Central Adiposity and Other Anthropometric Factors in Relation to Risk of Macrosomia in an African American population

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Abstract

Previous studies have consistently identified maternal obesity and gestational weight gain as risk factors for macrosomia, but little is known about the effects of central adiposity and body fat distribution. Using self-reported data from the Black Women's Health Study (BWHS), a large follow-up study of U.S. black women, we examined the risk of macrosomia in relation to prepregnancy waist circumference, prepregnancy waist-to-hip ratio, prepregnancy body mass index (BMI), and gestational weight gain. During 1995–2003, BWHS participants ages 21 to 44 years delivered 6,687 full-term singleton births (gestational age >37 weeks). We compared mothers of 691 infants weighing   4000g with mothers of 5,996 infants weighing <4000g. Generalized estimating equation models that accounted for more than one birth per mother were used to estimate multivariable odds ratios (OR) and 95% confidence intervals (CI). Independent of prepregnancy BMI, prepregnancy waist circumference was positively associated with risk of macrosomia (OR=1.58, 95% CI 1.07–2.32, for   35.0 vs. <27.0 inches (88.9 vs. <68.6 cm); P-trend= 0.04). As expected, prepregnancy BMI was also positively associated with macrosomia (OR=1.74, 95% CI 1.25–2.41 for BMI   35.0 vs. 18.5–24.9 kg/m^2). Gestational weight gain above the amount recommended by the 2009 Institute of Medicine report was associated with an increased risk of macrosomia and the association was present in each category of prepregnancy BMI (18.5–24.9, 25.0–29.9, and   30.0 kg/m^2; P-trend<0.001). Our data suggest that overall obesity, high gestational weight gain, and high waist circumference are independent risk factors for macrosomia among U.S. black women.

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INTRODUCTION

The prevalence of macrosomia (birth weight of 4000 grams or greater) (1) ranges between 5% and 12% among healthy pregnant women in the United States and some industrialized nations (2, 3), and is as high as 20% to 40% of pregnancies among women with pre-existing or gestational diabetes (4–6). Macrosomic infants are at higher risk of intrauterine death, birth injury, longer stays in intensive care (7, 8) and higher likelihood of childhood obesity (9). The risks are even greater for babies with birth weights exceeding 4500g (10). Moreover, women with larger fetuses have greater risks of delivery complications, such as hemorrhage, infection, cesarean section, preeclampsia and perinatal mortality (5), regardless of the presence of diabetes (7).

Macrosomia has been linked to high maternal body mass index (BMI), gestational and type 2 diabetes, and high gestational weight gain (GWG) (4–6, 11–13). The mechanisms that explain these associations include higher energy accumulation by the fetus resulting from increased maternal glucose concentration and insulin resistance (14, 15). Central adiposity, measured by waist circumference or waist-to-hip ratio (WHR) (16, 17), is also related to glucose and insulin metabolic changes independent of BMI (18–20). However, few studies have examined the relation between central adiposity and birth weight. In the only published study of the association, an 0.1-unit increase in WHR predicted a 281-g greater birth weight among obese women (BMI $\geq$ 30kg/m^2) (21).

The obesity epidemic in the U.S. has affected black women more than any other ethnic group (22, 23). Most studies of anthropometric risk factors and macrosomia have been conducted in white populations. In the present study, we evaluated the associations of prepregnancy waist circumference, WHR, BMI, and GWG with risk of macrosomia in a large prospective cohort study of U.S. black women.

METHODS AND PROCEDURES

Source Population

The Black Women's Health Study (BWHS) is an ongoing follow-up study of 59,000 African-American women that began in 1995 (24). Women ages 21 to 69 years were enrolled through postal questionnaires, which were sent primarily to subscribers of *Essence* magazine, a popular magazine targeted to black women. The baseline questionnaire collected information on demographic, anthropometric, lifestyle, reproductive, and medical factors. Health-related information is updated biennially through follow-up questionnaires. Follow-up of the baseline cohort had exceeded 80% through 2003 (the period of data collection on births). The human subjects protocol for this study was approved by the Boston University Medical Center Review Board.

