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Effects of Race/Ethnicity and BMI on the Association between Height and Risk for Spontaneous Preterm Birth

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Abstract

OBJECTIVE—Short height and obesity have each been associated with increased risk for preterm birth (PTB). However, the effect of short height on PTB risk, across different race/ethnicities and BMI categories, has not been studied. Our objective was to determine the influence of maternal height on the risk for PTB within race/ethnic groups, BMI groups, or adjusted for weight.

STUDY DESIGN—All California singleton, live births between 2007–2010 were included from birth certificate data (vital statistics) linked to hospital discharge data. Pre-pregnancy BMI (kg/m²) was categorized as underweight (< 18.5); normal (18.5–24.9); overweight (25.0–29.9) or obese (> 30.0). Maternal race/ethnicity was categorized as: Non-Hispanic White, Non-Hispanic Black, Hispanic and Asian. Maternal height was classified into 5 categories (shortest, short, middle, tall, tallest) based on racial/ethnic-specific height distributions, with the middle category serving as reference. Poisson regression models were used to estimate relative risks (RR) for the association between maternal height and risk of spontaneous PTB (< 37 weeks and < 32 weeks). Models were stratified on race/ethnicity and BMI. Generalized additive regression models (GAM) were used to detect nonlinearity of the association. Covariates considered were: maternal age, weight, parity, prenatal care, education, medical payment, previous PTB, gestational and pre-gestational diabetes, pre-gestational hypertension, preeclampsia/eclampsia, and smoking.

RESULTS—Among 1,655,385 California singleton live births, 5.2% were spontaneous preterm births < 37 weeks. Short stature (1st height category) was associated with increased risk for PTB

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for Non-Hispanic Whites and Hispanics across all BMI categories. Among obese women, tall stature (5th category) was associated with reduced risk for spontaneous PTB for Non-Hispanic Whites, Asians and Hispanics. Same pattern of association was seen for height and risk for spontaneous PTB < 32 weeks. In the GAM plots, short stature was associated with increased risk for spontaneous PTB of < 32 and <37 weeks of gestation among Whites and Asians. However, this association was not observed for Blacks and Hispanics.

CONCLUSION—Maternal shorter height is associated with a modest increased risk for spontaneous PTB regardless of BMI. Our results suggest that PTB risk assessment should consider race/ethnicity specific height with respect to the norm in addition to BMI assessment.

Keywords

Maternal height; Race/ethnicity; BMI; spontaneous preterm birth

Introduction

In the US, 12.3% of births occur before 37 weeks of gestation, with 5.4% categorized as spontaneous preterm birth (PTB) among singleton live births¹. PTB is the primary cause of perinatal morbidity and mortality in the developed world² and in the US it is associated with an annual cost that exceeds \$26 billion³. Many maternal characteristics have been associated with PTB, including age, race/ethnicity, marital and socio-economic status as well as anthropometrics characteristics (weight and height)^{4–7}. Over the past two decades, there has been substantial investigation into the associations between women's pre-pregnancy body mass index (BMI), weight gain during pregnancy and risk for adverse pregnancy outcomes^{7–11}. Both extremes of BMI categories (underweight and obese) have been associated with increased risk of PTB^{7, 10, 12, 13}. Height, which is an indicator of the interplay between genetic and early-life factors, has been inversely associated with the risk of PTB in some but not all studies^{14–19}. Average height differs across diverse population subgroups, with non-Hispanic White or non-Hispanic Black usually taller than Asian women²⁰. Previous studies that examined the association between height and risk for spontaneous PTB did not stratify according to race/ethnicity. Therefore, It remained unclear whether the inverse association of height with PTB varies across different race/ethnicities. In addition, although height is a component in BMI, its association with spontaneous PTB across BMI categories has rarely been studied.

Our aim was to investigate the association between women's height and spontaneous PTB in a large population-based birth cohort. We examined whether the association varied across women of different races/ethnicities, across different BMI categories, or was influenced by adjustment for weight.

Materials and Methods

All singleton live births in California between 2007 and 2010 were identified from birth certificates (Vital statistics) linked to prenatal screening and hospital discharge databases (i.e., Office of Statewide Health Planning and Development). Inclusion criteria were linked, singleton, live births, born 20–41 weeks of gestation to Non-Hispanic White, Non-Hispanic

Black, Hispanic, and Asian mothers. Exclusion criteria were gestational week at delivery <20 or >41 (often resulting from erroneous gestational dating), missing education, maternal age <13 or >55 years, height <53 or >77 inches (these height cutoffs reflect at least 3 standard deviations for any race/ethnicity), pre-pregnancy weight <75 or >450 pounds, and parity missing or >10. Mothers with unknown month of prenatal care initiation were grouped with those who did not initiate or initiated at 6 months or later. Additionally, unreported medical payment was grouped with uninsured and unreported smoking was grouped with non-smokers. Pre-pregnancy BMI, race/ethnicity and height were obtained from birth certificates. Maternal height was divided into 5 categories based on the approximate 20th, 40th, 60th, and 80th percentiles specific to each racial-ethnic group (shortest, short, middle, tall, tallest), with the middle category serving as reference. The numbers of women in each category are unequal because height was reported to the nearest inch, and certain values were particularly frequent. BMI was categorized according to the WHO classification: underweight (<18.5); normal (18.5–24.9); overweight (25.0–29.9) or obese (≥30.0). Maternal race/ethnicity was categorized as Non-Hispanic White, Non-Hispanic Black, Hispanic and Asian.

