Published in final edited form as:
Epidemiology. 2010 March ; 21(2): 243–252. doi:10.1097/EDE.0b013e3181cb61a9.

Prepregnancy body size, gestational weight gain, and risk of preterm birth in African-American women

Lauren A. Wise, Sc.D.[1], **Julie R. Palmer, Sc.D.**[1], **Linda J. Heffner, M.D. Ph.D.**[2], and **Lynn Rosenberg, Sc.D.**[1]

[1]Slone Epidemiology Center, Boston University, 1010 Commonwealth Avenue, Boston, MA, 02215

[2]Department of Obstetrics and Gynecology, Boston University School of Medicine, 85 East Concord Street, 6th Floor, Boston, MA 02118

Abstract

Objective—We examined the risk of preterm birth in relation to prepregnancy BMI (kg/m^2), waist circumference, adult weight gain, and gestational weight gain among African-American women.

Methods—Using prospective data from the Black Women's Health Study, we assessed the association between maternal anthropometric factors and preterm birth among 7,841 singletons born to women ages 21–44 in 1995–2003. We compared mothers of infants born three or more weeks early (597 spontaneous preterm births (SPTB); 517 medically-indicated preterm births (MPTB)) with mothers of 6,727 term infants. We used generalized estimating equation models to derive odds ratios (OR) and 95% confidence intervals (CI) adjusted for potential confounders.

Results—Women with prepregnancy BMI <18 were at increased risk of SPTB and MPTB relative to normal weight women (BMI 20–24), and obese women (BMI ≥30) were at increased risk of MPTB. There were modest positive associations between waist circumference, a measure of central adiposity, and both preterm birth subtypes. Adult weight gain was also positively related to both preterm birth subtypes. Associations with SPTB were generally stronger for gestations of <32 weeks. Low gestational weight gain (<0.5 lbs/week) was associated with an increased risk of SPTB among normal weight and obese women. High gestational weight gain (≥1.5 lbs/week) was associated with increased risk of SPTB among overweight (BMI 25–29) and obese women.

Conclusion—Our data suggest that prepregnancy adiposity (overall and central), prepregnancy weight gain, and gestational weight gain influence risk of preterm birth among African-American women.

Introduction

Preterm birth is two times more common among Black women than White women[1–3] and is a leading cause of infant morbidity and mortality in the U.S.[1, 4, 5] In 2006, preterm birth accounted for 12.8% of all births in the U.S. and its prevalence has been on the rise among single and multiple gestations.[1] The ethnic disparity in preterm birth is not fully explained by established risk factors such as personal history of preterm birth, intrauterine infections, and low socioeconomic status.[6]

Address for correspondence: Lauren A. Wise, Slone Epidemiology Center, Boston University,1010 Commonwealth Avenue, Boston, MA, 02215; Telephone (617) 734-6006; Fax (617) 738-5119. lwise@slone.bu.edu..

The prevalence of overweight and obesity has been increasing in the U.S., especially among Black women of childbearing age.[7, 8] High body mass index (BMI, kg/m^2), a measure of absolute body fat,[9] is associated with markers of systemic inflammation (e.g., c-reactive protein),[10–12] dyslipidemia,[10, 13] and hyperinsulinemia and insulin resistance,[14] all of which are associated with an increased risk of preterm birth. These findings suggest that obesity-related metabolic and endothelial disturbances could influence risk of preterm birth via several pathways.[15] In addition, maternal obesity is positively associated with urogenital and intrauterine infections, which are thought to be a leading cause of preterm birth.[16] On the other hand, obesity is inversely associated with short cervix,[17, 18] another risk factor for preterm birth.

The obesity epidemic observed in recent decades has paralleled the increase in preterm birth rates. An unanswered question is whether obesity explains part of the increase in preterm birth. The literature on obesity in relation to preterm birth is mixed. While some studies have reported a positive association between overweight or obesity and preterm birth,[19–23] others found no association[24–31] or an inverse association.[32–35] Most,[19, 20, 22, 23, 36, 37] but not all[32] studies, found a positive association between obesity and preterm birth at very early gestational ages (e.g., ≤32 weeks); two of the studies found a positive association among nulliparous women only.[22, 23] In the studies that examined preterm birth subtypes separately,[17, 21, 33, 38, 39] obesity was consistently associated with an increased risk of medically-indicated preterm birth[17, 21, 33, 38, 39] but its influence on spontaneous preterm birth was unclear, with studies reporting no association,[38, 39] an inverse association[17, 33] and a positive association (for preterm premature rupture of membranes only).[21]

To our knowledge, no studies have examined whether adult weight gain, a correlate of systemic inflammation,[40] increases preterm birth risk. Likewise, the relation of central adiposity to preterm birth has not been explored. Central adiposity, the distribution of excess fat in the upper trunk region, is often measured by waist circumference and is associated with hormonal and metabolic changes, including altered estrogen metabolism, insulin resistance, and hyperinsulinemia.[41–43] Central obesity is more common in Black women than White women.[44]

Finally, there is conflicting evidence about the joint association of maternal weight gain during mid- to late- gestation and obesity with preterm birth: studies have reported both decreased[36–38] and increased[31] risks of preterm birth associated with low gestational weight gain among obese women. In addition, experts disagree as to whether the current Institute of Medicine guidelines for gestational weight gain[45] are appropriate for Black women,[46] with some arguing that Black women should strive for weight gain towards the upper end of the ranges recommended for white women of similar prepregnancy BMI to reduce risk of low birth weight.[45] Although smaller studies of prepregnancy body weight and adverse pregnancy outcomes have included Black women,[27, 37] only one stratified by race/ ethnicity.[27]

Using data from the Black Women's Health Study, a U.S. prospective cohort study of approximately 59,000 Black women, we assessed the relation of selected anthropometric variables measured before pregnancy – BMI, waist circumference, and adult weight gain – with risk of spontaneous and medically-indicated preterm birth. We also examined the role of weight gain during pregnancy on risk of these preterm birth subtypes.

Materials and Methods

Study population

The Black Women's Health Study (BWHS) is an ongoing national prospective cohort study of 59,000 African-American women aged 21 to 69 at baseline (1995).[47] Women were enrolled in 1995 through questionnaires mailed to subscribers of *Essence* magazine, members of Black professional organizations, and friends and relatives of respondents. The baseline questionnaire elicited information on demographic and behavioral characteristics, reproductive and contraceptive histories, anthropometric factors, health care utilization, and medical history. BWHS respondents live in various states across the country, with the majority residing in California, New York, Illinois, Michigan, Georgia, and New Jersey. The study is approved by the Institutional Review Board at Boston University Medical Center.