Assessment and Validation of Pregnancy Outcomes

On the 1997, 1999, 2001, and 2003 questionnaires, women were asked if they had delivered a singleton livebirth or stillbirth in the previous two years, and were asked to record the infant's birth weight in pounds and ounces. The women were also asked whether the infant was born 3 or more weeks early.

In a validation study carried out using registry data from the Massachusetts Department of Public Health, birth records were successfully obtained for 76% of singletons (167/232) born to BWHS participants who lived in Massachusetts during 1995–2003 (25). The median birth weights according to registry and self-report were 3,340g and 3,348g, respectively (Pearson correlation: r=0.98), suggesting high accuracy of self-report of infant birth weight in our cohort (25).

Assessment and Validation of Exposures

In 1995, BWHS participants reported their height (feet and inches), current weight (pounds), waist circumference (inches) at the level of the umbilicus, and hip circumference (inches) at its widest location. Current weight was updated on all follow-up questionnaires. We used waist circumference to measure abdominal fat, WHR (calculated as waist circumference divided by hip circumference) to measure relative body fat distribution (26), and BMI calculated as weight (kg)/height (m)^2 to measure overall body fat (17). Weight reported on the questionnaire prior to the questionnaire on which the birth was reported was used to derive prepregnancy BMI. Women who reported being currently pregnant on the baseline questionnaire (the only questionnaire on which we asked about waist circumference and hip circumference) were excluded from analyses because their measurements could have been distorted by their pregnancy. On each questionnaire, women were asked about their total pregnancy weight gain using the following categories: <10, 10–14, 15–19, 20–24, 25–29, 30–34, 35–39, >39 pounds.

Anthropometric variables were validated among 115 BWHS participants who took part in a physical activity validation study in 2001 (27). Pearson correlations coefficients between self-reported and technician-measured weight, height, BMI, waist circumference, hip circumference, and WHR were 0.97, 0.93, 0.96, 0.72, 0.74, and 0.54, respectively (28).

Self-reported GWG was validated against data from the Massachusetts Department of Public Health birth registry (supplied as a continuous measure) (25). For GWG, the weighted kappa statistic was 0.55 for the comparison of self-reported vs. registry-supplied data assessed in categories (based on 159 pregnancies with complete data on both measures). Two-thirds of women (107/159) reported their weight gain within 1 category of the registry-supplied data. Among women who misreported their weight gain by more than 1 category, 45% underreported their gain. We also considered GWG as a continuous variable: we converted the categorical self-reported GWG variable using the midpoint of each category, and assigned 5 lbs to the lowest category and 40 lbs to the highest; the Spearman correlation coefficient was 0.56.

Assessment of Covariates

The baseline questionnaire collected data on years of education, marital status, parity status before the index birth, smoking before and during the index pregnancy, and maternal medical conditions (type 2 diabetes or gestational diabetes, pre-gestational or gestational hypertension, or thyroid conditions). Information on household income was collected in 2003. With the exception of education, marital status, and income, all variables were updated on follow-up questionnaires.

Analytic Sample

A total of 8,727 singleton births were identified during the study period (1995–2003). Analyses were restricted to births with gestation >37 weeks (n=7,419) because macrosomia is rare among preterm babies. We also excluded women with missing information on prepregnancy BMI (n=84), infant birth weight (n=33), and number of previous births (n=8), and women who were pregnant when they completed the baseline questionnaire (n=607), leaving 6,687 full-term births available for analysis of prepregnancy BMI. For the analyses of waist circumference, WHR, and GWG, we further excluded women with missing information on waist circumference (n=1,133), WHR (n=1,299), or GWG (n=21), leaving 5,554, 5,388, and 6,666 full-term births, respectively, for analyses of these risk factors.