Only spontaneous PTBs were included for analysis. Spontaneous PTB was defined using the following ICD-9 and birth certificate codes: preterm premature rupture of membranes (PPROM), premature labor with intact membranes, and those for whom tocolytic medications were administered (ICD-9 codes: 658.1, 644.0 644.2)^{12, 21}. Spontaneous PTB was defined as less than 37 weeks, and sub-classified for analysis as less than 32 completed gestational weeks.

Poisson regression models were used to estimate relative risks (RR) for the association between height and risk of spontaneous PTB (less than 37 or less than 32 weeks of gestation). Models were stratified on race/ethnicity and BMI. Covariates considered were: maternal age (continuous), parity (nulliparous, multiparous), prenatal care (initiation within first 5 months of pregnancy), education (some high school or less, high school graduate, some college, college graduate or more), payor (Medi-Cal, private insurance, uninsured, other), previous PTB history, gestational and pre-gestational diabetes and pre-gestational hypertension, preeclampsia/eclampsia, and smoking (yes, no/not reported). A p-value of less than 0.05 was considered statistically significant. All analyses were performed with SAS 9.3. We used generalized additive regression models (GAM) with polynomial spline estimation, while adjusting for weight and the covariates above in order to explore the relationship between PTB and height and to evaluate the nonlinearity of the association. This study was approved by the Stanford University Institutional Review Board.

Results

Included for analysis were 1,655,385 California live singleton births (20–42 weeks of gestation) in the years 2007 through 2010. Characteristics of the study population by racial/ethnic group are displayed in Table 1. Occurrence of spontaneous PTB of less than 37 weeks was 4.8%, 7.7%, 5.0% and 5.2% for Non-Hispanic Whites, Non-Hispanic Blacks, Asians, and Hispanics, respectively (Table 1). 12% of the records were removed due to missing/outlier information. A large proportion of the missing/outlier information was attributed to

missing data on maternal weight (7.85%) and height (5.25%). In addition, missing information about gestational age at birth attributed a small proportion (1.49%). The proportion of missing information for weight, height, and gestational age at birth did not differ across race groups. With regard to the outcome and covariates, there were few meaningful differences between those with and without missing height information. Compared to women with complete height information, mothers with missing height information were slightly more likely to be Medical insured, less educated and were more likely to have missing information on other variables as well.

The total number of subjects for each height category based on a within race/ethnic distribution is presented in Table 2.

Among Non-Hispanic Whites and Hispanics the lowest height category (shortest) was associated with modest increased risk for spontaneous PTB (Table 3). This was observed across all BMI categories. Adjusted relative risks (aRR) ranged from 1.1 to 1.3 (associated p-values < 0.05). A similar trend was seen among Asians across all BMI categories. However, the lowest height category was associated with a statistically significant increased risk for spontaneous PTB with aRRs of 1.1 (95% CI 1.0, 1.2) and 1.2 (95% CI 1.0, 1.4) only among normal and overweight BMI categories, respectively. Among Non-Hispanic Blacks, the lowest height category was associated with a statistically significant increased risk for spontaneous PTB only among normal and obese BMI categories.

Top category of height (tallest) in contrast showed similar magnitude of reduction in risk of spontaneous PTB with aRRs approximating 0.9 for most race/ethnicities and BMI groups.

We further examined the association between height and spontaneous PTB at less than 32 weeks (Table 4). These analyses produced similar results to the <37 weeks gestation comparisons. However, owing to smaller numbers many of the estimated risks had associated confidence intervals that included 1.0.

These aRRs reflect adjustment for maternal age, parity, prenatal care, maternal education, payor, previous PTB history, pre-gestational and gestational diabetes, pre-gestational and gestational hypertension, preeclampsia/eclampsia, and smoking.

Figures 1 and 2 depict the association between height and spontaneous PTB, stratified by race/ethnicity, using spline regression (The shaded areas in Figures 1 and 2 represent the 95% confidence interval). Patterns of association were similar among Whites and Asians. However, a non-linear association was observed for Non-Hispanic Whites but not for Asians. Compared to the mean height among term births, the shortest height (53 inches) was associated with an increased risk for spontaneous PTB with aORs of 1.6 (1.2–2.2) for Asians (mean height: 63 inches) and 2.5 (1.8–3.2) for Non-Hispanic Whites (mean height: 65 inches). However, among Non-Hispanic Blacks and Hispanics whites, the relationship was not as pronounced (Figure 1). A similar pattern was observed for PTB<32 weeks (Figure 2).

