The Association Between Impaired Glucose Tolerance and Birth Weight Among Black and White Women in Central North Carolina

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OBJECTIVE — This study examines the relationship of glucose intolerance during pregnancy to birth weight among black and white participants of the Pregnancy, Infection, and Nutrition Study.

RESEARCH DESIGN AND METHODS — This prospective cohort study recruited women from prenatal clinics in central North Carolina at 24–29 weeks' gestation. A 1-h 50-g glucose challenge test (GCT) and 100-g oral glucose tolerance test (OGTT) were conducted. Impaired glucose tolerance (IGT) was defined as one high value on the OGTT, gestational diabetes mellitus (GDM) as two or more high values, and normal glucose tolerance (NGT) was defined as a low or high value on the GCT screen but no high values on the OGTT. Women with known glucose status and birth outcome information were included in this analysis ($n = 2055$).

RESULTS — Black women with IGT had higher rates of both macrosomia (38.5%) and large for gestational age (LGA) (53.9%) compared with white women (10.0% and 13.2%). Black infants' birth weights (3,800 g) and prevalence of macrosomia and LGA were significantly higher among mothers with IGT compared with NGT women (birth weight, 3,184 g; macrosomia, 7.0%; LGA, 11.6%). In contrast, among white infants, there was no significant increase in birth weight, macrosomia, or LGA associated with the mother's glucose tolerance status. In addition, there was no effect of GDM on birth weight in either group.

CONCLUSIONS — This study suggests that, independent of maternal prepregnant weight, there may be significant increased risk of macrosomia among black IGT women but not among white IGT women. Further investigations into factors that may contribute to the observed results are needed.

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Impaired glucose tolerance (IGT) during pregnancy is a degree of hyperglycemia that is not severe enough to be labeled as gestational diabetes mellitus (GDM). Some studies have shown a rate of IGT twice that of GDM (1–3). Untreated GDM has biologic consequences for both mother and infant, including excess fetal growth, risk of birth injury, and cesarean delivery (4,5). However, studies that examine the relationship between IGT and pregnancy outcomes are inconclusive. Some studies have found increased birth weights, rates of macrosomia, and LGA in infants of women with IGT compared with women with GDM who are under good glucose control (1,2,6,7). Other similar studies have not found an effect of IGT on fetal growth (8,9).

Epidemiologic studies suggest that the relationship between GDM and birth weight may be influenced by race or ethnicity (10–15). Other studies have shown that race may influence insulin response. The Bogalusa Heart Study found differential effects in insulin response to an oral glucose load between ethnic groups (16), and hyperglycemic clamp studies of nonobese adolescents showed a higher insulin response and decreased insulin sensitivity among blacks compared with whites (17).

No studies to date have directly examined the race differences in the relationship between fetal growth and IGT, while controlling for confounders. Therefore, this study examines the effect that IGT has on fetal growth of infants born to black women compared with infants born to non-Hispanic white women, while controlling for potential confounders. Better understanding of the effects of IGT may inform health care practices for women found to have abnormal glucose tolerance during pregnancy.

RESEARCH DESIGN AND METHODS

— This study uses data from the Pregnancy, Infection and Nutrition (PIN) Study, a prospective cohort study designed to identify determinants of preterm delivery, conducted at the University of North Carolina (UNC) Resident and Private Physician Obstetrics Clinic, the Wake County Department of Human Services, and the Wake Area Health Edu-

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Abbreviations: GCT, glucose challenge test; GDM, gestational diabetes mellitus; IGT, impaired glucose tolerance; IOM, Institute of Medicine; LGA, large for gestational age; LMP, last menstrual period; NGT, normal glucose tolerance; OGTT, oral glucose tolerance test; PIN, Pregnancy, Infection and Nutrition Study; UNC, University of North Carolina.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

cation Center Prenatal Care Clinics. Women recruited between 24 and 29 weeks of pregnancy were eligible to participate in the study if they were having singleton pregnancies, were >16 years of age, spoke English, had access to a phone, and planned to continue their care and deliver at one of the study sites. Women were contacted by telephone within 2 weeks of recruitment for completion of a questionnaire. Information was gathered on current and pregravid health behaviors, including physical activity and sociodemographic characteristics. Birth outcome information was obtained from labor and delivery logs on all women. Glucose tolerance information was obtained from both hospital computer databases and the medical charts. Details on the study design and the population's characteristics through March 1997 have been previously presented (18). Preliminary analysis showed that 57% of eligible women were recruited, with a slightly higher success rate among white women (61%) compared with black women (54%) (18). The reasons for not participating were similar for both groups. Characteristics (including race, income, and educational level) that might be related to refusal rate have been previously examined and found to have either a weak relationship or no relationship to the refusal rate (18). PIN study protocols were reviewed and approved by the Institutional Review Board of the School of Medicine at UNC at Chapel Hill and Wake Medical Center.