Statistical Analysis

Macrosomia was defined as birth weight ≥ 4000g (1). Prepregnancy waist circumference and WHR were categorized into quintiles based on their frequency distributions within the analytic sample. Prepregnancy BMI categories were divided as <18.5, 18.5–24.9, 25.0–29.9, 30.0–34.9 and ≥ 35.0 kg/m^2 based on the World Health Organization standards (29). GWG was examined in the following categories, <25, 25–34, 35–39, ≥ 40 lb (<11.3, 11.3–15.8, 15.9–18.0, ≥ 18.1 kg). In analyses stratified on BMI, we categorized GWG based on the ranges recommended by the Institute of Medicine in 2009: 25–35 lb (11.3–15.9 kg) for women with BMI 18.5–24.9 kg/m^2, 15–25 lb (6.8–11.3 kg) for women with BMI 25.0–29.9 kg/m^2 and 11–20 lb (5.0–9.1 kg) for women with BMI ≥ 30 kg/m^2 (30). BMI was updated every 2 years in the analysis, whereas waist and WHR were measured only at baseline and were treated as fixed exposure variables.

Generalized estimating equation models (GEE) (31), PROC GENMOD statement with the "logit" link function and the "exchangeable" correlation structure, were used to estimate odds ratios (OR) and 95% confidence intervals (CI) for the associations between selected anthropometric factors and macrosomia. These models account for correlation arising from women who contributed more than one birth to the analysis (n=1,026). Multivariable models were adjusted for questionnaire cycle and risk factors for macrosomia identified in the literature, including maternal age at delivery (continuous variable), parity (0, 1, 2, ≥ 3), education (≤ 12, 13–15, and ≥ 16 years), household income (<$25,000, $25,001–$50,000, $50,001–$100,000, and >$100,000), marital status (single, married or living as married, divorced or separated, and widowed), and smoking during pregnancy (yes or no). Since prepregnancy waist circumference (or WHR) and prepregnancy BMI were positively correlated in our cohort, additional models were conducted with simultaneous adjustment for BMI or waist circumference to assess the independent effects of central and overall

adiposity. For the analysis of GWG, we also controlled for prepregnancy waist circumference and BMI. We performed further analyses to account for maternal medical conditions (coded as 'yes' if had any of following conditions: type 2 diabetes or gestational diabetes, pre-gestational or gestational hypertension, or thyroid conditions), which were associated with macrosomia in this cohort. Tests for trend were conducted using Wald tests with the ordinal version of each anthropometric variable.

We performed stratified analyses to assess effect modification (statistical interaction) by prepregnancy BMI (<30 vs. 30 kg/m^2) and parity (nulliparous vs. parous), and by family income (<$50,000 vs. >$50,000) and education (<16 vs. 16 years) as well, because previous studies have shown that prepregnancy BMI and parity can modify the relation between GWG and the risk of adverse birth outcomes (12, 13). Wald tests were conducted to assess statistical interactions using cross-product terms between each potential effect modifier and each risk factor (coded as dichotomous variables). To minimize the influence of incomplete weight loss from a previous pregnancy on the results, we repeated the analyses after restricting the sample to the first birth contributed by each woman during the study period. We also repeated the analyses using a more stringent definition of macrosomia (birth weight 4500g). Finally, using GEE linear regression models, we calculated mean differences in infant birth weight (and 95% CI) for each category of the exposure variable relative to the reference category. All analyses were conducted in SAS version 9.1.

RESULTS

Characteristics of the study participants in 1995 are displayed in Table 1. The median age of the women was 31 years, 23% had a BMI 30.0 kg/m^2 and 17% had a waist circumference of 35 inches (88.9 cm). Prepregnancy waist circumference was positively related to prepregnancy WHR (r=0.53), prepregnancy BMI (r=0.72), being married or living as married, family income <$25,000, smoking during pregnancy, parity, and maternal medical conditions, and inversely related to GWG (r=−0.28). Prepregnancy BMI was positively associated with prepregnancy WHR (r=0.20), parity, and maternal medical conditions, and inversely related to GWG (r=−0.31). Furthermore, the proportion of women who smoked during pregnancy was higher among women with BMI <18.5 and 35.0 kg/m^2.

Among 6,687 singleton births, we identified 691 cases of macrosomia (birth weight 4000g). As shown in Table 2, high prepregnancy waist circumference was associated with an increased risk of macrosomia (OR=1.58, 95% CI 1.07–2.32, for waist circumference 35 inches (88.9 cm) relative to <27 inches (68.6 cm); P-trend=0.036), after adjustment for covariates including prepregnancy BMI. Mothers with prepregnancy waist circumference 35 inches (88.9 cm) had infants that were, on average, 84g heavier (95% CI 57–101) than women with prepregnancy waist circumference <27 inches (68.6 cm), after controlling for all covariates. There was little evidence of an association between prepregnancy WHR and macrosomia. For both waist circumference and WHR, further control for maternal medical conditions did not appreciably change the results (data not shown).