To evaluate the impact of adding height to existing prediction models, we have examined model performance based on BMI alone as a predictor for spontaneous PTB, and with the

addition of height into the model. Model performance was improved by the addition of height to models containing BMI and other covariates (Appendix Table 1.)

Comment

In this large population-based study we observed that maternal height was modestly inversely associated with risk for spontaneous preterm birth among Non-Hispanic Whites and Asians but not among Non-Hispanics Blacks and Hispanics. An inverse association between height and risk for spontaneous PTB was found within all BMI categories.

Our findings are consistent with several prior studies that examined the association between height and PTB^{14, 16, 17} while other studies did not detect this association^{15, 18}. A recent systematic review and meta-analyses found that shorter women had a higher unadjusted risk for PTB of less than 37 weeks²². However, the results were inconsistent in the adjusted data²². Meis et al. examined the association between maternal height and risk for spontaneous and indicated PTB. Height of less than 155 centimeters was associated with increased risk for spontaneous PTB in the univariable model, however it was not statistically significant in the multivariable model¹⁵. Similarly, Savitz et al. did not find a significant association between height and spontaneous PTB in the multivariable model¹⁹. The small number in some categories may have limited their statistical power to detect modest differences. Conversely, a larger study by Smith et al. found an increased risk for spontaneous PTB for short women (<150 cm) with HR of 1.39 (95% CI 1.07, 1.79)¹⁴.

The current study adds to the literature with the examination of height and PTB stratified by race/ethnicity. Different races/ethnicities have different height distributions. Our results show different patterns of association between height and risk for spontaneous PTB. To our knowledge, the effect of race/ethnicity on the association between height and spontaneous PTB has not been previously investigated. Our results demonstrate that within each BMI category, shortest height is associated with increased risk, and tallest height is associated with decreased risk for spontaneous PTB. This implies that height, and not just BMI, is important to describe anthropometric aspects influencing the risk for spontaneous PTB.

Several underlying mechanisms may account for the observed association between short stature and an increased risk for spontaneous PTB. Height is the product of the interplay between genetic, intrauterine, childhood and environmental factors. Concordantly, height has been associated with good health and good nutrition. Undernourished girls often grow up to become women of below average height, and often give birth to smaller infants than women who were nourished adequately in their childhood²³. Childhood deficiencies may reflect on both a woman's uterus and her embryo and lead to intra uterine growth restriction, low birth weight or PTB^{24–27}.

Our study has several potential limitations. First, data were derived from birth certificates and discharge databases. Thus, we are limited by the particular reporting and coding in the data set. In particular, height and weight are self-reported in the birth certificate. Consequently, this may have some potential for error owing to women not accurately reporting their height and pre-pregnancy weight. A few previous studies examined the accuracy of height in birth certificate records. Bodnar et al. reported that Birth certificate-

based height was within 1 inch (2.5 cm) of medical record height in 95% of births²⁸. Park et al. have reported that the correlation between birth certificate data and WIC (Women, Infants, and Children Program) data was high further indicating that pre-pregnancy weight, height, and BMI from birth certificates are generally reliable measures²⁹. Second, the non-continuous nature owing to the imprecision of height being measured to the nearest inch in the current study data, limited our ability to use equal quintiles. Nevertheless we used height categories that approximated the 20th, 40th, 60th, 80th percentiles. Third, our findings need to be considered in light of incomplete information for approximately 12% of the population. Lastly, we may have been underpowered to appropriately assess the effect of smoking and prior PTB as under-reporting is implied by the lower rates in our cohort when compared to previous studies (Table 1). The strengths of our study include the large cohort analyzed of heterogeneous race/ethnicity with comprehensive information on maternal, obstetrical, and neonatal characteristics.

Conclusions

Our findings suggest that maternal height is inversely associated with risk for spontaneous PTB, regardless of BMI. Height has been associated with poor nutrition and poor health at childhood. Specifically, mal-nurtured girls grow into mothers that give birth to smaller babies^{24, 27}. Implementation of proven interventions in high burden populations accompanied by improvement in social services may reduce stunting and subsequent rates of spontaneous PTB³⁰. Short stature is an indicator of possible genetic factors and early-life events that may confer increased risk for spontaneous PTB. Our results suggest that PTB risk assessment should consider race/ethnicity specific height with respect to the norm in addition to BMI assessment.