Every two years, participants are mailed a follow-up questionnaire to update their health information; follow-up through 2007 has exceeded 80%. We have compared respondents to nonrespondents for various cycles in order to assess whether there are selective losses. In 2001, for example, respondents were older than non-respondents (mean age: 39.2 vs. 37.2) and had slightly higher education levels (14.9 vs. 14.5 years), but were similar in every other factor assessed (e.g., BMI ≥30, 30% vs. 31%; parity ≥3, 20% vs. 20%).

Assessment of pregnancy outcomes

We identified all women who reported a preterm birth during 1995–2003. On the 1997, 1999, 2001, and 2003 questionnaires, women were asked whether they had given birth to a live or still born child in the previous two years. For singleton live or still births, women were asked “did the doctor say this child was born at least 3 weeks early?” and, if yes, how early (3, 4, 5, 6, 7, 8, 9, or ≥10 weeks), and whether the birth was early due to preterm labor for no known reason or early rupture of membranes (spontaneous preterm birth (SPTB)) or medically-indicated labor or cesarean section (medically-indicated preterm birth (MPTB)). Due dates and birth dates were also elicited for a more precise estimate of gestational age.

Validation of pregnancy outcomes

Clinically, preterm birth is defined as a birth occurring <37 weeks of gestation from the date of the last menstrual period.[48] In the BWHS, we defined preterm birth as a birth occurring “three or more weeks early.” The proportion of preterm birth in our sample (15.2%) is similar to the proportion in national data for Black babies born <37 weeks of gestation (15.6%).[48] In a validation study carried out using registry data from the Massachusetts Department of Public Health, 21 of 23 (91.3%) BWHS participants from Massachusetts who reported a singleton preterm delivery during 1995–2003 had gestations ≤37 weeks documented by the registry (we prioritized the LMP estimate of gestational age, unless the clinical estimate was earlier). Moreover, 11 out of 12 reports of spontaneous preterm birth were corroborated by registry data. Finally, the distribution of birth weight among preterm births in the BWHS (birth weight from registry data: mean=2,320g,median=2,495g, interquartile range: 1,875g–2,778g) closely matches national data on Black babies,[48] suggesting that our definition of preterm birth is consistent with the clinical definition.

Assessment of maternal anthropometric factors

In 1995, BWHS participants reported their height (feet and inches), current weight (pounds), weight at age 18 (pounds), waist circumference (inches) at the level of the umbilicus, and hip circumference (inches) at its widest location. Current weight was updated every two years by questionnaire. Adult weight gain was defined as the difference between current weight and weight at age 18 (kg). We used body mass index (BMI = weight (kg) divided by height squared (m^2)) to measure overall obesity and waist circumference to estimate total abdominal fat.[49] Although waist-to-hip ratio is used more widely in the medical literature, waist circumference provides an estimate of absolute abdominal adiposity, the component most correlated with metabolic abnormalities such as hyperinsulinemia, hypertension, and high triglyceride levels.[49] Weight and BMI data were derived from the questionnaire prior to the questionnaire on which a woman reported the birth. (If the woman was currently pregnant at that time, data were taken from an earlier questionnaire.) Women were asked about their pregnancy weight gain using the following categories: <10, 10–14, 15–19, 20–24, 25–29, 30–34, 35–39, >39 pounds.

We used a gestational weight gain formula developed by Dietz et al.[37] that accounts for expected weight gain per trimester and gestational age. Given that the rate of weight gain is typically low in the first trimester and is higher and linear in the second and third trimesters,[45, 50]assuming a constant rate of weight gain across trimesters would create an upward bias because women with shorter gestation would be misclassified as having lower weight gain. Therefore, in accordance with Dietz et al.,[37] we estimated weight gain during the second and third trimesters by subtracting an expected average weight gain during the first trimester from total gestational weight gain and then dividing by gestational weeks minus 14 weeks. First-trimester weight gain was based on Institute of Medicine data,[45] which estimates an average weight gain of 5 lbs for underweight women, 3.5 lbs for normal-weight women, and 2 lbs for overweight, obese, or very obese women.

Validation of anthropometric measures

In 2001, we conducted a validation study of anthropometric measures among 115 BWHS participants from the Washington D.C. area. The Spearman correlation between self-reported (mean=176 lbs) and technician-measured weight (mean=181 lbs) was 0.97. The correlation between self-reported (mean=64.4 inches) and technician-measured height (mean=64.0 inches) was 0.93. The correlation for self-reported versus technician-measured waist circumference was 0.75.

For gestational weight gain assessed in categories, the weighted kappa statistic was 0.55 for the comparison of self-reported vs. registry-supplied data from the Massachusetts Department of Public Health birth registry. When we converted the categorical BWHS gestational weight gain variable into a continuous variable using the midpoint of each category, and assigning 5 lbs. to the lowest category and 40 lbs. to the highest, the Spearman correlation coefficient was 0.56.

Assessment of covariates

Data on participant's age at delivery, state of residence, gravidity (number of pregnancies), parity (number of births), smoking before and during pregnancy, previous preterm birth, participant born preterm, and maternal medical conditions (pregestational or gestational diabetes; pre-gestational or gestational hypertension; or thyroid conditions) were obtained on the baseline and follow-up questionnaires. Information on education was elicited in 1995 and marital status was elicited in 1995, 1997, and 1999.

Exclusions

Analyses were restricted to mothers ages 21–44 years who reported singleton births during 1995–2003 (N=8,718). Women who reported that they were currently pregnant at the time of the 1995 questionnaire (N=685) were excluded because their anthropometric measurements could have been influenced by pregnancy weight gain. Women with missing BMI data were also excluded (N=96). We examined spontaneous and medically-indicated preterm births separately because they are thought to have different etiologies. Women reporting preterm births without sufficient data to be classified with respect to preterm birth subtype were excluded (N=96), leaving 7,841 births for the present analysis (6,727 term, 597 SPTB, and 517 MPTB).