The PIN study recruited 2,898 women from 1 August 1995 to 31 May 2000. Of the 2,898 successfully recruited women, 2,055 were retained for this analysis. Excluded women included 31 with preexisting diabetes, 314 who had no screening glucose data, 63 who had a high screen without an oral glucose tolerance test (OGTT) and thus could not be classified, 23 with missing birth outcome data, 178 for whom BMI could not be imputed, and 140 from racial groups other than white or black. In addition, 94 women had two pregnancies in the cohort; their second pregnancies were excluded.

Glucose tolerance status

Glucose status was determined using a two-step approach. The initial screening test measures the plasma glucose concentration 1-h after a 50-g glucose challenge test (GCT). This test is a random screen and thus does not require that women be in the fasting state (19). Site-specific protocols established the cut-points for follow-up testing. The GCT screening cut-points for each clinic were different because there is still a disagreement about which cut-point represents risk. Analysis of the effect of differential cut-points showed either no effect or a slightly attenuated effect on the results. A value of ≥140 mg/dl at the UNC sites and a value ≥130 mg/dl at the Wake sites indicated the need for a full 3-h 100-g OGTT. The OGTT is conducted in the fasting state with glucose analysis performed at fasting and at 1, 2, and 3 h after the oral glucose load. These tests are performed on serum samples using a glucose oxidase method. Carpenter and Coustan (20) cut-points of 95 mg/dl for fasting, 180 for 1-h, 155 for 2-h, and 135 for 3-h values were used to define abnormal values. All women were classified into one of three groups. IGT was defined as one abnormal value from the OGTT. Normal glucose tolerance (NGT) was defined as women with a normal or high GCT but no high values on the OGTT. To provide further comparisons, women with GDM were included in the analysis and defined by two or more abnormal values on the OGTT. Women with GDM received both diet and or insulin treatment at both clinics and women with IGT were not treated at either clinic.

Outcomes

Three newborn growth outcomes were examined: birth weight (in grams) as a continuous variable, macrosomia defined as birth weight ≥4,000 g, and large for gestational age (LGA). The LGA variable was defined as sex-, race-, and parity-specific birth weight for gestational age above the 90th percentile of U.S. population fetal growth curves (21). LGA was examined to provide information about gestational age–specific growth rates. Macrosomia was examined to provide an evaluation of high birth weight irrespective of gestational age and to make comparisons with other previously published studies. Previous studies have shown macrosomia defined as ≥4,000 g to be associated with increased risk of infant birth trauma, fetal death, and cesarean delivery (22).

Covariates

Race was self-identified by women during the interviewer-administered telephone questionnaire or from the medical charts if missing. There were 18 possible categories, although only white and black women were included in this analysis. White or black women constituted 94% of the successfully recruited population.

Pregravid BMI (in kilograms divided by meters squared) was classified following guidelines established by the Institute of Medicine (IOM), which are <19.8 (underweight), 19.8–26 (normal), 26–30 (overweight), and ≥30 (obese) (23). Height measured at clinic visits and prepregnancy weight based on the women's recall were used for these calculations. If recalled prepregnancy weight was not available (4.7% of subjects) then the first measured weight between 1 and 15 weeks' gestation was used, with a correction factor for the week of measurement. Recalled prepregnancy weight has been shown to be consistent with clinical records (24,25).

Gestational age was defined as completed weeks, based on last menstrual period (LMP) and/or the earliest ultrasound assessment. When both were available and the estimates were within 14 days of one another, LMP was used (78%). When the disagreement exceeded 14 days (12%) or only the ultrasound was available (10%), the ultrasound estimate was used.