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References

1. Gyamfi-Bannerman C, Ananth CV. Trends in spontaneous and indicated preterm delivery among singleton gestations in the United States, 2005–2012. *Obstetrics and gynecology*. 2014; 124:1069–74. [PubMed: 25415156]
2. Goldenberg RL, Rouse DJ. Prevention of premature birth. *The New England journal of medicine*. 1998; 339:313–20. [PubMed: 9682045]
3. Behrman, RE.; Butler, AS., editors. *Preterm Birth: Causes, Consequences, and Prevention*. Washington (DC): 2007.
4. Iams JD. Clinical practice. Prevention of preterm parturition *The New England journal of medicine*. 2014; 370:254–61. [PubMed: 24428470]
5. Behrman, REB.; AS. *Preterm Birth: Causes, Consequences, and Prevention*. Behrman, RE.; Butler, AS., editors. Washington (DC): 2007.
6. Martin JA, Hamilton BE, Ventura SJ, Osterman MJ, Mathews TJ. Births: final data for 2011. *National vital statistics reports : from the Centers for Disease Control and Prevention, National Center for Health Statistics, National Vital Statistics System*. 2013; 62:1–69. 72.
7. Cnattingius S, Villamor E, Johansson S, et al. Maternal obesity and risk of preterm delivery. *Jama*. 2013; 309:2362–70. [PubMed: 23757084]

8. Carnero AM, Mejia CR, Garcia PJ. Rate of gestational weight gain, pre-pregnancy body mass index and preterm birth subtypes: a retrospective cohort study from Peru. *BJOG : an international journal of obstetrics and gynaecology*. 2012; 119:924–35. [PubMed: 22607522]
9. Truong YN, Yee LM, Caughey AB, Cheng YW. Weight gain in pregnancy: does the Institute of Medicine have it right? *American journal of obstetrics and gynecology*. 2015; 212:362, e1–8. [PubMed: 25725659]
10. Sharma AJ, Vesco KK, Bulkley J, et al. Associations of Gestational Weight Gain with Preterm Birth among Underweight and Normal Weight Women. *Maternal and child health journal*. 2015
11. Rasmussen, KM.; Yaktine, AL., editors. *Weight Gain During Pregnancy: Reexamining the Guidelines*. Washington (DC): 2009.
12. Shaw GM, Wise PH, Mayo J, et al. Maternal prepregnancy body mass index and risk of spontaneous preterm birth. *Paediatric and perinatal epidemiology*. 2014; 28:302–11. [PubMed: 24810721]
13. Gyamf IBC. Maternal obesity is an independent risk factor for spontaneous extremely preterm delivery. *Evidence-based medicine*. 2014; 19:71. [PubMed: 24037124]
14. Smith GC, Shah I, White IR, Pell JP, Crossley JA, Dobbie R. Maternal and biochemical predictors of spontaneous preterm birth among nulliparous women: a systematic analysis in relation to the degree of prematurity. *International journal of epidemiology*. 2006; 35:1169–77. [PubMed: 16882673]
15. Meis PJ, Michielutte R, Peters TJ, et al. Factors associated with preterm birth in Cardiff, Wales. II. Indicated and spontaneous preterm birth. *American journal of obstetrics and gynecology*. 1995; 173:597–602. [PubMed: 7645640]
16. Lao TT, Ho LF. Relationship between preterm delivery and maternal height in teenage pregnancies. *Human reproduction*. 2000; 15:463–8. [PubMed: 10655324]
17. Kramer MS, Coates AL, Michoud MC, Dagenais S, Hamilton EF, Papageorgiou A. Maternal anthropometry and idiopathic preterm labor. *Obstetrics and gynecology*. 1995; 86:744–8. [PubMed: 7566841]
18. Honest H, Bachmann LM, Ngai C, Gupta JK, Kleijnen J, Khan KS. The accuracy of maternal anthropometry measurements as predictor for spontaneous preterm birth--a systematic review. *European journal of obstetrics, gynecology, and reproductive biology*. 2005; 119:11–20.
19. Savitz DA, Dole N, Herring AH, et al. Should spontaneous and medically indicated preterm births be separated for studying aetiology? *Paediatric and perinatal epidemiology*. 2005; 19:97–105. [PubMed: 15787884]
20. Ogden CL, Fryar CD, Carroll MD, Flegal KM. Mean body weight, height, and body mass index, United States 1960–2002. *Advance data*. 2004; 1–17. [PubMed: 15544194]
21. Jelliffe-Pawlowski LL, Shaw GM, Currier RJ, et al. Association of early-preterm birth with abnormal levels of routinely collected first- and second-trimester biomarkers. *American journal of obstetrics and gynecology*. 2013; 208:492, e1–11. [PubMed: 23395922]
22. Han Z, Lutsiv O, Mulla S, McDonald SD. Maternal height and the risk of preterm birth and low birth weight: a systematic review and meta-analyses. *Journal of obstetrics and gynaecology Canada : JOGC = Journal d'obstetrique et gynecologie du Canada : JOGC*. 2012; 34:721–46.
23. Bryce J, Coitinho D, Darnton-Hill I, et al. Maternal and child undernutrition: effective action at national level. *Lancet*. 2008; 371:510–26. [PubMed: 18206224]
24. Ozaltin E, Hill K, Subramanian SV. Association of maternal stature with offspring mortality, underweight, and stunting in low- to middle-income countries. *Jama*. 2010; 303:1507–16. [PubMed: 20407060]
25. Hart N. Famine, maternal nutrition and infant mortality: a re-examination of the Dutch hunger winter. *Population studies*. 1993; 47:27–46. [PubMed: 11623195]
26. A WHO Collaborative Study. Maternal anthropometry and pregnancy outcomes. *Bulletin of the World Health Organization*. 1995; 73 (Suppl):1–98.
27. Martorell R, Zongrone A. Intergenerational influences on child growth and undernutrition. *Paediatric and perinatal epidemiology*. 2012; 26 (Suppl 1):302–14. [PubMed: 22742617]
28. Bodnar LM, Abrams B, Bertolet M, et al. Validity of birth certificate-derived maternal weight data. *Paediatric and perinatal epidemiology*. 2014; 28:203–12. [PubMed: 24673550]

