BMI ≥ 40.0), the prevalence in the cohort overall was 2.1% (95% CI 1.9–2.3) and the prevalence for the NHOPI population was 3.6% (95% CI 3.2–4.1) vs. 1.3% (95% CI 1.1–1.6) for the non-NHOPI population (Table 1).

Characteristics of the NHOPI Population

In addition to having higher overall rates of pre-pregnancy obesity compared to non-NHOPI women, the NHOPI mothers had a lower weighted mean age at delivery compared to non-NHOPI mothers [25.9 (7.0) vs. 29.0 (6.9) years, $p < 0.01$]. They had significantly lower levels of educational attainment, with 33.4% going on to post-high school education compared with 61.1% for non-NHOPI women ($p < 0.01$), and 60.0% participated in WIC during pregnancy compared with 34.4% of non-NHOPI mothers ($p < 0.01$) (Table 1). NHOPI women surveyed by PRAMS had higher rates of smoking during pregnancy (8.5%) compared to non-NHOPI women (3.7%, $p < 0.01$) (Table 1). Rates of gestational diabetes were not significantly different between these two groups, but NHOPI women did have higher rates of hypertension during pregnancy than non-NHOPI women (13.4 vs 10.7%, $p < 0.01$) (Table 1).

Risk Factors for Prematurity

Significant risk factors for prematurity in the group as a whole included age and non-white maternal race (Table 2). The adjusted odds of prematurity were 1.39 ($p < 0.01$) for NHOPI mothers compared to White mothers. Women under 20 (aOR 1.37, $p < 0.01$) and over 35 years (aOR 1.56, $p < 0.01$) were also at higher risk compared to mothers in their mid- to late-twenties as were women 20–24.9 years (aOR 1.9, $p = 0.03$) and women 30–34.9 (aOR 1.21, $p = 0.02$) (Table 2). Lower levels of maternal education and receiving WIC benefits during pregnancy were not significantly associated with increased risk of prematurity. For NHOPI women, maternal age greater than 35 years (aOR 1.80, $p < 0.01$) and lower maternal education status (12 years of education or less, aOR 1.25, $p = 0.03$) were both associated with an increased risk of prematurity.

Hypertension was associated with an increased risk of prematurity (aOR 2.39, $p < 0.01$) for the study population overall including both NHOPI (aOR 2.44, $p < 0.01$) and non-NHOPI (aOR 2.35, $p < 0.01$) women. Diabetes during pregnancy similarly was associated with increased risk of prematurity. (Table 2). When we analyzed risk factors for prematurity with and without hypertension during pregnancy, there were differences in risk for prematurity based on level of obesity. For women with hypertension during pregnancy, extreme obesity (BMI ≥ 40.0) was strongly associated with prematurity (aOR 2.01, $p < 0.01$; results not shown). For women with no hypertension during pregnancy, none of the BMI categories were significantly associated with an increased or decreased risk of prematurity (results not shown). When an interaction term between BMI category and hypertension was included in the model, it trended towards significance ($F = 1.97$; $p = 0.096$).

Table 1 Weighted frequencies of maternal demographics and maternal and infant health characteristics