Information from the telephone interview was used to construct additional variables that were assessed as potential confounders. Family income was ascertained and used to calculate poverty index according to U.S. Bureau of the Census 1996 poverty guidelines. Information on cigarette smoking habits during the first 6 months of the pregnancy and participation in regular or strenuous physical activity 3 months before becoming pregnant were recorded as categorical variables of any versus none. Additional variables assessed for potential confounding include marital status, parity, mother's age, and education. Hypertension and the appropriate weight gain measurements were not available for these analyses.

Statistical analysis

Initial data preparation was performed using the SAS 6.12 statistical package (26) with all analysis conducted using STATA release 6.0 (27). Descriptive statistics of the main outcomes and exposures were calculated. χ^2 analysis was used to test for

differences in categorical variables, and a Student's *t* test or one-way ANOVA was used to test for differences in continuous variables. To examine the association between glucose tolerance status and the outcomes of macrosomia and LGA, logistic regression was used. Odds ratios and 95% CIs were calculated. To examine the association between glucose tolerance status and birth weight, multiple linear regression was used.

We first tested for an interaction between glucose status and race in the logistic regression models by comparing goodness-of-fit statistics for fully saturated models (including the interaction term) and reduced models (removing the interaction term). Interaction in the linear regression model was assessed by evaluating significance at $P < 0.1$. Because interaction between glucose status and race was found to be significant, all analyses were stratified by race.

Potential confounders of the relationship between glucose tolerance status and birth weight were identified from the literature and included maternal race, prepregnancy BMI, age, height, education, marital status, and infant's gestational age. Covariates that resulted in at least a 10% change in the β coefficient of the continuous birth weight model were retained in the final models. These variables include mother's prepregnancy BMI, age, height, and gestational age of the infant. Gestational age was not included in macrosomia or LGA models. Marital status, mother's education, and poverty level were not confounders nor did they explain the black-white differences and were therefore not included in the final models.

Some studies have found individual glucose values to be highly correlated with increased infant birth weight (28). Therefore, to understand whether the race differences were due to differences in individual glucose values, analysis was conducted using the individual glucose values from the OGTT for women with IGT. Additional analysis examined the racial differences in the GCT screen for all women. Individual values that were significantly different between white and black women were then examined in continuous birth weight multivariate models.

Table 1—*Selected characteristics of the study population stratified by race*

	White	Black
n	1,190	865
Maternal age (years)	1,190 27.4 ± 6.4	865 24.1 ± 5.4*
Maternal height (inches)	1,190 65 ± 2.5	865 65 ± 2.8
BMI categories		
Under	226 (19)	121 (14)*
Normal	623 (52)	363 (42)
Over	127 (11)	116 (13)
Obese	214 (18)	265 (31)
Marital status		
Single	273 (23)	605 (70)*
Married	822 (69)	196 (23)
Other	94 (8)	63 (7)
Maternal education (years)	1,188 14.1 ± 3.2	864 12.5 ± 2.1*
Poverty index (n = 1,778)		
Low <185%	445 (41)	540 (77)*
Medium 185–350%	229 (21)	127 (18)
High ≥350%	403 (37)	34 (5)
Parity	1,187 0.76 ± 0.93	862 0.98 ± 1.2*
Smoker (n = 1,885)	335 (30)	145 (19)*
Participated in physical activity	352 (31)	110 (14)*
Gestational age at delivery (weeks)	1,190 38.9 ± 2.1	865 38.6 ± 2.3†
1-h 50-g GCT (mg/dl)	1,185 110 ± 27	864 102 ± 25*

Data are *n* and means ± SD or *n* (%). *Indicates significant difference between black and white women, $P \leq 0.001$; †indicates significant difference between black and white women, $P \leq 0.01$.

RESULTS — Significant differences existed between whites and blacks on most demographic variables (Table 1). Compared with white women, black women in the PIN study were younger, more likely to be single, had less college education, and were poorer. In addition, black women were heavier, with larger percentages in the overweight and obese BMI categories compared with whites. Blacks had higher parity, smoked less, and participated less in physical activity from 3 months before pregnancy through the second trimester.

The overall prevalence of IGT in the cohort was 2.6% and the prevalence of GDM was 5.0%. The prevalence of IGT and GDM were higher among white women (3.4 and 5.9%, respectively) compared with blacks (1.5 and 3.7%, respectively). Race-stratified analysis of the OGTT values for women with IGT showed the only significant difference in the individual mean glucose values was the fasting plasma value. This was 8 mg/dl higher for black women (94 mg/dl) with IGT compared with white women (86 mg/dl) with IGT ($P = 0.01$). Race-stratified analysis of the GCT for all women showed significantly higher values among white women (110 mg/dl) compared with black women (102 mg/dl) ($P = 0.000$).