29. Park S, Sappenfield WM, Bish C, Bensyl DM, Goodman D, Menges J. Reliability and validity of birth certificate prepregnancy weight and height among women enrolled in prenatal WIC program: Florida, 2005. *Maternal and child health journal*. 2011; 15:851–9. [PubMed: 19937268]
30. Victora CG, Adair L, Fall C, et al. Maternal and child undernutrition: consequences for adult health and human capital. *Lancet*. 2008; 371:340–57. [PubMed: 18206223]

Figure 1.

Log-odds for the risk of spontaneous PTB <37 weeks associated height and stratified by race/ethnicity. Predicted log-odds estimated from the Generalized Additive logistic regression Model (GAM). The shaded areas represent the 95% CI (confidence interval). Adjusted for: Maternal age, weight, prenatal care, education, parity, payor, smoking, previous PTB, hypertension and diabetes.

Figure 2.

Log-odds for the risk of spontaneous PTB <32 weeks associated height and stratified by race/ethnicity. Predicted log-odds estimated from the Generalized Additive logistic regression Model (GAM). The shaded areas represent the 95% CI (confidence interval). Adjusted for: Maternal age, weight, prenatal care, education, parity, payor, smoking, previous PTB, hypertension and diabetes.

Demographic characteristics, 2007–2010 California singleton live births stratified by race/ethnicity

Table 1

Variable		Non-Hispanic White n (%)	Non-Hispanic Black n (%)	Asian n (%)	Hispanic n (%)
Age	<25	102,173 (21.1)	42,069 (43.5)	16,279 (9.7)	362,847 (40.0)
	25–29	133,367 (27.6)	24,526 (25.4)	41,576 (24.8)	246,675 (27.2)
	30–34	139,551 (28.9)	17,677 (18.3)	64,033 (38.2)	182,243 (20.1)
	≥35	108,453 (22.4)	12,378 (12.8)	45,777 (27.3)	115,761 (12.8)
Pre-pregnancy BMI	Underweight	20,365 (4.2)	3,894 (4.0)	18,044 (10.8)	25,660 (2.8)
	Normal	275,410 (57.0)	40,731 (42.1)	117,271 (69.9)	390,611 (43.0)
	Overweight	107,204 (22.2)	25,461 (26.3)	24,664 (14.7)	270,538 (29.8)
	Obese I	46,829 (9.7)	13,949 (14.4)	5,983 (3.6)	139,261 (15.3)
	Obese II	21,077 (4.4)	6,939 (7.2)	1,336 (0.8)	52,993 (5.8)
	Obese III	12,659 (2.6)	5,676 (5.9)	367 (0.2)	28,463 (3.1)
Prenatal care	Initiation in first 5 months	460,897 (95.3)	87,991 (91.0)	160,838 (95.9)	841,902 (92.8)
	Initiation 6 months or later/No initiation/Unknown	22,647 (4.7)	8,659 (9.0)	6,827 (4.1)	65,624 (7.2)
Education	Some high school or less	30,130 (6.2)	16,294 (16.9)	8,782 (5.2)	381,073 (42.0)
	High school diploma/GED	106,598 (22.0)	33,539 (34.7)	25,306 (15.1)	279,086 (30.8)
	Some college	137,358 (28.4)	33,295 (34.4)	30,512 (18.2)	176,530 (19.5)
	College graduate or more	209,458 (43.3)	13,522 (14.0)	103,065 (61.5)	70,837 (7.8)
Payor	Medi-Cal	112,409 (23.2)	52,074 (53.9)	34,871 (20.8)	594,620 (65.5)
	Private	351,058 (72.6)	36,630 (37.9)	122,972 (73.3)	268,971 (29.6)
	Uninsured/Unknown	5,245 (1.1)	1,700 (1.8)	4,865 (2.9)	21,472 (2.4)
	Other	14,832 (3.1)	6,246 (6.5)	4,957 (3.0)	22,463 (2.5)
Parity	Parity 1	218,379 (45.2)	40,759 (42.2)	80,770 (48.2)	323,233 (35.6)
	Parity 2+	265,165 (54.8)	55,891 (57.8)	86,895 (51.8)	584,293 (64.4)
Previous PTB	No	479,798 (99.2)	95,588 (98.9)	166,962 (99.6)	903,436 (99.5)
	Yes	3,746 (0.8)	1,062 (1.1)	703 (0.4)	4,090 (0.5)
Smoking	No/Unreported	456,747 (94.5)	91,742 (94.9)	166,627 (99.4)	899,333 (99.1)
	Yes	26,797 (5.5)	4,908 (5.1)	1,038 (0.6)	8,193 (0.9)