Data Analysis

BMI categories were based on World Health Organization standards,[51] with added cut points at the extremes. Obesity is defined as BMI ≥30 kg/m^2. We categorized waist circumference into quintiles and adult weight gain into 10-kilogram increments. We categorized gestational weight gain as low (<0.5 lbs/week), average (0.5–1.4 lbs/week), and high (≥1.5 lbs/week) based on the Institute of Medicine's recommendation that women of average prepregnancy BMI gain 1 lb/week during the second and third trimesters.[37, 45]

Generalized estimating equation models[52] were used to estimate odds ratios (OR) and 95% confidence intervals (CI) for the association between selected anthropometric factors (BMI, adult weight gain, waist circumference, and gestational weight gain) and each preterm birth subtype. These models account for any correlation resulting from the contribution of more than one birth per women (1,452 women contributed more than 1 birth to the analysis). Multivariable models were adjusted for time period (i.e., questionnaire cycle) and known or suspected risk factors for preterm birth, including maternal age at delivery, parity, years of education, marital status, smoking during pregnancy, previous preterm birth, and participant born preterm. Full multivariable models simultaneously controlled for BMI and waist circumference to assess their independent effects.

The analyses for SPTB were repeated using more stringent cut points for gestational age. Since the effect of obesity on pregnancy outcomes may operate through pre-gestational diabetes and hypertension, which have independent effects on pregnancy outcomes,[53, 54] we performed separate analyses in which we controlled for maternal medical conditions – diabetes (pre-existing or gestational), hypertension (pre-existing or gestational), and thyroid conditions. Given that the relation between prepregnancy BMI and preterm birth may be modified by gestational weight gain[31, 36–38] and parity,[22, 23, 33] we assessed effect modification (statistical interaction) by average gestational weight gain per week in the 2nd and 3rd trimesters (<0.5, 0.5–1.4, ≥1.5) and parity (parous vs. nulliparous). Formal tests for interaction were conducted using the likelihood ratio test comparing models with and without cross-product terms between BMI and the effect modifier, all coded as polytomous categorical variables. All analyses were conducted using SAS version 9.1.

Results

Prepregnancy BMI was positively associated with waist circumference, weight change since age 18, smoking during pregnancy, parity, previous preterm birth, and maternal medical conditions (diabetes, hypertension, and thyroid conditions) and inversely associated with gestational weight gain and educational attainment (Table 1). In addition to being associated with BMI, prepregnancy waist circumference was positively associated with smoking during pregnancy, being parous, being married or living as married, previous preterm birth, and maternal medical conditions, and inversely associated with educational attainment and gestational weight gain.

Data on the association of selected anthropometric factors with risk of SPTB and MPTB are shown in Table 2. Women with BMI <18 had more than 2-fold increased risk of SPTB relative to women with BMI 20–24 after adjustment for all risk factors including waist circumference (OR=2.72, 95%CI=1.43–5.17). Prepregnancy obesity was not associated with SPTB after adjustment for waist circumference (OR=1.15, 95%CI=0.75–1.77 for BMI ≥40). Both low and high BMI categories were associated with an increased risk of MPTB after adjustment for waist circumference: ORs for BMI <18 and ≥40 were 2.91 (95%CI=1.38–

6.14) and 1.73 (95%CI=1.11, 2.71), respectively. In additional analyses (data not shown), adjustment for maternal medical conditions weakened the association between high BMI and MPTB (ORs for BMI 25–29, 30–34, 35–39, and ≥40 relative to 20–24 were: 1.01, 95%CI=0.78–1.30; 1.77, 95%CI=1.31–2.40; 1.35, 95%CI=0.88–2.06; and 1.12, 95%CI=0.70–1.78) but strengthened the association between low BMI and MPTB (BMI <18 relative to 20–24: OR=4.08, 95%CI=1.94–8.58).

We observed a positive association between waist circumference and SPTB that remained after adjustment for BMI (≥35 vs. <27 inches: OR=1.37, 95%CI=0.91–2.06), but there was little evidence of a dose-response relation. A positive association between waist circumference and MPTB (≥35 vs. <27 inches: OR=1.88, 95%CI=1.36–2.60) attenuated after adjustment for BMI (OR=1.30, 95%CI=0.87–1.95).

Weight gain of ≥30 kg since age 18 was positively associated with SPTB relative to weight gain of 0–9 kg (OR=1.58, 95%CI=1.18–2.12), but there was no dose-response relation (Table 2). Weight gain since age 18 was also positively associated with MPTB: ORs comparing 10–19, 20–29, and ≥30 with 0–9 kg were 1.26 (95%CI=0.99–1.61), 1.71 (95%CI=1.30–2.24), and 2.18 (95%CI=1.59–2.99). Further control for waist circumference did not alter the association of weight gain with MPTB, but attenuated that with SPTB (≥30 vs. 0–9 kg: OR=1.35, 95%CI=0.97–1.87).

Low and high gestational weight gain in the 2^{nd} and 3^{rd} trimesters were associated with an increased risk of SPTB (Table 2). The multivariable ORs for SPTB were 1.51 among women gaining <0.5 lbs/week during gestation (95%CI=1.17–1.97) and 1.42 for weight gain ≥1.5 lbs/week (95%CI=1.13–1.78) relative to a gain of 0.5–1.4 lbs/week. A similar pattern was observed for MPTB. Results were virtually unchanged after adjustment for maternal medical conditions.

Table 3 presents data on the association between anthropometric factors and risk of SPTB according to gestational age at the infant's birth. Associations of low pregregnancy BMI, high waist circumference, high weight gain since age 18, and low and high gestational weight gain with SPTB risk were generally strongest in the <32 week gestation category. In addition, obesity was associated with an increased risk of SPTB at <32 weeks gestation (BMI ≥40 vs. 20–24: OR=2.54, 95%CI=1.03–6.25). The association between high BMI and SPTB <32 weeks strengthened with further control for maternal medical conditions (data not shown); relative to BMI 20–24, multivariable ORs for BMI 25–29, 30–34, 35–39, and ≥40 were: 1.08 (95%CI=0.64–1.84), 2.18 (95%CI=1.24–3.83), 2.49 (95%CI=1.08–5.77), and 3.20 (95%CI=1.27–8.06).

Associations between gestational weight gain and SPTB, within levels of prepregnancy BMI and waist circumference, are shown in Table 4. Among normal weight women (BMI 20–24), low gestational weight gain (<0.5 lbs/wk) was associated with a greater than two-fold increased risk of SPTB (OR=2.62, 95%CI=1.62–4.26) relative to average weight gain (0.5–1.4 lbs/week); in contrast, high gestational weight gain (≥1.5 lbs/week) was not associated with an increased risk. Low gestational weight gain was also positively associated with SPTB among obese women (OR=1.55, 95%CI=1.02–2.35). Among overweight and obese women, high gestational weight gain (≥1.5 lbs/wk) was associated with an increased risk of SPTB: ORs were 1.90 (95%CI=1.27–2.85) and 2.93 (95%CI=1.86–4.63), respectively. Low gestational weight gain was associated with an increased risk of SPTB in both categories of prepregnancy waist circumference. Among women with high waist circumference, a strong positive association was observed between high gestational weight gain and SPTB risk (OR=3.68, 95%CI=2.13–6.35).