Variable	Total N = 20,061	Total % (95% CI)	N NHOPI	NHOPI% (95% CI)	N Non- NHOPI	Non-NHOPI % (95% CI)	P value
Race							
NHOPI	7657	33.2 (32.6–33.7)					
Non-NHOPI	12,404	66.8 (66.3–67.4)					
White	3934	22.1 (21.5–22.7)					
Filipino	3467	18.8 (18.3–19.4)					
Other Asian	4123	20.5 (19.9–21.1)					
Other	880	5.4 (5.0–5.8)					
Age							< 0.01
<20 years	1814	8.4 (7.9–8.8)	1159	14.2 (13.3–15.1)	655	5.5 (5.0–6.0)	
20–24.9 years	4844	24.3 (23.6–24.9)	2452	32.0 (30.8–33.3)	2392	20.4 (19.6–21.2)	
25–29.9 years	5186	26.7 (26.0-27.4)	1990	27.1 (26.0-28.4)	3196	26.4 (25.5–27.3)	
30–34.9 years	4687	23.5 (22.8–24.2)	1301	17.1 (16.1–18.1)	3386	26.7 (25.8–27.6)	
≥ 35 years	3530	17.2 (16.7–17.8)	755	9.6 (8.9–10.4)	2775	21.0 (20.2–21.8)	
Education level							< 0.01
≤ 12 years	9633	48.1 (47.3–48.9)	5008	66.6 (65.4–67.9)	4625	38.9 (38.0-39.9)	
> 12 years	10,428	51.9 (51.1–52.7)	2649	33.4 (32.1–34.6)	7779	61.1 (60.1–62.0)	
WIC during pregnancy							< 0.01
Yes	8789	42.9 (42.1–43.7)	4508	60.0 (58.6–61.3)	4281	34.4 (33.5–35.4)	
No	11,272	57.1 (56.3–57.9)	3149	40.0 (38.7–41.4)	8123	65.6 (64.6–66.5)	
Marital status							< 0.01
Married	12,802	65.0 (64.2–65.7)	3479	44.1 (42.8–45.5)	9323	75.3 (74.4–76.1)	
Not married	7258	35.0 (34.3–35.8)	4177	55.9 (54.5–57.2)	3081	24.7 (23.9–25.6)	
Pre-pregnancy BMI							< 0.01
Underweight, < 18.5	1244	6.0 (5.6–6.3)	322	3.9 (3.4–4.4)	922	7.0 (6.5–7.5)	
Normal, 18.5–24.9	11,587	56.9 (56.1–57.7)	3716	46.7 (45.4–48.1)	7871	61.9 (61.0–62.9)	
Overweight, 25.0–29.9	4272	22.2 (21.5–22.9)	1887	25.5 (24.3–26.7)	2385	20.5 (19.7–21.4)	
Obese, 30.0–39.9	2543	12.9 (12.4–13.4)	1461	20.3 (19.2–21.4)	1082	9.2 (8.7–9.9)	
Extreme obesity, ≥ 40.0	415	2.1 (1.9–2.3)	271	3.6 (3.2–4.1)	144	1.3 (1.1–1.6)	
Smoking during pregnancy							< 0.01
Yes	1125	5.3 (4.9–5.6)	699	8.5 (7.8–9.3)	426	3.7 (3.3–4.1)	
No	18,936	94.7 (94.4–95.1)	6958	91.5 (90.7–92.2)	11,978	96.3 (95.9–96.7)	
Hypertension in pregnancy							< 0.01
Yes	2362	11.6 (11.1–12.1)	1063	13.4 (12.6–14.4)	1299	10.7 (10.1–11.3)	
No	17,669	88.4 (87.9–88.9)	6586	86.6 (85.6–87.4)	11,083	89.3 (88.7–89.9)	
Diabetes in pregnancy							0.18
Yes	2191	11.0 (10.5–11.5)	817	11.5 (10.6–12.4)	1374	10.7 (10.1–11.4)	
No	17,870	89.0 (88.5–89.5)	6840	88.5 (87.6–89.4)	11,030	89.3 (88.6–89.9)	
Birth weight							< 0.01
LBW, < 2500 g	1833	6.9 (6.6–7.3)	641	6.6 (6.0–7.1)	1192	7.1 (6.7–7.5)	
Normal BW, 2500–3999 g	16,691	85.1 (84.6–85.6)	6360	84.6 (83.6–85.4)	10,331	85.4 (84.7–86.0)	
HBW, > 4000 g	1537	8.0 (7.5–8.4)	656	8.9 (8.1–9.7)	881	7.5 (7.0-8.1)	
Preterm birth							0.44
Gestational age < 37 weeks	2060	8.9 (8.5–9.3)	785	9.1 (8.4–9.8)	1275	8.8 (8.2–9.3)	
Gestational age ≥ 37 weeks	18,001	91.1 (90.7–91.5)	6872	90.9 (90.2–91.6)	11,129	91.2 (90.7–91.8)	

Weighted according to PRAMS stratification protocol, with "N" from unweighted data. "Non-NHOPI" includes all individuals who did not identify as Native Hawaiian or other Pacific Islander (including White, Filipino, Other Asian) (including Chinese, Japanese, Korean, and Vietnamese), and Other (including Black, Mexican, Puerto Rican, Portuguese, and all others). "Smoking during pregnancy" was estimated from the birth certificate variable for maternal smoking rather than PRAMS self-report

Table 2 Maternal demographic and health-associated risk factors for prematurity (GA < 37 weeks)