Table 2 compares fetal growth outcomes in race-specific glucose tolerance groups. Black women with IGT had higher rates of both LGA and macrosomia compared with white women with IGT. In addition, among black women, infants' birth weights, macrosomia, and LGA were significantly higher in those with IGT compared with NGT. In contrast, among white women there was no significant increase in infants' birth weight, macrosomia, or LGA associated with IGT.

Crude and adjusted odds ratios for macrosomia and LGA stratified by race are shown in Table 3. Black women with IGT are at greater risk of both macrosomia and LGA compared with black women with NGT. Among white women there was no significant increased risk of delivering either a macrosomic or LGA infant associated with IGT. Neither white nor black GDM women were at increased risk of delivering either a macrosomic or LGA infant.

Infants of black women with IGT were on average 616 g heavier than infants of black women with NGT ($P < 0.001$; 95% CI 280–952). Among black women, the linear regression models adjusted for prepregnancy BMI, mother's

Table 2—*Prevalence of glucose tolerance status and selected birth outcomes by glucose tolerance status and race*

	White (n = 1,190)			Black (n = 865)		
	Normal	IGT	GDM	Normal	IGT	GDM
n	1,080	40	70	820	13	32
Birth weight (g)	3,385 ± 620	3,463 ± 499	3,453 ± 676	3,184 ± 609	3,800 ± 726	3,271 ± 614*
Macrosomia (≥4,000 g)	14.8 (160)	10.0 (4)	20.0 (14)	7.0 (57)	38.5 (5)	6.1 (2)†
LGA*	11.5 (117)	13.2 (5)	19.1 (13)	11.6 (94)	53.9 (7)	18.9 (6)†

Data are means ± SD or % (n) *Indicates a sample size reduction due to missing LGA values (white n = 1,126, black n = 859); †Indicates significant difference between glucose tolerance status among race-specific groups, $P < 0.0001$.

age and height, and gestational age continued to show a significant increase in birth weight of 468 g (95% CI 224–714) associated with IGT women compared with NGT. In contrast, among white women there was no significant increase in birth weight associated with IGT compared with NGT in either the crude (77 g; 95% CI −118 to 274) or adjusted models (−15 g; 95% CI −158 to 129). Additionally, there was no significant effect of GDM on birth weight outcomes among white or black women.

Among women with IGT there was no significant effect of fasting glucose value on birth weight for either racial/ethnic group. Although regression analysis showed significant differences in the effect of the 1-h 50-g GCT value on birth weight in both white women (β = 1.2, P = 0.02) and black women (β = 2.9, P = 0.000) while controlling for prepregnancy BMI, gestational age, mother's age, and mother's height. For each unit increase in GCT glucose values, blacks had almost three times the increase in birth weight compared with whites.

CONCLUSIONS — The overall prevalence of GDM in the PIN study sample is consistent with other studies in the U.S. population (1–4%) (29). The overall prevalence of IGT was lower than some studies that were based on high risk screening (1,2,8) and were similar to those based on universal screening (6,7,30). In our population, the prevalence of IGT was lower than the prevalence of GDM. In addition, prevalences of both IGT (1.5%) and GDM (3.7%) were lower among blacks than whites (IGT 3.4%, GDM 5.9%). This is in contrast to previously published rates of GDM in blacks, which were slightly higher than whites of the same study population (10,11).

This analysis examines the relationship between glucose status and birth weight by race. Our results show higher birth weights and rates of macrosomia and LGA among infants born to black women with IGT compared with black women with NGT, but not among infants born to white women with IGT compared with white women with NGT. To our knowledge, this is the first time that effect modification by race has been investigated in the relationship between IGT and birth weight. However, two studies of diabetes during pregnancy support a relationship between race and glucose levels and increased fetal growth (12,14).