NIH-PA Author Manuscript

NIH-PA Author Manuscript

No appreciable differences in association were found by parity status for any of the anthropometric variables in relation to SPTB or MPTB (data not shown).

Discussion

We found a positive association between prepregnancy BMI <18 kg/m^2 and both SPTB and MPTB, but there were few women in that category of low BMI. Although high prepregnancy BMI was not associated with SPTB overall, it was associated with very early SPTB (<32 weeks). Most,[19, 20, 22, 23, 36, 37] but not all[32] studies, have reported a positive association between maternal obesity and very early preterm birth (all subtypes combined); two of these studies found a positive association among nulliparous women only.[22, 23] In our data, the association of prepregnancy obesity with early preterm birth was present in both nulliparous and parous women. We observed a positive association between prepregnancy BMI and MPTB overall, but it weakened appreciably after adjustment for maternal medical conditions, suggesting the association is explained by conditions such as pre-gestational hypertension or diabetes. In contrast, the results for very early SPTB (<32 weeks) did not change with further adjustment for maternal medical conditions, suggesting a different mechanism for an effect. While many previous studies have found a positive association of obesity with MPTB,[17, 21, 33, 38, 39] only one[21] of five previous studies[17, 21, 33, 38, 39] of SPTB showed a positive association with obesity.[21]

Our data suggest a modest positive association of waist circumference with SPTB and MPTB, but the results were not statistically significant and there was no evidence of a dose-response relation. There are no previous studies on this topic with which to compare our results. However, if the mechanism that explains this finding operates through insulin resistance or hyperinsulinemia, then our findings are supported by a recent study of pregnant women in which insulin levels were higher in pregnant women with upper-body (central) obesity than in pregnant women with lower-body obesity or lean pregnant women, following an oral glucose tolerance test.[55]

Adult weight gain was positively associated with risk of both SPTB and MPTB. To our knowledge, there are no previous studies examining adult weight gain in relation to preterm birth. Control for waist circumference attenuated the association between weight gain and SPTB. To the extent that risk of preterm birth is associated with systemic inflammation,[10–12] there is biologic support for an association between adult weight gain and preterm birth, given the correlation between adult weight gain and systemic inflammation.[40]

In 1990, the Institute of Medicine published guidelines for gestational weight gain based on a woman's prepregnancy BMI.[45] Women with prepregnancy BMI <19.8 were advised to gain 28–40 lbs (average: 0.7–1.0 lbs/week), those with BMI 19.8–26.0 were advised to gain 25–35 lbs (average: 0.6–0.9 lbs/week), and those with BMI 26.1–29.0 were advised to gain 15–25 lbs (0.4–0.6 lbs/week). A lower bound of 15 lbs (average ≥0.4 lbs/week) was recommended for women with BMI >29.0. It was also recommended that Black women gain at the upper end of the recommended ranges. These race-specific recommendations have been questioned because there is limited evidence that they reduce risk of small-for-gestational age births and some evidence that they increase risk of large-for-gestational age births.[46, 56] In the present study, low and high gestational weight gain were associated with increased risks of both preterm birth subtypes, which is consistent with the literature.[23] Low gestational weight gain was associated with an increased risk of SPTB among normal weight women and obese women. In addition, overweight or obese women with high weight gain during pregnancy had an increased risk of SPTB. These results are generally consistent with other studies that have shown low or average weight gain among obese women to be associated with reduced risk of preterm birth.[36–38, 57] Therefore, our results suggest that weight gain recommendations should also incorporate an upper bound for obese women.

In our study, data on anthropometric variables and covariates were recorded before the index pregnancy, thereby avoiding differential exposure misclassification (e.g., recall bias). The ideal time to measure baseline BMI of a pregnant woman is before she has started gaining weight due to gestation. Because true prepregnancy BMI is seldom available in registries or hospital databases, which represent the largest sources of data from studies to date,[20, 23, 32, 36] researchers often use BMI in early pregnancy. However, by the time a woman is seen for her first prenatal visit, she may have gained (or lost) several pounds compared with her true prepregnancy weight.[22] While self-reported BMI and adult weight gain are subject to error, we observed high agreement between self-reported and technician-measured weight.[58] Moreover, we observed reasonable agreement between self-reported and registry-supplied gestational weight gain.

We collected data on a wide range of potential confounders not routinely collected in large registries, including whether the participant herself was born preterm and whether she had a previous preterm birth, which allowed for better control of potential confounding variables. The large sample size of the present study permitted an informative assessment of risk factors in the overall dataset. Because there were small numbers in some categories when we stratified by gestational age and BMI, caution is needed when interpreting those results. Cohort retention was satisfactorily high, enough to reduce the influence of selection bias. We have assessed the potential for bias due to selective losses by comparing baseline characteristics of respondents and non-respondents and have found them to be similar in important characteristics, such as BMI and parity.

We were able to analyze preterm birth subtypes separately, which can clarify the etiologic role of the factors under study. However, preterm birth was self-reported and not based on clinical assessment. Moreover, it is unclear whether the self-reported gestational age information was based on ultrasound or LMP methods. It is reassuring that the BWHS validation study indicated good accuracy of self-reported preterm birth and the overall prevalence of preterm birth was comparable to the prevalence based on national data.[48]

The BWHS is a convenience sample of U.S. Black women. Because women must be literate to participate in a study that collects data by mailed questionnaires, most BWHS participants have completed high school or a higher level of education.[47] Given that about 85% of Black women of the same ages nationally have graduated high school,[59] the BWHS results should be generalizable to a large segment of the U.S. Black population.

The elucidation of risk factors for preterm birth is of great public health importance given its increasing prevalence in the U.S. and its strong influence on infant morbidity and mortality. The relation of obesity to preterm birth is especially relevant to African-American women because they are disproportionately affected by both conditions. Our data suggest that both overall and central adiposity, adult weight gain, and gestational weight gain influence the risk of preterm birth among African-American women. If our results are replicated in future studies, they offer the potential to improve birth outcomes through management of obesity and gestational weight gain.