The OR for prepregnancy BMI 35.0 kg/m^2 relative to BMI 18.5–24.9 kg/m^2 was 1.74 (95% CI 1.25–2.41) after adjustment for all covariates including prepregnancy waist

circumference (Table 2). The mean infant birth weight was 3235g among women with BMI 18.5–24.9 kg/m^2, and was increased by 32g (95% CI 13–51g), 55g (95% CI 32–79g), and 58g (95% CI 27–89g) for prepregnancy BMIs of 25.0–29.9, 30.0–34.9 and 35.0 kg/m^2, respectively, after controlling for all covariates. Further adjustment for maternal medical conditions had little impact on these results (data not shown). The number of macrosomia cases among women with BMI <18.5 kg/m^2 was too small (N = 10 cases) for meaningful analysis.

In the analyses of waist circumference and prepregnancy BMI, we further adjusted for GWG. All associations were slightly increased (for waist circumference 35 vs. <27 inches (88.9 vs. <68.6 cm), OR=1.76, 95% CI 1.19–2.60; for prepregnancy BMI 35.0 vs. 18.5–24.9 kg/m^2, OR=2.25, 95% CI 1.60–3.17; for WHR 0.86 vs. <0.72, OR=1.31, 95% CI 0.98–1.74).

We observed a linear trend of increasing risk of macrosomia with increasing GWG (*P*-trend <0.001) (Table 2). Further adjustment for prepregnancy BMI and waist circumference had little effect on the association, and results were similar after adjustment for maternal medical conditions. The associations of prepregnancy waist circumference, prepregnancy BMI, and GWG with macrosomia were similar within strata of parity (nulliparous vs. parous), education (<16 vs. 16 years), and family income (<$50,000 vs. >$50,000), and none of the interaction tests was significant (data not shown).

When we used a more stringent definition of macrosomia (birth weight 4500g), ORs for the highest category of each exposure were higher than in the original analysis (waist circumference 35 vs. <27 inches (88.9 vs. <68.6 cm), OR=3.46, 95% CI 1.30–9.24, P-trend=0.03; prepregnancy BMI 35.0 vs. 18.5–24.9 kg/m^2, OR=2.11, 95% CI 1.01–4.37, P-trend=0.007; GWG 40 vs. 25–34 lb (18.0 vs. 11.3–15.8 kg), OR=3.20, 95% CI 1.84–5.58, P-trend<0.001). However, these analyses were based only on 106 infants with birth weight 4500g. As in analyses that used the standard definition of macrosomia (Table 2), the strongest evidence of a linear trend was with GWG.

Associations between GWG and macrosomia, within levels of prepregnancy BMI, are shown in Table 3. Within each category of prepregnancy BMI, the odds ratio for macrosomia was highest for women whose GWG was above the range recommended by the Institute of Medicine and lowest for those whose GWG was below the recommendation. Obese women who gained within the recommended weight gain for their BMI category had a risk of macrosomia above that of the reference group, normal weight women (BMI 18.5–24.9 kg/m^2) who gained the recommended amount of weight for their BMI category.

We repeated all analyses after restricting the sample to women without maternal medical conditions (n=5,186 births) because maternal medical conditions could be a potential causal intermediate. The overall ORs for the associations of macrosomia with waist circumference, prepregnancy BMI, and GWG increased slightly (data not shown). To minimize the influence of incomplete weight loss from a previous pregnancy on our results, we restricted our sample to the first birth during the study period (n=5,583). Results were virtually identical, albeit less precise, to those obtained from the complete set of births.

DISCUSSION

In the present prospective study of U.S. black women, we found that high prepregnancy waist circumference but not WHR was positively associated with risk of macrosomia, independent of prepregnancy BMI. We also found a positive association between prepregnancy BMI and risk of macrosomia, after accounting for maternal medical conditions. Women with greater GWG had a higher risk of macrosomia than those with lower GWG, and this association was found within each category of prepregnancy BMI.