Variable	Non-Hispanic White n (%)	Non-Hispanic Black n (%)	Asian n (%)	Hispanic n (%)
Pregestational hypertension, preeclampsia/eclampsia	No 457,264 (94.6)	No 91,291 (94.5)	No 148,910 (88.8)	No 834,417 (91.9)
	Yes 26,280 (5.4)	Yes 5,359 (5.5)	Yes 18,755 (11.2)	Yes 73,109 (8.1)
Pregestational/ gestational diabetes	No 451,899 (93.5)	No 86,251 (89.2)	No 161,598 (96.4)	No 852,987 (94.0)
	Yes 31,645 (6.5)	Yes 10,399 (10.8)	Yes 6,067 (3.6)	Yes 54,539 (6.0)

Table 2

Maternal height categories (within race distribution)

	Race/ethnicity							
	Non-Hispanic White		Non-Hispanic Black		Asian		Hispanic	
Maternal height category*	Inches	n (%)	Inches	n (%)	Inches	n (%)	Inches	n (%)
Shortest	53–62	80,709 (16.7)	53–61	10,658 (11.0)	53–60	25,827 (15.4)	53–60	159,839 (17.6)
Short	63	51,691 (10.7)	62–63	21,681 (22.4)	61	18,456 (11.0)	61	106,563 (11.7)
Middle	64–65	134,442 (27.8)	64	13,395 (13.9)	62	31,116 (18.6)	62	164,341 (18.1)
Tall	66	68,057 (14.1)	65–66	25,041 (25.9)	63–64	54,591 (32.6)	63–64	253,286 (27.9)
Tallest	67–77	148,645 (30.7)	67–77	25,875 (26.8)	65–77	37,675 (22.5)	65–77	223,497 (24.6)

* Categories are based on cutoffs for each group at 20th, 40th, 60th, and 80th percentiles

Table 3

Height and risk for spontaneous PTB less than 37 weeks, stratified by race/ethnicity and BMI.