Characteristic	N Premature (total)	Overall aOR (95% CI)	N Premature (total) NHOPI	aOR for NHOPI (95% CI)	N Premature (total) non-NHOPI	aOR for non-NHOPI (95% CI)
Race						
White	306 (3934)	Ref.			306 (3628)	Ref.
NHOPI	785 (7657)	1.39 (1.18–1.64)	785 (7657)			
Filipino	425 (3467)	1.77 (1.48–2.10)			425 (3467)	1.76 (1.48–2.10)
Other Asian	430 (4123)	1.35 (1.13–1.61)			430 (4123)	1.36 (1.14–1.62)
Other	114 (880)	1.66 (1.28–2.14)			114 (880)	1.63 (1.26–2.11)
Age (years)						
<20	196 (1814)	1.37 (1.10–1.70)	118 (1159)	1.24 (0.92–1.67)	78 (655)	1.43 (1.04–1.95)
20–24.9	484 (4844)	1.19 (1.02–1.40)	239 (2452)	1.05 (0.83–1.33)	245 (2392)	1.29 (1.04–1.59)
25–29.9	456 (5186)	Ref.	181 (1990)	Ref.	275 (3196)	Ref.
30–34.9	478 (4687)	1.21 (1.03–1.41)	134 (1301)	1.15 (0.88–1.50)	344 (3386)	1.24 (1.02–1.50)
≥ 35	446 (3530)	1.56 (1.33–1.84)	113 (755)	1.80 (1.35–2.40)	333 (2775)	1.52 (1.25–1.85)
Education level						
≤ 12 years	981 (9633)	1.07 (0.95–1.20)	523 (5008)	1.25 (1.03–1.52)	458 (4625)	0.99 (0.85–1.15)
> 12 years	1079 (10,428)	Ref.	262 (2649)	Ref.	817 (7779)	Ref.
WIC during pregnancy						
Yes	923 (8789)	1.02 (0.91–1.15)	464 (4508)	0.98 (0.81–1.19)	459 (4281)	1.05 (0.91–1.23)
No	1137 (11,272)	Ref.	321 (3149)	Ref.	816 (8123)	Ref.
Pre-pregnancy BMI						
Underweight, < 18.5	134 (1244)	1.17 (0.94–1.47)	42 (322)	1.42 (0.92–2.17)	92 (922)	1.11 (0.86–1.44)
Normal, 18.5–24.9	1121 (11,587)	Ref.	370 (3716)	Ref.	751 (7871)	Ref.
Overweight, 25.0–29.9	470 (4272)	1.10 (0.97–1.26)	191 (1887)	0.99 (0.80–1.23)	279 (2385)	1.16 (0.98–1.37)
All obese (≥ 30.0)	335 (2958)	1.24 (1.06–1.45)	182 (1732)	1.04 (0.83–1.29)	153 (1126)	1.40 (1.13–1.74)
Obese, 30.0–39.9	277 (2543)	1.17 (1.00–1.39)	145 (1461)	0.99 (0.79–1.26)	132 (1082)	1.31 (1.04–1.65)
Extremely obese ≥ 40.0	58 (415)	1.68 (1.21–2.34)	37 (271)	1.29 (0.86–1.95)	21 (144)	2.10 (1.25–3.51)
Hypertension during pregnancy						
Yes	454 (2362)	2.39 (2.09–2.72)	192 (1063)	2.44 (1.99–2.99)	262 (1299)	2.35 (1.97–2.97)
No	1908 (17,669)	Ref.	591 (6586)	Ref.	1009 (11,083)	Ref.
Diabetes in pregnancy						
Yes	313 (2191)	1.44 (1.24–1.69)	117 (817)	1.55 (1.21–1.99)	196 (1374)	1.38 (1.14–1.68)
No	1747 (17,870)	Ref.	668 (6840)	Ref.	1076 (11,030)	
Smoking during pregnancy						
Yes	125 (1125)	0.93 (0.76–1.15)	72 (699)	0.85 (0.64–1.13)	53 (426)	1.02 (0.74–1.40)
No	1935 (18,936)	Ref.	713 (6958)	Ref.	1222 (11,978)	Ref.