The association between central adiposity and macrosomia has received little study. The only previous study was of WHR and birth weight among 702 Caucasian women from the greater Twin Cities area. Higher WHR was associated with greater birth weight (21). In contrast, in the present study of 5,578 black women from all regions of the United States, waist circumference, but not WHR, was associated with risk of macrosomia independent of prepregnancy BMI. If the mechanism for increased birth weight operates through insulin resistance and glucose intolerance, the findings of both studies support the hypothesis that a central pattern of body fat distribution is an important determinant of insulin sensitivity and insulin resistance rather than body size alone (19, 20). The null association for WHR in our study may reflect greater misclassification of this variable, which is a ratio of two variables measured with error (32, 33). Waist circumference has less measurement error than WHR and may also be a better measure of central adiposity (16, 34). Although there was a significant linear trend with increasing quintile of waist circumference, this was mainly driven by the increased risk associated with the highest quintile. This may indicate a threshold effect or may simply be due to sampling variation. In this respect, the findings with regard to waist circumference are less robust than those for BMI and GWG.

Both prepregnancy BMI and GWG have been identified as risk factors for macrosomia in previous studies conducted in white women (4, 11–13, 35, 36). BMI ≥ 30 kg/m^2 and GWG higher than recommended were associated with 50–80% increased risks of macrosomia (4, 5, 11, 13). For very high GWG (>20 kg), the risk of macrosomia was increased 160–190% relative to GWG of 10–15kg after controlling for various covariates, including prepregnancy BMI (13, 37). The results of the present study of black women were similar for prepregnancy BMI and for GWG. In addition, we assessed the joint effects of prepregnancy BMI and GWG, and observed that women with greater GWG had a higher risk of macrosomia than those with lower GWG within each category of prepregnancy BMI. Our results, in agreement with findings in white women (11, 13, 36), indicate that obese women who adhered to the 2009 Institute of Medicine recommendations for GWG do have a lower risk of macrosomia than obese women who gained more than the recommended amount, but they may have a higher risk relative to that of normal weight women who followed the recommendations.

There are two plausible mechanisms by which obesity may affect macrosomia. The first is based on insulin resistance and glucose intolerance mechanisms. Heavier women have higher plasma concentrations of glucose and free fatty acids regardless of pregnancy (14, 15). During pregnancy, maternal glucose and free fatty acids, but not insulin, are freely transferred to the fetus. These higher levels of nutrients will increase the energy

accumulation in the fetus (15). The second is related to regulation of fetal growth factors. It has been demonstrated that levels of glucose and free fatty acids play a role in fetal insulin secretion (15). The higher the levels of glucose and free fatty acids, the higher the levels of insulin and insulin-like growth factors in cord-blood, which may accelerate fetal growth. .

There are some limitations to our study. First, the study was based on self-reported data. However, a validation study of birth characteristics, including infant birth weight, indicated high accuracy of self-report (25). Our validation studies of maternal anthropometric variables indicated high accuracy in reporting for prepregnancy weight and height, moderate accuracy for waist circumference and hip circumference, and lower accuracy for WHR and GWG (25). Since all maternal anthropometric variables, with the exception of GWG, were reported prospectively, non-differential misclassification would likely have biased associations for the extreme categories of exposure toward the null (38). WHR, the ratio of two self-reported measures, waist and hip circumference, has a greater degree of misclassification than waist circumference alone because it is influenced by misclassification of both waist and hip sizes (32, 33). Greater misclassification of WHR may have contributed to the weaker association between WHR and macrosomia. Weight gain from a previous pregnancy could have influenced our measurement of prepregnancy BMI. However, results among first births were similar to those obtained from all births, suggesting the impact of this bias was minimal. Because our study did not have an exact measurement of gestational age, we were unable to derive a measure of large-for-gestational age. Thus, we were unable to adjust for gestational age and there may have been some macrosomic post-term infants (gestational age 42 weeks) who were not large for their gestational age. Given that post-pregnancy dating 42 weeks is a standard indicator of labor induction in the United States (39), the misclassification is likely to be small.