Spontaneous PTB < 37 weeks														
BMI categories														
Race/ethnicity	Height category	Inch	Underweight			Normal			Overweight			Obese		
			N	cRR (CI)	aRR (CI)	N	cRR (CI)	aRR (CI)	N	cRR (CI)	aRR (CI)	N	cRR (CI)	aRR (CI)
Non-Hispanic White	Shortest	53–62	226	1.3 (1.1,1.6)	1.2 (1.1,1.5)	2454	1.2 (1.2,1.3)	1.2 (1.1,1.3)	1108	1.2 (1.1,1.3)	1.2 (1.1,1.3)	1015	1.2 (1.1,1.3)	1.2 (1.1,1.3)
	Short	63	102	1.0 (0.8,1.3)	1.0 (0.8,1.2)	1433	1.0 (1.0,1.1)	1.0 (1.0,1.1)	550	1.1 (1.0,1.2)	1.1 (1.0,1.2)	555	1.1 (1.0,1.2)	1.1 (1.0,1.2)
	Middle	64–65	321	1.0 (ref)	1.0 (ref)	3631	1.0 (ref)	1.0 (ref)	1313	1.0 (ref)	1.0 (ref)	1224	1.0 (ref)	1.0 (ref)
	Tall	66	147	0.9 (0.7,1.1)	0.9 (0.8,1.1)	1642	0.9 (0.9,1.0)	0.9 (0.9,1.0)	675	0.9 (0.9,1.0)	1.0 (0.9,1.0)	550	0.9 (0.8,1.0)	0.9 (0.9,1.0)
	Tallest	67–77	440	0.9 (0.7,1.0)	0.9 (0.8,1.0)	3358	0.9 (0.8,0.9)	0.9 (0.8,0.9)	1296	0.9 (0.8,0.9)	0.9 (0.8,0.9)	1064	0.9 (0.8,0.9)	0.8 (0.8,0.9)
Non-Hispanic Black	Shortest	53–61	28	0.9 (0.6,1.5)	0.9 (0.6,1.4)	409	1.2 (1.1,1.4)	1.2 (1.0,1.3)	253	1.2 (1.0,1.4)	1.2 (1.0,1.4)	273	1.1 (1.0,1.3)	1.2 (1.0,1.4)
	Short	62–63	80	1.0 (0.7,1.3)	0.9 (0.7,1.3)	773	1.1 (0.9,1.2)	1.1 (0.9,1.2)	453	1.1 (0.9,1.3)	1.1 (0.9,1.3)	527	1.1 (1.0,1.3)	1.1 (1.0,1.3)
	Middle	64	57	1.0 (ref)	1.0 (ref)	444	1.0 (ref)	1.0 (ref)	245	1.0 (ref)	1.0 (ref)	301	1.0 (ref)	1.0 (ref)
	Tall	65–66	98	0.8 (0.6,1.1)	0.8 (0.5,1.1)	817	1.0 (0.9,1.1)	1.0 (0.9,1.1)	418	0.9 (0.7,1.0)	0.9 (0.7,1.0)	524	1.0 (0.9,1.1)	1.0 (0.9,1.1)
	Tallest	67–77	134	0.8 (0.6,1.1)	0.8 (0.6,1.1)	673	0.9 (0.8,1.0)	0.9 (0.8,1.0)	438	0.9 (0.7,1.0)	0.9 (0.7,1.0)	519	0.9 (0.8,1.0)	0.9 (0.8,1.0)
Asian	Shortest	53–60	105	1.3 (1.0,1.7)	1.2 (1.0,1.6)	972	1.1 (1.1,1.3)	1.1 (1.0,1.2)	325	1.2 (1.0,1.4)	1.2 (1.0,1.4)	118	0.9 (0.7,1.1)	1.0 (0.7,1.3)
	Short	61	68	1.0 (0.8,1.4)	1.0 (0.8,1.3)	686	1.1 (1.0,1.2)	1.1 (1.0,1.2)	179	1.1 (0.9,1.3)	1.1 (0.9,1.3)	66	0.8 (0.6,1.1)	0.9 (0.7,1.2)
	Middle	62	161	1.0 (ref)	1.0 (ref)	1039	1.0 (ref)	1.0 (ref)	258	1.0 (ref)	1.0 (ref)	120	1.0 (ref)	1.0 (ref)
	Tall	63–64	280	1.1 (0.9,1.3)	1.1 (0.9,1.4)	1756	0.9 (0.9,1.0)	0.9 (0.9,1.0)	409	1.0 (0.8,1.1)	1.0 (0.8,1.2)	148	0.8 (0.6,1.0)	0.8 (0.6,1.0)
	Tallest	65–77	238	1.0 (0.8,1.2)	1.0 (0.8,1.2)	1041	0.8 (0.8,0.9)	0.9 (0.8,0.9)	257	0.9 (0.8,1.1)	0.9 (0.8,1.1)	80	0.7 (0.5,0.9)	0.7 (0.5,0.9)
Hispanic	Shortest	53–60	214	1.4 (1.1,1.6)	1.3 (1.1,1.6)	3547	1.1 (1.0,1.1)	1.1 (1.0,1.1)	2947	1.1 (1.0,1.2)	1.1 (1.0,1.2)	2382	1.1 (1.1,1.2)	1.1 (1.1,1.2)
	Short	61	130	1.1 (0.9,1.3)	1.0 (0.9,1.3)	2461	1.0 (1.0,1.1)	1.0 (1.0,1.1)	1685	1.1 (1.0,1.1)	1.1 (1.0,1.1)	1546	1.1 (1.0,1.2)	1.1 (1.0,1.2)
	Middle	62	297	1.0 (ref)	1.0 (ref)	3575	1.0 (ref)	1.0 (ref)	2467	1.0 (ref)	1.0 (ref)	2165	1.0 (ref)	1.0 (ref)
	Tall	63–64	439	1.0 (0.9,1.2)	1.0 (0.9,1.2)	5434	0.9 (0.9,1.0)	0.9 (0.9,1.0)	3399	1.0 (0.9,1.0)	1.0 (0.9,1.0)	3422	1.0 (1.0,1.1)	1.0 (0.9,1.0)
	Tallest	65–77	579	1.0 (0.8,1.1)	1.0 (0.9,1.1)	4176	0.9 (0.8,0.9)	0.9 (0.8,0.9)	2824	0.9 (0.9,1.0)	0.9 (0.8,0.9)	3065	1.0 (0.9,1.1)	0.9 (0.9,1.0)

cRR: Crude Relative Risk

aRR: Adjusted Relative Risk for: Maternal age, parity, education, prenatal care, previous PTB, smoking, pregestational and gestational diabetes, pregestational hypertension and preeclampsia/eclampsia

Bold font designates P value < 0.05

Table 4

Height and risk for spontaneous PTB of less than 32 weeks, stratified by race/ethnicity and BMI.