Acknowledgments

This work was funded by National Cancer Institute grant CA58420 (PI: Rosenberg) and the Hood Foundation (PI: Wise). Validation data on gestational age and infant birth weight were obtained from the Massachusetts Department of Public Health. The authors would like to acknowledge the technical assistance of Mr. Kevin Foster from the

Massachusetts Department of Public Health and Dr. Ghasi S. Phillips, as well as the ongoing contributions of BWHS participants and staff.

Abbreviations

BMI	body mass index
BWHS	Black Women's Health Study

References

1. Martin, JA.; Hamilton, BE.; Sutton, PD., et al. National vital statistics reports. Vol. vol 56. National Center for Health Statistics; Hyattsville, MD: 2007. Births: Final data for 2005. no 6
2. Ananth CV, Misra DP, Demissie K, Smulian JC. Rates of preterm delivery among Black women and White women in the United States over two decades: an age-period-cohort analysis. Am J Epidemiol. 2001; 154:657–65. [PubMed: 11581100]
3. Blackmore CA, Savitz DA, Edwards LJ, Harlow SD, Bowes WA Jr. Racial differences in the patterns of preterm delivery in central North Carolina, USA. Paediatr Perinat Epidemiol. 1995; 9:281–95. [PubMed: 7479277]
4. Goldenberg RL. The management of preterm labor. Obstet Gynecol. 2002; 100:1020–37. [PubMed: 12423870]
5. Green NS, Damus K, Simpson JL, et al. Research agenda for preterm birth: recommendations from the March of Dimes. Am J Obstet Gynecol. 2005; 193:626–35. [PubMed: 16150253]
6. Berkowitz GS, Blackmore-Prince C, Lapinski RH, Savitz DA. Risk factors for preterm birth subtypes. Epidemiology. 1998; 9:279–85. [PubMed: 9583419]
7. Ogden CL, Carroll MD, Curtin LR, et al. Prevalence of Overweight and Obesity in the United States, 1999–2004. JAMA. 2006; 295:1549–55. [PubMed: 16595758]
8. Kim SY, Dietz PM, England L, Morrow B, Callaghan WM. Trends in Pre-pregnancy Obesity in Nine States, 1993–2003. Obesity. 2007; 15:986–93. [PubMed: 17426334]
9. Willett, W. Nutritional Epidemiology. 2nd edition. Oxford University Press; New York: 1998.
10. Catov JM, Bodnar LM, Ness RB, Barron SJ, Roberts JM. Inflammation and dyslipidemia related to risk of spontaneous preterm birth. Am J Epidemiol. 2007; 166:1312–9. [PubMed: 17906337]
11. Lohsoonthorn V, Qiu C, Williams MA. Maternal serum C-reactive protein concentrations in early pregnancy and subsequent risk of preterm delivery. Clin Biochem. 2007; 40:330–5. [PubMed: 17289011]
12. Pitiphat W, Gillman MW, Joshipura KJ, et al. Plasma C-reactive protein in early pregnancy and preterm delivery. Am J Epidemiol. 2005; 162:1108–13. [PubMed: 16236995]
13. Catov JM, Bodnar LM, Kip KE, et al. Early pregnancy lipid concentrations and spontaneous preterm birth. Am J Obstet Gynecol. 2007; 197:610, e1–7. [PubMed: 18060950]
14. Jensen DM, Korsholm L, Ovesen P, et al. Adverse pregnancy outcome in women with mild glucose intolerance: is there a clinically meaningful threshold value for glucose? Acta Obstetricia et Gynecologica Scandinavica. 2008; 87:59–62. [PubMed: 18158628]
15. Yu CKH, Teoh TG, Robinson S. Obesity in pregnancy. BJOG: An International Journal of Obstetrics and Gynaecology. 2006; 113:1117–25. [PubMed: 16903839]
16. Goldenberg RL, Hauth JC, Andrews WW. Intrauterine Infection and Preterm Delivery. N Engl J Med. 2000; 342:1500–7. [PubMed: 10816189]
17. Hendler I, Goldenberg RL, Mercer BM, et al. The Preterm Prediction study: Association between maternal body mass index and spontaneous and indicated preterm birth. Am J Obstet Gynecol. 2005; 192:882–6. [PubMed: 15746686]
18. Liabsuetrakul T, Suntharasaj T, Suwanrath C, et al. Serial translabial sonographic measurement of cervical dimensions between 24 and 34 weeks' gestation in pregnant Thai women. Ultrasound Obstet Gynecol. 2002; 20:168–73. [PubMed: 12153668]
19. Callaway LK, Prins JB, Chang AM, McIntyre HD. The prevalence and impact of overweight and obesity in an Australian obstetric population. Med J Aust. 2006; 184:56–9. [PubMed: 16411868]

20. Cedergren MI. Maternal Morbid Obesity and the Risk of Adverse Pregnancy Outcome. Obstet Gynecol. 2004; 103:219–24. [PubMed: 14754687]

21. Nohr EA, Bech BH, Vaeth M, et al. Obesity, gestational weight gain and preterm birth: a study within the Danish National Birth Cohort. Paediatric and Perinatal Epidemiology. 2007; 21:5–14. [PubMed: 17239174]

22. Bhattacharya S, Campbell D, Liston W, Bhattacharya S. Effect of Body Mass Index on pregnancy outcomes in nulliparous women delivering singleton babies. BMC Public Health. 2007; 7:168. [PubMed: 17650297]

23. Cnattingius S, Bergstrom R, Lipworth L, Kramer MS. Prepregnancy Weight and the Risk of Adverse Pregnancy Outcomes. N Engl J Med. 1998; 338:147–52. [PubMed: 9428815]

24. Jensen DM, Damm P, Sorensen B, et al. Pregnancy outcome and prepregnancy body mass index in 2459 glucose-tolerant Danish women. Am J Obstet Gynecol. 2003; 189:239–44. [PubMed: 12861169]

25. Raatikainen K, Heiskanen N, Heinonen S. Transition from Overweight to Obesity Worsens Pregnancy Outcome in a BMI-dependent Manner. Obesity. 2006; 14:165–71. [PubMed: 16493135]

26. Robinson HE, O'Connell CM, Joseph KS, McLeod NL. Maternal Outcomes in Pregnancies Complicated by Obesity. Obstet Gynecol. 2005; 106:1357–64. [PubMed: 16319263]

27. Rosenberg TJ, Garbers S, Lipkind H, Chiasson MA. Maternal obesity and diabetes as risk factors for adverse pregnancy outcomes: differences among 4 racial/ethnic groups. Am J Public Health. 2005; 95:1545–51. [PubMed: 16118366]