Our study has several strengths. First, it controlled for a wide range of potential confounders, many of which were not available in previous studies, such as education, income, smoking history, and maternal health conditions. Second, the prospective design minimized the potential for systematic bias in the reporting of the anthropometric variables. Third, high cohort retention of our study will have reduced the likelihood of selection bias. Lastly, almost all BWHS participants (97%) had a high school degree at baseline (24) and national data indicate that about 80% of black women of the same ages in 1995 had completed high school (40). Therefore, our results may be applicable to a large segment of U.S. black women.

In conclusion, our results indicate a higher risk of macrosomia among women with a high central adiposity, independent of overall adiposity. In addition, our findings confirm in black women previous findings of overall obesity and increased GWG with risk of macrosomia.

ACKNOWLEDGEMENT

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Table 1

Maternal characteristics according to prepregnancy waist circumference and BMI among women who had term births[a]

Characteristics	Prepregnancy waist circumference (quintiles, inches)[b] (N=5,554)						Prepregnancy BMI (kg/m²) (N=6,687)					
	<27.0 (n=1,205)	27.0–28.9 (n=1,127)	29.0–30.9 (n=1,049)	31.0–34.9 (n=1,212)	35.0 (n=961)	P_{trend}[d]	<18.5 (n=104)	18.5–24.9 (n=3,078)	25.0–29.9 (n=1,974)	30.0–34.9 (n=883)	35.0 (n=648)	P_{trend}[d]
Age at delivery, year (mean)	31.0	31.1	31.3	31.1	31.1	0.68	29.3	30.8	31.3	31.2	30.9	0.01
Prepregnancy waist circumference, inches (mean)	25.0	27.6	29.5	32.5	38.5	--	25.0	27.7	31.0	34.0	38.1	<0.001
Prepregnancy WHR (mean)	0.72	0.75	0.78	0.82	0.86	<0.001	0.75	0.76	0.79	0.81	0.81	<0.001
Prepregnancy BMI, kg/m² (mean)	22.3	23.7	25.5	28.1	34.3	<0.001	17.8	22.3	27.2	32.2	40.6	--
Married/living as married (%)	40.1	46.7	47.6	51.1	50.0	<0.001	37.8	48.0	48.4	47.5	42.3	0.22
Education, year (mean)	15.3	15.4	15.3	15.0	14.8	<0.001	15.1	15.4	15.1	14.9	14.7	<0.001
Family Income $25,000 (%)	5.0	3.5	5.6	7.6	11.2	<0.001	9.9	4.5	7.2	9.5	12.9	<0.001
Smoked during pregnancy (%)	1.8	2.0	3.2	5.4	5.4	<0.001	7.9	2.6	4.2	5.1	5.9	<0.001
Parous (%)	46.4	48.5	53.4	58.2	59.1	<0.001	50.6	50.5	58.1	60.1	58.7	<0.001
Gestational weight gain, lb (mean)	31.0	30.5	29.7	26.5	23.2	<0.001	31.8	30.8	27.8	24.1	20.6	<0.001
Maternal medical condition (%)[c]	13.7	15.4	19.7	25.1	36.7	<0.001	10.3	15.1	23.3	30.7	45.1	<0.001

BMI, body mass index; WHR, waist-to-hip ratio.

[a] The Black Women' Health Study, 1995–2003. All characteristics (other than age) are adjusted for age at delivery.

[b] Excludes 1,133 women with missing data on waist circumference in 1995.

[c] Defined as type 2 diabetes or gestational diabetes, gestational or pre-gestational hypertension, or thyroid conditions.

[d] Derived from the tests for linear trend.

Table 2

Anthropometric factors in relation to risk of macrosomia (birth weight ≥ 4000g) among term births