Weighted according to PRAMS stratification protocol, with "N" from unweighted data. Multivariate logistic regression model adjusted for race, age, education level, WIC participation, pre-pregnancy BMI and smoking

"Non-NHOPI" includes all individuals who did not identify as Native Hawaiian or other Pacific Islander (including White, Filipino, Other Asian) (including Chiense, Japanese, Korean, and Vietnamese), and Other (including Black, Mexican, Puerto Rican, Portuguese, and all others). "Smoking during pregnancy" was estimated from the birth certificate variable for maternal smoking rather than PRAMS self-report

Maternal pre-pregnancy BMI was associated with prematurity for the study population overall and for non-NHOPI women (Table 2). Underweight (BMI < 18.5) and overweight (BMI 25.0–29.9) did not increase risk of preterm birth, but overall obesity (including obesity with BMI 30.0-39.9 and extreme obesity BMI ≥ 40) were associated with a higher risk of prematurity (aOR 1.24, $p < 0.01$, for BMI ≥ 30). These associations remained significant for the non-NHOPI group for obesity (aOR 1.31, $p = 0.02$) and

extreme obesity (aOR 2.10, $p < 0.01$) but were not significant for NHOPI women (Table 2).

Risk Factors for Low Birthweight

The odds of LBW were elevated among NHOPI (aOR 1.33, $p < 0.01$), Filipino, Other Asian, and Other maternal racial groups as compared to White mothers (Table 3). In addition, both low maternal age (< 20 years) and advanced maternal age (> 35 years) were significant risk factors for LBW overall as were the early to middle 20's (20–24.99) and early to middle 30's (30–34.9) compared to 25–29.9 years. These associations were significant for the NHOPI and non-NHOPI sub-groups. Smoking during pregnancy was significantly associated with a higher risk of LBW outcomes overall (aOR 1.38, $p < 0.01$) and for both the NHOPI and non-NHOPI sub-groups.

While the association between pre-pregnancy BMI and LBW trended towards significance with the strongest association between maternal overweight and LWB, this association was not as strong as that between BMI and prematurity (Table 3). For the overall study population, maternal underweight BMI was associated with a higher risk of LBW (aOR 1.33, $p < 0.01$) compared with normal pre-pregnancy BMI. Overweight and obese pre-pregnancy BMI were both slightly protective, with aORs of 0.85 ($p = 0.02$) and 0.84 ($p = 0.05$) respectively. This association was not present for extreme obesity (BMI ≥ 40). For NHOPI mothers, there was no association between underweight or overweight BMI and LBW, but similarly obesity was protective (aOR 0.76, $p = 0.04$).

The results of a stratified analysis indicated that obesity status differentially impacted gestational diabetes risk on LBW. Overall, gestational diabetes was associated with higher risk of LBW (aOR 1.28, $p < 0.01$). Women with gestational diabetes had no significantly increased risk of LBW from underweight BMI (aOR 1.37, $p = 0.48$) but a significant protective effect from obese BMI (aOR 0.50, $p < 0.01$), while women without gestational diabetes had an increased risk of LBW from underweight BMI (1.34, $p < 0.01$) and no significant protective effect from obesity (aOR 0.90, $p = 0.28$) (results not shown). However, an interaction term between gestational diabetes and BMI category when modeled showed no statistical significance for LBW outcome (results not shown).

Similarly, mothers without hypertension who were underweight were more likely to have a LBW infant (aOR 1.42, $p < 0.01$) but less likely if they were obese (aOR 0.73, $p < 0.01$) (results not shown). An interaction term between hypertension and BMI category, when included in the multivariable model for LBW, neared statistical significance ($F = 2.05$; $p = 0.07$).

Discussion

Our study comprehensively examines the association between maternal obesity and associated co-morbidities such as gestational diabetes and hypertension with prematurity and LBW in the state of Hawaii with a focus on better understanding the relationship between the high prevalence of obesity in NHOPI and adverse birth outcomes.

Overall, we found slightly lower rates of prematurity in Hawaii [8.9%, 95% CI (8.5–9.3)] as compared to statewide yearly estimates produced by the National Center for Health Statistics (NCHS), ranging from 12.1 to 13.7% between 2002 and 2013 (National Center for Health Statistics (NCHS) 2014). Our lower estimate may be due to differences in how the NCHS and PRAMS calculate variables and impute missing data. For example, when date of last menstrual period, or LMP, is incomplete, the NCHS has an algorithm that assigns one based on other records with similar race and birthweight, while PRAMS uses gestational age as recorded on the birth certificate only which is reported based on clinical estimate of gestational age (Hayes et al. 2010). Our weighted estimate of LBW infants [6.9%, 95% CI (6.6–7.3)] was slightly lower than statewide rates of 7.9 to 8.6% between 2002 and 2013, as reported by the NCHS. We found a higher overall rate of prematurity in NHOPI women than those for other racial/ethnic groups [9.1%, 95% CI (8.4–9.8)]. Prematurity contributes to increased risk of respiratory distress syndrome, retinopathy of prematurity, patent ductus arteriosus, and other health issues requiring care in the Neonatal Intensive Care Unit, as well as infant death. LBW infants are often born premature, and are also paradoxically at risk of developing obesity, metabolic syndrome, and cardiovascular disease later in life (Gluckman et al. 2008; Casey 2008; Vasylyeva et al. 2013).