28. Perlow JH, Morgan MA, Montgomery D, Towers CV, Porto M. Perinatal outcome in pregnancy complicated by massive obesity. Am J Obstet Gynecol. 1992; 167:958–62. [PubMed: 1415432]

29. Garbaciak JA Jr. Richter M, Miller S, Barton JJ. Maternal weight and pregnancy complications. Am J Obstet Gynecol. 1985; 152:238–45. [PubMed: 4003470]

30. Gilboa SM, Correa A, Alverson CJ. Use of Spline Regression in an Analysis of Maternal Prepregnancy Body Mass Index and Adverse Birth Outcomes: Does It Tell Us More Than We Already Know? Annals of Epidemiology. 2008; 18:196–205. [PubMed: 18201903]

31. Schieve LA, Cogswell ME, Scanlon KS, et al. Prepregnancy Body Mass Index and Pregnancy Weight Gain: Associations With Preterm Delivery. Obstet Gynecol. 2000; 96:194–200. [PubMed: 10908762]

32. Sebire NJ, Jolly M, Harris JP, et al. Maternal obesity and pregnancy outcome: a study of 287,213 pregnancies in London. Int J Obes Relat Metab Disord. 2001; 25:1175–82. [PubMed: 11477502]

33. Smith GCS, Shah I, Pell JP, Crossley JA, Dobbie R. Maternal Obesity in Early Pregnancy and Risk of Spontaneous and Elective Preterm Deliveries: A Retrospective Cohort Study. Am J Public Health. 2007; 97:157–62. [PubMed: 17138924]

34. Gross T, Sokol RJ, King KC. Obesity in pregnancy: risks and outcome. Obstet Gynecol. 1980; 56:446–50. [PubMed: 7422189]

35. Kumari AS. Pregnancy outcome in women with morbid obesity. Int J Gynaecol Obstet. 2001; 73:101–7. [PubMed: 11336728]

36. Cedergren M. Effects of gestational weight gain and body mass index on obstetric outcome in Sweden. Int J Gynecol Obstet. 2006; 93:269–74.

37. Dietz PM, Callaghan WM, Cogswell ME, et al. Combined effects of prepregnancy body mass index and weight gain during pregnancy on the risk of preterm delivery. Epidemiology. 2006; 17:170–7. [PubMed: 16477257]

38. Salihu HM, Lynch ON, Alio AP, Liu J. Obesity Subtypes and Risk of Spontaneous versus Medically Indicated Preterm Births in Singletons and Twins. Am J Epidemiol. 2008; 168:13–20. [PubMed: 18456643]

39. Rudra CB, Frederick IO, Williams MA. Pre-pregnancy body mass index and weight gain during pregnancy in relation to preterm delivery subtypes. Acta Obstetricia et Gynecologica Scandinavica. 2008; 87:510–7. [PubMed: 18446533]

40. Fogarty AW, Glancy C, Jones S, et al. A prospective study of weight change and systemic inflammation over 9 y. Am J Clin Nutr. 2008; 87:30–5. [PubMed: 18175734]

41. Huang Z, Willett WC, Colditz GA, et al. Waist circumference, waist:hip ratio, and risk of breast cancer in the Nurses' Health Study. Am J Epidemiol. 1999; 150:1316–24. [PubMed: 10604774]

42. Kirschner MA, Samojlik E, Drejka M, et al. Androgen-estrogen metabolism in women with upper body versus lower body obesity. J Clin Endocrinol Metab. 1990; 70:473. [PubMed: 2298859]

43. Evans DJ, Hoffmann RG, Kalkhoff RK, Kissebah AH. Relationship of body fat topology to insulin sensitivity and metabolic profiles in premenopausal women. Metabolism. 1984; 33:68–75. [PubMed: 6361449]

44. Burke GL, Jacobs DR, Sprafka PJ, Sidney S, Wagenknecht LE. Obesity and overweight in young adults: the CARDIA study. Prev Med. 1990; 19:476–88. [PubMed: 2204915]

45. Institute of Medicine. Weight gain. National Academy Press; Washington, DC: 1990. Nutrition during pregnancy. Part I.

46. Schieve LA, Cogswell ME, Scanlon KS. An empiric evaluation of the Institute of Medicine's pregnancy weight gain guidelines by race. Obstet Gynecol. 1998; 91:878–84. [PubMed: 9610990]

47. Rosenberg L, Adams-Campbell LL, Palmer JR. The Black Women's Health Study: a follow-up study for causes and preventions of illness. J Am Med Womens Assoc. 1995; 50:56–8. [PubMed: 7722208]

48. Vahratian A, Buekens P, Alexander GR. State-specific trends in preterm delivery: are rates really declining among non-Hispanic African Americans across the United States? Matern Child Health J. 2006; 10:27–32. [PubMed: 16362234]

49. Giovannucci E, Ascherio A, Rimm EB, et al. Physical activity, obesity, and risk for colon cancer and adenoma in men. Ann Intern Med. 1995; 122:327–34. [PubMed: 7847643]

50. Carmichael S, Abrams B, Selvin S. The pattern of maternal weight gain in women with good pregnancy outcomes. Am J Public Health. 1997; 87:1984–8. [PubMed: 9431288]

51. World Health Organisation. Physical Status: The Use and Interpretation of Anthropometry. World Health Organisation; Geneva: 1995.

52. Liang KY, Zeger SL. Regression analysis for correlated data. Annu Rev Public Health. 1993; 14:43–68. [PubMed: 8323597]

53. Sibai BM, Caritis S, Hauth J, et al. Risks of preeclampsia and adverse neonatal outcomes among women with pregestational diabetes mellitus. National Institute of Child Health and Human Development Network of Maternal-Fetal Medicine Units. Am J Obstet Gynecol. 2000; 182:364–9. [PubMed: 10694338]

54. Rosenberg TJ, Garbers S, Chavkin W, Chiasson MA. Prepregnancy weight and adverse perinatal outcomes in an ethnically diverse population. Obstet Gynecol. 2003; 102:1022–7. [PubMed: 14672480]

55. Landon MB, Osei K, Platt M, et al. The differential effects of body fat distribution on insulin and glucose metabolism during pregnancy. Am J Obstet Gynecol. 1994; 171:875–84. [PubMed: 7943097]

56. Caulfield LE, Stoltzfus RJ, Witter FR. Implications of the Institute of Medicine weight gain recommendations for preventing adverse pregnancy outcomes in black and white women. Am J Public Health. 1998; 88:1168–74. [PubMed: 9702142]

57. Zhou W, Olsen J. Gestational weight gain as a predictor of birth and placenta weight according to pre-pregnancy body mass index. Acta Obstet Gynecol Scand. 1997; 76:300–7. [PubMed: 9174421]

58. Wise LA, Palmer JR, Spiegelman D, et al. Influence of body size and body fat distribution on risk of uterine leiomyomata in U.S. black women. Epidemiology. 2005; 16:346–54. [PubMed: 15824551]

59. Current Population Reports P20-543. U.S. Department of Commerce; Educational attainment in the United States. March 1998 (Update).