Characteristics	Birth weight ≥ 4000g	Birth weight <4000g	Multivariable OR (95% CI)[a]	Multivariable OR (95% CI)[b]
Prepregnancy waist circumference	n = 5,554			
<27 in / <68.6 cm	104	1,101	1.00 reference	1.00 reference
27–28 in / 68.8–73.6 cm	92	1,035	0.94 (0.69–1.28)	0.92 (0.67–1.25)
29–30 in / 73.7–78.6 cm	107	942	1.21 (0.90–1.63)	1.13 (0.82–1.54)
31–34 in / 78.7–88.8 cm	127	1,085	1.28 (0.96–1.71)	1.14 (0.81–1.59)
≥35 in / ≥88.9 cm	138	823	1.91 (1.43–2.53)	1.58 (1.07–2.32)
P-value, test for trend			<0.001	0.036
Prepregnancy WHR	n = 5,388			
<0.72	137	1,198	1.00 reference	1.00 reference
0.72–0.75	99	949	0.88 (0.67–1.17)	0.88 (0.67–1.17)
0.76–0.79	79	888	0.78 (0.57–1.05)	0.75 (0.55–1.01)
0.80–0.85	111	850	1.15 (0.86–1.52)	1.07 (0.80–1.42)
≥0.86	130	947	1.24 (0.95–1.63)	1.13 (0.85–1.49)
P-value, test for trend			0.047	0.268
Prepregnancy BMI (kg/m^2)	n = 6,687			
<18.5	10	94	1.23 (0.62–2.44)	1.27 (0.64–2.54)
18.5–24.9	254	2,824	1.00 reference	1.00 reference
25.0–29.9	224	1,750	1.38 (1.13–1.67)	1.28 (1.04–1.60)
30.0–34.9	101	782	1.43 (1.11–1.85)	1.22 (0.91–1.67)
≥35.0	102	546	2.14 (1.65–2.78)	1.74 (1.25–2.41)
P-value, test for trend			<0.001	<0.001
Gestational weight gain	n = 6,666			
<25 lb / <11.3 kg	191	2,231	0.81 (0.66–1.00)	0.68 (0.55–0.84)
25–34 lb / 11.3–15.8 kg	211	2,018	1.00 reference	1.00 reference
35–39 lb / 15.9–18.0 kg	81	648	1.24 (0.95–1.63)	1.33 (1.01–1.75)
≥40 lb / ≥18.1 kg	204	1,082	1.86 (1.51–2.30)	2.02 (1.63–2.50)
P-value, test for trend			<0.001	<0.001

CI, confidence interval; OR, odds ratio; BMI, body mass index; WHR, waist-to-hip ratio.

[a]Adjusted for age, questionnaire cycle, marital status, education, income, smoking during pregnancy, and parity.

[b]Waist circumference and waist-to-hip ratio analyses additionally adjusted for BMI; BMI analysis additionally adjusted for waist circumference; gestational weight gain analysis additionally adjusted for BMI and waist circumference

Table 3

GWG in relation to risk of macrosomia according to prepregnancy BMI among 6,563 term births

Prepregnancy BMI (kg/m²)[a] / GWG[b]	Birth weight 4000g	Birth weight <4000g	Multivariable OR (95% CI)[c]
BMI 18.5–24.9 / Below recommendation	42	742	0.82 (0.53–1.27)
BMI 18.5–24.9 / Within recommendation	72	1,035	1.00 reference
BMI 18.5–24.9 / Above recommendation	138	1,040	2.10 (1.51–2.92)
BMI 25.0–29.9 / Below recommendation	7	204	0.41 (0.18–0.91)
BMI 25.0–29.9/ Within recommendation	41	474	0.99 (0.64–1.52)
BMI 25.0–29.9 / Above recommendation	175	1,067	1.94 (1.41–2.69)
BMI 30.0 / Below recommendation	11	173	0.76 (0.36–1.58)
BMI 30.0 / Within recommendation	46	372	1.45 (0.89–2.37)
BMI 30.0 / Above recommendation	145	779	2.25 (1.48–3.41)

CI, confidence interval; OR, odds ratio; BMI, body mass index; GWG, gestational weight gain.

[a]BMI <18.5 kg/m² category was excluded from table due to small numbers,

[b]Defined according to 2009 Institute of Medicine guidelines: women with pregnancy BMI 18.5–24.9 (below: <25 lb, within: 25–35 lb, above: >35 lb), BMI 25.0–29.9 (below: <15 lb, within: 15–25 lb, above >25 lb), BMI 30.0 (below: <11 lb, within: 11–20 lb, above: >20 lb),

[c]Adjusted for age, questionnaire cycle, marital status, education, income, smoking during pregnancy, parity and waist circumference.