Maternal Pre-pregnancy Obesity

Multiple reviews have shown an association between maternal pre-pregnancy obesity and preterm birth (McDonald et al. 2010; Torloni et al. 2009). In our study, we found that overall maternal obesity (BMI ≥ 30.0) and extreme obesity (BMI ≥ 40.0), were both associated with higher rates of prematurity after controlling for other confounders including maternal race, age, socioeconomic status, and smoking during pregnancy.

In NHOPI women, however, the relationship between pre-pregnancy BMI and prematurity was not statistically significant. It is possible the dynamics between obesity and preterm birth are different in the NHOPI population than the non-NHOPI population. One reason obesity increases

Table 3 Maternal demographic and health-associated risk factors for low birthweight

Characteristic	N # LBW (total)	Overall aOR (95% CI)	N LBW (Total) NHOPI	aOR for NHOPI (95% CI)	N LBW (Total) Non-NHOPI	aOR for Non-NHOPI (95% CI)
Race						
White	260 (3934)	Ref.			260 (3934)	Ref.
NHOPI	644 (7657)	1.33 (1.12–1.58)	644 (7657)			
Filipino	432 (3467)	2.00 (1.68–2.40)			432 (3467)	1.99 (1.66–2.38)
Other Asian	395 (4123)	1.40 (1.16–1.68)			395 (4123)	1.41 (1.17–1.70)
Other	109 (880)	1.97 (1.52–2.56)			109 (880)	1.95 (1.51–2.54)
Age (years)						
<20	198 (1814)	1.80 (1.45–2.23)	111 (1159)	1.59 (1.17–2.15)	87 (655)	2.02 (1.49–2.73)
20–24.9	438 (4844)	1.33 (1.13–1.57)	201 (2452)	1.30 (1.01–1.66)	237 (2392)	1.35 (1.09–1.68)
25–29.9	385 (5186)	Ref.	134 (1990)	Ref.	251 (3196)	Ref.
30–34.9	416 (4687)	1.30 (1.10–1.53)	108 (1301)	1.41 (1.05–1.89)	308 (3386)	1.26 (1.03–1.53)
≥35	403 (3530)	1.64 (1.39–1.94)	90 (755)	1.90 (1.39–2.59)	313 (2775)	1.57 (1.29–1.92)
Education level						
≤ 12 years	865 (9633)	1.03 (0.91–1.17)	434 (5008)	1.13 (0.92–1.40)	431 (4625)	0.98 (0.84–1.15)
> 12 years	975 (10,428)	Ref.	210 (2649)	Ref.	765 (7779)	Ref.
WIC during pregnancy						
Yes	829 (8789)	1.09 (0.97–1.23)	389 (4508)	1.08 (0.89–1.31)	440 (4281)	1.10 (0.94–1.28)
No	1011 (11,272)	Ref.	255 (3149)	Ref.	756 (8123)	Ref.
Prepregnancy BMI						
Underweight, < 18.5	144 (1244)	1.33 (1.08–1.65)	39 (322)	1.41 (0.95–2.08)	105 (922)	1.31 (1.02–1.67)
Normal, 18.5–24.9	1073 (11,587)	Ref.	324 (3716)	Ref.	749 (7871)	Ref.
Overweight, 25.0–29.9	372 (4272)	0.85 (0.74–0.98)	147 (1887)	0.82 (0.66–1.03)	225 (2385)	0.86 (0.72–1.03)
All obese (BMI ≥ 30)		0.89 (0.75–1.04)		0.82 (0.65–1.04)		0.91 (0.73–1.15)
Obese, 30.0–39.9	208 (2543)	0.84 (0.70-1.00)	104 (1461)	0.76 (0.59–0.98)	104 (1082)	0.89 (0.70–1.14)
Extremely obese ≥40	43 (415)	1.19 (0.83–1.70)	30 (271)	1.20 (0.77–1.88)	13 (144)	1.07 (0.59–1.96)
Hypertension in pregnancy						
Yes	175 (2362)	2.55 (2.23–2.92)	91 (1063)	2.41 (1.94–3.00)	84 (1299)	2.62 (2.21–3.12)
No	1362 (17,669)	Ref.	565 (6586)	Ref.	797(11,083)	Ref.
Diabetes in pregnancy						
Yes	219 (2191)	1.28 (1.08–1.51)	108 (817)	1.37 (1.04–1.79)	111 (1374)	1.24 (1.01–1.53)
No	1318 (17,870)	Ref.	548 (6840)	Ref.	770 (11.030)	Ref.
Smoking in pregnancy						
Yes	138 (1125)	1.38 (1.12–1.69)	75 (699)	1.34 (1.01–1.78)	63 (426)	1.39 (1.03–1.87)
No	1702 (18,936)	Ref.	569 (6958)	Ref.	1133 (11,978)	Ref.