Table 1

Age-adjusted maternal characteristics according to prepregnancy BMI and waist circumference. The Black Women's Health Study, 1995–2003*

	BMI (kg/m²)					Waist circumference (quartiles)†				
Characteristics	**<20**	**20–24**	**25–29**	**30–34**	**≥35**	**<27**	**27–28**	**29–31**	**32–34**	**≥35**
No. of women	568	3,149	2,304	1,101	815	1,408	1,344	1,521	1,161	1,204
Prepregnancy BMI, kg/m² (mean)	19.0	22.7	27.2	32.1	40.5	22.3	23.8	25.7	28.6	34.5
Weight gain since age 18, kg (mean)	2.8	7.8	15.3	22.9	35.0	7.2	9.4	12.6	18.0	25.8
Prepregnancy waist circumference, inches (mean)	25.6	27.9	31.0	34.1	37.9	24.8	27.6	29.8	32.9	38.6
Age at delivery, years (mean)	29.8	31.0	31.3	31.3	31.1	31.0	31.1	31.3	31.1	31.2
Marital Status (%)										
Married/living as married	42.0	47.8	47.5	46.9	41.8	39.3	45.4	47.2	49.3	49.3
Divorced/separated/widowed	6.2	7.2	8.2	7.8	8.3	8.7	6.5	7.4	6.9	9.4
Single	49.8	44.2	43.2	44.4	48.6	50.0	47.5	44.5	42.9	40.4
Education in 1995, years (mean)										
≤ 12	9.4	7.0	10.5	14.2	16.0	7.8	7.5	9.2	11.5	14.8
13–15	33.2	32.2	37.4	37.3	43.4	34.2	33.7	31.1	38.0	43.0
≥ 16	57.4	60.8	52.1	48.5	40.6	58.0	58.8	59.7	50.5	42.2
Smoked during pregnancy (%)	4.4	2.8	4.3	5.6	5.6	2.2	2.5	3.5	6.0	5.4
Parous (%)	47.4	50.1	57.7	58.9	57.7	45.8	47.1	52.4	58.7	57.8
Participant born preterm (%)										
No	56.7	59.3	58.0	57.1	61.1	59.5	59.3	58.9	60.5	57.1
Yes	7.2	7.1	7.0	6.0	6.7	8.1	6.9	7.2	5.6	6.5
Unsure	36.2	33.5	35.0	36.9	32.2	32.4	33.8	33.9	33.9	36.4
Previous preterm birth (%)	10.4	8.2	10.0	10.7	13.8	6.9	8.9	9.9	10.2	12.3
Gestational weight gain, lbs/wk (mean)	1.06	1.09	1.09	0.91	0.77	1.10	1.10	1.08	0.96	0.88
Maternal medical condition (%)‡	9.5	17.0	24.6	34.0	47.2	14.7	17.3	20.2	28.9	40.0

*All characteristics (other than age) are adjusted for age at delivery.

†Excludes 1,299 women with missing data on waist circumference in 1995.

‡Defined as pre-gestational or gestational diabetes, hypertension, or thyroid conditions.

Table 2

Selected anthropometric factors in relation to risk of spontaneous and medically-indicated preterm birth

		Spontaneous preterm birth			Medically-indicated preterm birth		
Characteristic	**Term**	**Preterm**	**Multi variable OR(95%CI)[a]**	**Multi variable OR (95% CI)[b]**	**Preterm**	**Multi variable OR(95%CI)[a]**	**Multi variable OR(95%CI)[b]**
All women	6727	597			517		
Prepregnancy BMI (kg/m^2)							
<18	53	12	2.40 (1.28, 4.51)	2.72 (1.43, 5.17)	9	2.73 (1.30, 5.74)	2.91 (1.38, 6.14)
18–19	423	43	1.16 (0.82, 1.65)	1.23 (0.86, 1.77)	22	0.86 (0.55, 1.35)	0.90 (0.56, 1.43)
20–24	2721	229	1.00 (ref.)	1.00 (ref.)	162	1.00 (ref.)	1.00 (ref.)
25–29	1987	152	0.89 (0.71, 1.11)	0.82 (0.65, 1.04)	136	1.13 (0.89, 1.44)	1.13 (0.88, 1.44)
30–34	891	88	1.17 (0.91, 1.52)	1.00 (0.74, 1.34)	114	2.18 (1.67, 2.83)	2.19 (1.63, 2.93)
35–39	361	37	1.16 (0.80, 1.69)	0.96 (0.63, 1.45)	42	1.92 (1.33, 2.78)	1.95 (1.30, 2.92)
≥40	291	36	1.42 (0.97, 2.08)	1.15 (0.75, 1.77)	32	1.70 (1.14, 2.51)	1.73 (1.11, 2.71)
Waist circumference (in)							
<27	1219	96	1.00 (ref.)	1.00 (ref.)	70	1.00 (ref.)	1.00 (ref.)
27–28	1134	104	1.16 (0.87, 1.56)	1.27 (0.93, 1.71)	92	1.39 (1.00, 1.94)	1.41 (1.01, 1.98)
29–31	1315	98	0.92 (0.68, 1.24)	1.05 (0.76, 1.45)	93	1.22 (0.88, 1.69)	1.17 (0.83, 1.64)
32–34	962	96	1.24 (0.92, 1.68)	1.42 (0.99, 2.02)	86	1.60 (1.14, 2.23)	1.34 (0.92, 1.94)
≥35	967	111	1.37 (1.02, 1.85)	1.37 (0.91, 2.06)	108	1.88 (1.36, 2.60)	1.30 (0.87, 1.95)
Weight gain since age 18 (kg)							
<0	411	39	1.01 (0.71–1.45)	1.03 (0.71–1.50)	26	1.06 (0.68–1.66)	0.98 (0.62–1.55)
0–9	2,325	200	1.00 (ref.)	1.00 (ref.)	131	1.00 (ref.)	1.00 (ref.)
10–19	2,156	186	0.98 (0.79–1.22)	0.99 (0.79–1.22)	156	1.26 (0.99–1.61)	1.26 (0.99–1.61)
20–29	1,170	85	0.83 (0.63–1.10)	0.84 (0.64–1.11)	115	1.75 (1.34–2.29)	1.71 (1.30–2.24)
≥30	629	84	1.56 (1.18–2.08)	1.58 (1.18–2.12)	85	2.31 (1.72–3.12)	2.18 (1.59–2.99)
Gestational weight gain (lbs/wk)							
<0.5	762	97	1.58 (1.23–2.03)	1.51 (1.17–1.97)	85	1.80 (1.38–2.35)	1.53 (1.16–2.02)
0.5–1.4	4,760	368	1.00 (ref.)	1.00 (ref.)	284	1.00 (ref.)	1.00 (ref.)
≥1.5	1,180	127	1.34 (1.08–1.67)	1.42 (1.13–1.78)	147	2.00 (1.61–2.48)	2.17 (1.73–2.72)