Spontaneous PTB < 32 weeks											
BMI categories											
Race/ethnicity	Height category	Inch	Underweight			Normal			Overweight		
			N	cRR (CI)	aRR (CI)	N	cRR (CI)	aRR (CI)	N	cRR (CI)	aRR (CI)
Non-Hispanic White	Shortest	53–62	36	1.9 (1.2,3.0)	1.6 (1.0,2.6)	336	1.3 (1.1,1.5)	1.2 (1.0,1.4)	154	1.4 (1.1,1.7)	1.4 (1.1,1.7)
	Short	63	17	1.5 (0.8,2.6)	1.3 (0.8,2.4)	169	0.9 (0.8,1.1)	0.9 (0.7,1.1)	60	0.9 (0.7,1.3)	0.9 (0.7,1.3)
	Middle	64–65	37	1.0 (ref)	1.0 (ref)	486	1.0 (ref)	1.0 (ref)	164	1.0 (ref)	1.0 (ref)
	Tall	66	23	1.2 (0.7,2.0)	1.2 (0.7,2.1)	191	0.8 (0.7,0.9)	0.8 (0.7,0.9)	83	0.9 (0.7,1.2)	0.9 (0.7,1.2)
	Tallest	67–77	53	0.9 (0.6,1.3)	1.0 (0.6,1.5)	386	0.7 (0.6,0.8)	0.8 (0.7,0.9)	168	0.9 (0.7,1.1)	0.9 (0.7,1.1)
Non-Hispanic Black	Shortest	53–61	6	1.6 (0.5,4.7)	1.5 (0.5,4.5)	79	1.0 (0.7,1.3)	0.9 (0.7,1.2)	55	1.2 (0.8,1.8)	1.2 (0.8,1.8)
	Short	62–63	15	1.4 (0.6,3.5)	1.4 (0.6,3.4)	155	0.9 (0.7,1.1)	0.9 (0.7,1.1)	102	1.2 (0.9,1.7)	1.2 (0.9,1.7)
	Middle	64	7	1.0 (ref)	1.0 (ref)	109	1.0 (ref)	1.0 (ref)	51	1.0 (ref)	1.0 (ref)
	Tall	65–66	21	1.3 (0.5,3.0)	1.2 (0.5,2.8)	173	0.8 (0.7,1.1)	0.8 (0.7,1.1)	113	1.1 (0.8,1.6)	1.1 (0.8,1.5)
	Tallest	67–77	29	1.4 (0.6,3.1)	1.3 (0.6,3.0)	158	0.8 (0.6,1.0)	0.8 (0.6,1.0)	93	0.9 (0.6,1.2)	0.9 (0.6,1.2)
Asian	Shortest	53–60	14	1.3 (0.7,2.6)	1.2 (0.6,2.3)	130	1.3 (1.1,1.7)	1.2 (1.0,1.6)	54	1.2 (0.8,1.8)	1.2 (0.8,1.8)
	Short	61	6	0.7 (0.3,1.7)	0.6 (0.3,1.6)	82	1.1 (0.9,1.5)	1.1 (0.8,1.4)	34	1.3 (0.8,2.0)	1.3 (0.8,2.1)
	Middle	62	21	1.0 (ref)	1.0 (ref)	119	1.0 (ref)	1.0 (ref)	42	1.0 (ref)	1.0 (ref)
	Tall	63–64	36	1.1 (0.6,1.8)	1.1 (0.7,1.9)	210	1.0 (0.8,1.2)	1.0 (0.8,1.3)	60	0.9 (0.6,1.3)	0.9 (0.6,1.3)
	Tallest	65–77	34	1.1 (0.6,1.8)	1.1 (0.6,1.9)	111	0.8 (0.6,1.0)	0.8 (0.6,1.1)	44	0.9 (0.6,1.4)	1.0 (0.6,1.5)
Hispanic	Shortest	53–60	38	1.6 (1.1,2.5)	1.6 (1.0,2.5)	485	1.0 (0.9,1.1)	1.0 (0.9,1.1)	477	1.1 (0.9,1.2)	1.0 (0.9,1.2)
	Short	61	25	1.3 (0.8,2.2)	1.3 (0.8,2.2)	366	1.0 (0.9,1.2)	1.0 (0.9,1.2)	272	1.0 (0.9,1.2)	1.0 (0.9,1.2)
	Middle	62	45	1.0 (ref)	1.0 (ref)	533	1.0 (ref)	1.0 (ref)	416	1.0 (ref)	1.0 (ref)
	Tall	63–64	74	1.2 (0.8,1.7)	1.2 (0.8,1.7)	792	0.9 (0.8,1.0)	0.9 (0.8,1.0)	548	0.9 (0.8,1.1)	0.9 (0.8,1.1)
	Tallest	65–77	92	1.0 (0.7,1.4)	1.0 (0.7,1.5)	642	0.9 (0.8,1.0)	0.9 (0.8,1.0)	499	1.0 (0.8,1.1)	0.9 (0.8,1.0)

cRR: Crude Relative Risk

aRR: Adjusted Relative Risk for: Maternal age, parity, education, prenatal care, payor, previous PTB, smoking, pre-gestational and gestational diabetes, pre-gestational hypertension and preeclampsia/eclampsia.

Bold font designates P value < 0.05

Appendix 1

The addition of maternal height above BMI to the Performance model

Performance Model	Predictor	Event	AIC
Crude model	BMI	Spontaneous PTB <37 weeks	677876.5684
Adjusted limited model	BMI + Height		677331.3986
Adjusted full model	BMI + * covariates		657483.2449
Adjusted full model plus	BMI + * covariates + Height		656808.3241

AIC Akaike Information Criterion

* Covariates: Maternal age, race/ethnicity, parity, education, prenatal care, payor, hypertension, diabetes, previous PTB and smoking