Weighted according to PRAMS stratification protocol, with "N" from unweighted data. Multivariate logistic regression model adjusted for race, age, education level, WIC participation, pre-pregnancy BMI and smoking

"Non-NHOPI" includes all individuals who did not identify as Native Hawaiian or other Pacific Islander (including White, Filipino, Other Asian) (including Chiense, Japanese, Korean, and Vietnamese), and Other (including Black, Mexican, Puerto Rican, Portuguese, and all others). "Smoking during pregnancy" was estimated from the birth certificate variable for maternal smoking rather than PRAMS self-report

risk of preterm delivery is the higher rate of maternal health complications such as preeclampsia (Cnattingius et al. 2013), which is also associated with advanced maternal age (Paré et al. 2014). It is possible that the protective effect of the significantly younger age demographics of the NHOPI population surveyed by PRAMS outweighs the risk of obesity to some extent. Future studies should conduct a more detailed analysis of the type of preterm

delivery (spontaneous vs. medically indicated) to assess whether induction for preeclampsia and other pregnancy-related complications differ for by ethnicity in the state of Hawaii.

In addition, our results demonstrate that the affect of obesity on increased risk of prematurity may be in part due to the presence or absence of hypertension, as women with both hypertension and extreme obesity had a significantly increased risk of prematurity (aOR 2.01, $p < 0.01$), while women without hypertension showed no relationship between obesity and prematurity. As NHOPI women have higher rates of hypertension and obesity during pregnancy than non-NHOPI women, this and other health disparities not accounted for in our analysis may explain why there was greater overall risk for prematurity in NHOPI women.

In addition, we found maternal BMI was associated with significant differences in risk for LBW overall. Underweight was significantly associated with an increased risk of LBW, while overweight (BMI 25.0–29.9) and obesity (BMI 30.0–39.9) were significantly protective against LBW. This protective effect was not present for extreme obesity (BMI ≥ 40), which appeared to cause an increase in LBW, although this was not significant. These results correspond with prior studies, which show that pre-pregnancy underweight increases the risk of LBW while pre-pregnancy overweight and obesity generally does not (Yu et al. 2013), and that high BMI is generally associated with higher birthweights and may be protective against LBW (Sharifzadeh et al. 2014, McDonald et al. 2010).

Maternal Race/Ethnicity

We found a significant increase in prematurity and LBW for NHOPI, Filipino, Other Asian (including Chinese, Japanese, Korean, and Vietnamese), and Other (including Black, Puerto Rican, Portuguese, Mexican, and all other) mothers when compared to White mothers after adjusting for potential confounders. These results correspond with studies showing an increased risk of prematurity and LBW in Asian immigrants in California, with the highest risk group being Filipino women (Schempf et al. 2010; Qin and Gould 2010).

We examined the sub-group of Native Hawaiian and Other Pacific Islander women using a stratified analysis. NHOPI women, including many descended from the indigenous inhabitants of the Hawaiian islands, are the focus of many targeted interventions to improve maternal health, and our goal was to better characterize risk factors unique to this population to assist with future efforts to improve birth outcomes.