CI, confidence interval; OR, odds ratio.

NIH-PA Author Manuscript
NIH-PA Author Manuscript

[a] Adjusted for age, questionnaire cycle, marital status, education, smoking during pregnancy, parity, participant born preterm, and previous preterm birth.

[b] BMI analyses additionally adjusted for waist circumference; waist circumference analyses additionally adjusted for BMI; adult weight gain analyses additionally adjusted for BMI at age 18; gestational weight gain additionally adjusted for BMI and waist circumference.

Table 3

Anthropometric factors in relation to risk of spontaneous preterm birth, by gestational age

	35–37 weeks gestation (3, 4, or 5 weeks early)		<35 weeks gestation (6 or more weeks early)		<32 weeks gestation (9 or more weeks early)	
Characteristic	**Cases**	**Multivariable OR (95% CI)[a]**	**Cases**	**Multivariable OR (95% CI)[a]**	**Cases**	**Multivariable OR (95% CI)[a]**
All women						
Prepregnancy BMI (kg/m^2)						
<18	8	2.48 (1.16–5.31)	4	3.21 (1.11–9.28)	2	3.50 (0.84–14.7)
18–19	29	1.16 (0.75–1.78)	14	1.41 (0.77–2.58)	5	1.08 (0.39–2.97)
20–24	160	1.00 (ref.)	69	1.00 (ref.)	35	1.00 (ref.)
25–29	87	0.68 (0.51–0.91)	65	1.15 (0.78–1.68)	29	1.05 (0.62–1.77)
30–34	46	0.77 (0.52–1.13)	42	1.51 (0.97–2.34)	24	2.02 (1.15–3.55)
35–39	23	0.89 (0.53–1.50)	14	1.12 (0.58–2.19)	11	2.12 (0.92–4.88)
≥40	22	1.07 (0.63–1.81)	14	1.37 (0.69–2.71)	10	2.54 (1.03–6.25)
Waist circumference (in)						
<27	69	1.00 (ref.)	27	1.00 (ref.)	12	1.00 (ref.)
27–28	68	1.14 (0.80–1.63)	36	1.52 (0.90–2.57)	19	2.09 (0.94–4.65)
29–31	58	0.90 (0.61–1.33)	40	1.38 (0.79–2.39)	28	2.28 (1.01–5.16)
32–34	64	1.45 (0.95–2.21)	32	1.33 (0.73–2.41)	17	1.58 (0.66–3.82)
≥35	61	1.21 (0.73–2.01)	50	1.69 (0.88–3.21)	29	1.62 (0.62–4.24)
Weight gain since age 18 (kg)						
<0	26	1.07 (0.69–1.67)	13	0.99 (0.53–1.85)	6	1.06 (0.43–2.66)
0–9	136	1.00 (ref.)	64	1.00 (ref.)	28	1.00 (ref.)
10–19	115	0.90 (0.70–1.18)	71	1.16 (0.81–1.65)	37	1.42 (0.85–2.36)
20–29	50	0.74 (0.52–1.04)	35	1.06 (0.68–1.65)	17	1.28 (0.71–2.30)
≥30	46	1.28 (0.88–1.86)	38	2.19 (1.40–3.41)	28	4.09 (2.34–7.14)
Gestational weight gain (lbs/wk)						
<0.5	58	1.43 (1.04–1.98)	39	1.68 (1.10–2.56)	27	2.33 (1.35–4.02)
0.5–1.4	245	1.00 (ref.)	123	1.00 (ref.)	57	1.00 (ref.)
≥1.5	70	1.17 (0.87–1.56)	57	1.97 (1.38–2.81)	31	2.24 (1.38–3.64)

CI, confidence interval; OR, odds ratio.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

[a]Adjusted for age, questionnaire cycle, marital status, education, smoked during pregnancy, parity, participant born preterm, and previous preterm birth. BMI analyses additionally adjusted for waist circumference; waist circumference analyses additionally adjusted for BMI; adult weight gain analyses additionally adjusted for BMI at age 18; gestational weight gain additionally adjusted for BMI and waist circumference.

Table 4

Gestational weight gain in relation to risk of spontaneous preterm birth, by prepregnancy BMI and waist circumference

	Body mass index (kg/m^2)						Waist circumference (inches)			
	20–24		25–29		≥30		< 35		≥35	
Mean lbs/wk	**Cases**	**OR (95%CI)***	**Cases**	**OR (95%CI)***	**Cases**	**OR (95%CI)***	**Cases**	**OR (95%CI)***	**Cases**	**OR (95%CI)***
<0.5	28	2.62 (1.62–4.26)	18	1.25 (0.70–2.21)	47	1.55 (1.02–2.35)	50	1.55 (1.08–2.21)	33	1.87 (1.11–3.15)
0.5–1.4	157	1.00 (ref.)	90	1.00 (ref.)	78	1.00 (ref.)	259	1.00 (ref.)	51	1.00 (ref.)
≥1.5	42	0.73 (0.50–1.06)	44	1.90 (1.27–2.85)	33	2.93 (1.86–4.63)	82	1.12 (0.85–1.47)	25	3.68 (2.13–6.35)

CI, confidence interval; OR, odds ratio. BMI <20 category excluded from table due to small numbers.

* Adjusted for age, questionnaire cycle, marital status, education, smoked during pregnancy, parous, participant born preterm, previous preterm birth, and waist circumference (in analyses of BMI) and BMI (in analyses of waist circumference).