Table 3—*Crude and adjusted OR and 95% CIs for macrosomia and LGA by glucose tolerance status*

	White (n = 1,190)		Black (n = 865)	
	Crude RR (95% CI)	Adjusted OR† (95% CI)	Crude RR (95% CI)	Adjusted OR† (95% CI)
IGT*				
Macrosomia	0.6 (0.2–1.8)	0.6 (0.2–1.7)	8.4 (2.7–26)	5.7 (1.6–20)
LGA	1.2 (0.4–3.0)	1.1 (0.4–2.9)	8.9 (2.9–27)	7.7 (2.3–26)
GDM*				
Macrosomia	1.4 (0.8–2.6)	1.1 (0.6–2.1)	0.9 (0.2–3.8)	0.7 (0.2–3.3)
LGA	1.8 (0.9–3.4)	1.4 (0.7–2.7)	1.8 (0.7–4.4)	1.6 (0.6–4.2)

*Referent group: normal glucose tolerance; †models adjusted for prepregnant BMI, mother's age, and height.

In a study of Latino and African-American women, Homoko et al. (12) found differences in both the rates and risk of macrosomia. Latino women with GDM had a 50% rate of macrosomia (defined as birth weight ≥90th percentile for gestational age), as compared with a 19% rate in blacks. Latino women also had a relative risk of 2.68 (95% CI 1.57–4.59) for macrosomia when compared with blacks, even after controlling for level of glycemic control, BMI, insulin therapy, and maternal weight gain. Their study found that at similar glucose levels, fetal growth varied substantially by racial/ethnic group.

Using national vital records, Kieffer et al. (14) also found that the risk of delivering a macrosomic infant varied by race/ethnic group. Among black women, the odds ratio for delivering a macrosomic infant was 3.24 (95% CI 3.09–3.38), while among white women, the risk was much lower at 1.66 (95% CI 1.63–1.68). They also found that mean birth weights for GDM women were higher in both racial groups, but infants of black diabetic mothers were 220 g heavier than infants of nondiabetic black mothers, and infants of white diabetic mothers were only 94 g heavier than infants of white nondiabetic mothers. Because Kieffer et al. make no distinction between preexisting diabetes and GDM, we cannot directly compare their results with ours. In our study, infants of white GDM women had similar birth weights and magnitude of risk as white women with GDM in the Kieffer study. Yet, black GDM women in our study had no significant increased risk of macrosomia, while black women with GDM in the Kieffer study were over three times as likely to deliver macrosomic infants. The differences in risk for GDM women in our study were not significant, possibly due to the effect of treatment of all GDM women in our clinics.

Our study expanded upon these previous works by excluding preexisting diabetic subjects and by examining the risk associated with an intermediate level of glucose intolerance (IGT). We considered several potential explanations for the racial differences that were observed in fetal growth at similarly elevated glucose levels, defined as IGT. First, there might be significant differences in mean glucose values within glucose tolerance categories. Analysis of individual glucose values among IGT women showed that the mean fasting values were significantly higher among black women compared with whites (94 and 86 mg/dl). However, regression analysis among the women with IGT showed no significant effect of fasting glucose level on birth weight in either racial group. Sample size for this analysis was small, so we further explored the effect that an individual glucose value might have on birth weight differences between blacks and whites by examining the 1-h 50-g GCT glucose values for all women. Mean GCT values were significantly higher in white women, and exploratory analysis revealed a positive association between the GCT values and birth weight, although the relationship was different for each racial/ethnic group. These analyses support the idea that glucose tolerance may affect birth weight differently in blacks and whites.

Secondly, we explored how differences in sociodemographic factors among racial/ethnic groups might directly influencing birth weight. While marital status, mother's education, and poverty level were not confounders in the full model, it is important to know whether the significant differences observed in these sociodemographic characteristics are in fact influencing the birth weight relationship. An analysis of these as potential main effects on birth weight did not reduce the black-white differences seen in the effect of IGT on birth weight.

It is also possible that more proximate etiologic factors, which were not measured in this study, may account for the relationship observed. Some of these more proximal factors might include maternal weight gain, and its patterning during pregnancy, or differences in dietary intake and physical activity during pregnancy. Furthermore, residual confounding associated with the measured variables may be influencing the relationship. A limitation of this study is the small number of IGT cases among black women ($n = 13$), which limits the precision of the estimates of risk.

In summary, this study provides preliminary evidence that the effect of IGT on birth weight varies by race. No prior studies of IGT and excess fetal weight have examined these differences while adjusting for potential confounders. Failing to stratify by race may mask the true estimate of effect in each group. Further studies with larger sample sizes will be needed to corroborate these findings. Understanding whether there are differences in risk of excess fetal growth, which vary by race, may influence clinical screening and treatment of pregnant women.

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