Risk factors for prematurity and LBW differed significantly for NHOPI women from the overall cohort and from non-NHOPI women. For preterm birth, young maternal age increased risk significantly overall, but not for NHOPI women. In addition, lower maternal education was associated with a higher risk of prematurity compared to those with some post-high school education in the NHOPI group, but this was not significant for non-NHOPI group.

For LBW, there were fewer differences between NHOPI and non-NHOPI women, with the only exception being the role of BMI. For non-NHOPI women, underweight BMI was associated with an increased risk of LBW while there was no association for overweight and obese BMI. For the NHOPI group, higher weights (obesity and overweight) protected against LBW.

Collectively, these differences may be due to unknown confounders. Another consideration is the differential impact of maternal diabetes during pregnancy in relation to maternal weight status. Overall, women with gestational diabetes had no significant increase in risk of LBW but those who were obese were less likely to have a LBW baby, while underweight women without gestational diabetes had an increased risk of LBW and no protective effect from obesity. Future studies should assess specific risk factors for NHOPI mothers, as one study attributed almost half of the high rate of infant mortality in the NHOPI population to preterm or LBW births (Qin and Gould 2010).

In addition to possible biomedical differences, there are likely other sociodemographic factors that result in different risk profiles for NHOPI birth outcomes. Multiple studies have described lower rates of postsecondary education, lower average household income, and higher rates of smoking that likely result in less awareness of positive health behaviors and less access to medical care overall (Tsai et al. 2013; Hirai et al. 2013).

Limitations

The major limitations of our study include systemic biases in survey design as well as issues with data categorization and completeness. Both PRAMS data and birth certificate data are reported retrospectively, resulting in recall bias, and may also include self-report bias due to subject under- or over-reporting certain experiences and behaviors when surveyed by mail or phone. Maternal pre-pregnancy BMI, one of the major predictors in our study, was calculated based on self-reported pre-pregnancy weight and height on the PRAMS survey, which are less reliable than measurements taken as part of a study protocol due to the potential for both recall bias and self-report bias in this methodology. Previous studies of self-reported BMI have found that, in particular, obese individuals and female under-report their weight, however it is not clear if this bias would have differentially impacted NHOPI vs. non-NHOPI participants (Tang et al. 2016, 31). PRAMS data from 2000 to 2011 was combined for this study to maximize statistical power, but this also resulted in the use of three different variations of the PRAMS survey

(Phases 4, 5 and 6), which restricted the variables available for analysis somewhat to the information that was collected in all three versions. This resulted in an inability to look at socio-economic variables in detail, as information for household income and number of dependents was not available for Phase 4. In addition, we were not able to examine pre-existing maternal diabetes of hypertension because this data was not available for phase 4, so the analysis of the effect of diabetes during pregnancy was restricted to those who reported diabetes or hypertension during pregnancy.

A major limitation in the analysis of the effect on maternal race on our outcomes of interest was the restriction of maternal race to a single category. Native Hawaiians are an extremely heterogeneous group, with more than half (56%) reporting multiple races on the U.S. Census in 2010 (Tang et al. 2016). One study characterizing neonatal morbidity in single- and multiple-race Asian women found that outcomes differed significantly by multiple-race status (31), so health risks facing individual NHOPI women are likely influenced by a complex racial background not accounted for in this study. We also compared NHOPI with non-NHOPI, and future studies should compare NHOPI with whites and other Asian groups. We did not have a sufficient N to compare NHOPI with whites or other Asians for specific sub-categories including smoking or extreme obesity and prematurity or low birthweight outcomes.

Conclusions

We found significant associations between maternal pre-pregnancy obesity and preterm deliveries in the state of Hawaii. In addition, our study found that Native Hawaiian and other Pacific Islander women are at higher overall risk of these poor pregnancy outcomes when compared to White women, which calls attention to the serious health disparities faced by this indigenous population. The risk factors for prematurity and low birthweight appear to differ in NHOPI women compared to non-NHOPI women, highlighting a need for further research in this high-risk group to improve maternal and infant health in the future.

Author Contributors Dr. Ju conceptualized and designed the study, carried out the data analysis, drafted the initial manuscript, and approved the final manuscript as submitted. Dr. Wojcicki advised on study design and data analysis, reviewed and revised the manuscript, and approved the final manuscript as submitted. Drs. Heyman and Garber critically reviewed the manuscript and approved the final manuscript as submitted.

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Compliance with Ethical Standards

Conflict of interest The authors have no conflicts of interest relevant to this article to disclose.

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