High gestational weight gain does not improve birth weight in a cohort of African American adolescents\textsuperscript{1,2}

Jennifer Notkin Nielsen, Kimberly O’Brien, Frank R Witter, Shih-Chen Chang, Jeri Mancini, Maureen Schulman Nathanson, and Laura E Caulfield

**ABSTRACT**

**Background:** Because pregnant African American women and teens are at risk of low birth weight, they are frequently counseled to strive for gestational weight gains at the upper limits of the Institute of Medicine’s recommended ranges.

**Objective:** The objective was to examine whether such weight gains improve birth outcomes in a cohort of disadvantaged African American adolescents of low (<19.8), average (\(\geq 19.8\) to \(\leq 26.0\)), or high (>26) prepregnancy body mass index (BMI; in kg/m\(^2\)).

**Design:** Data were extracted from the medical charts of 1120 African American adolescents who received prenatal care at an inner-city maternity clinic between 1990 and 2000 and analyzed by using analysis of covariance and multivariate regression methods.

**Results:** Data were available for 815 adolescents, 711 of whom delivered at term (\(\geq 37\) wk). Fifty-eight percent (\(n = 409\)) of all term deliveries and 74\% of the high-BMI adolescents (\(n = 126\)) had gains in the upper half of or above the recommended ranges. For all BMI groups, the most significant differences in birth outcomes were found in comparisons of teens who gained below the recommended ranges with those who gained in the upper half of the recommendation range. Further gains were not clearly beneficial, particularly for infants of high-BMI mothers.

**Conclusions:** African American adolescents entering pregnancy underweight or at average weight should be counseled to gain within the recommended ranges, whereas overweight adolescents need support to avoid excessive gestational weight gain. Such advice would be prudent in light of the known associations between obesity and the increased likelihood of chronic diseases. *Am J Clin Nutr* 2006;84:183–9.

**KEY WORDS** Obesity, body mass index, disadvantaged African American adolescents, pregnancy, birth outcomes

**INTRODUCTION**

Pregnant adolescents in the United States are at high risk of adverse birth outcomes, including preterm delivery, low birth weight, and increased perinatal mortality (1). These elevated risks are thought to be due in part to the greater prevalence of such biological risk factors as low prepregnancy weight, the heightened nutritional demands of growth, and the structural and hormonal consequences of physiologic immaturity (2). The risks are also due to socioeconomic factors: adolescent mothers are more often poor, are more often members of racial minorities, have lower educational levels, and receive suboptimal prenatal care (3, 4).

Appropriate nutrient intake and weight gain during pregnancy are considered 2 of the most important modifiable behaviors for improved maternal and infant outcomes (5). In its 1990 report, the Institute of Medicine (IOM) suggested that because of their higher risk of lower birth weight for a given weight gain, young adolescents and African American women should be advised to gain at the upper limits of the IOM’s recommended weight gain ranges for women of low and average prepregnancy body mass index (BMI: weight in kg/height squared in m) (5). However, adolescents have also been shown to be at increased risk of excessive gestational weight gain (2, 6, 7), and African American women have been found to have an increased risk of postpartum weight retention (8, 9) and overweight and obesity (10, 11). For African American women in particular, there is increasing evidence that higher weight gains during pregnancy do not improve infant outcomes and instead may elevate the mothers’ long-term risk of chronic disease (12, 13). In 1997 an expert panel proposed an update of the 1990 IOM recommendations, suggesting that adolescents and African American adults be counseled to stay within the IOM-recommended BMI-specific weight gain ranges (14). Further research on the relation between observed weight gain and birth outcomes in African American adolescents is needed to provide a more solid basis for recommendations about optimal weight gain. The purpose of this study was to evaluate associations between levels of gestational weight gain and birth outcomes in a large sample of African American adolescents who delivered singleton infants in Baltimore between 1990 and 2000.

**SUBJECTS AND METHODS**

**Subject characteristics**

The data set used for this analysis was compiled from a retrospective medical chart review of all adolescents aged \(\leq 17\) y at conception who received prenatal care at the Maternity Center East clinic. This inner-city clinic was affiliated with the Johns Hopkins Hospital (FRW, JM, and LEC), the Johns Hopkins School of Medicine, Department of Obstetrics and Gynecology (FRW), Baltimore, MD.  

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Hopkins Hospital and served a predominantly disadvantaged African American community. Methods used to extract the medical data have been described elsewhere (15). Combined prepregnancy, weight gain, and birth weight measures were available for 815 (73%) of the 1120 African American pregnancies in the database. Examination showed no significant differences in maternal age, height, parity, smoking, or incidence of preeclampsia between subjects with and without birth weight or weight gain data (data not shown). Data on the characteristics of this population and on relations between hematologic status and birth outcomes, diet, and fetal growth were previously reported (15–17). The study was approved by the Joint Committee of Clinical Investigation at the Johns Hopkins Hospital.

Weight gain determinations

Prepregnancy BMI was calculated by using measured height and self-reported prepregnancy weight. Although the tendency for overweight subjects to underreport weight and for underweight subjects to overreport weight may introduce bias, previous research suggests that self-reported weights correlate well with actual weight among adults (18) and among teens (19). In these populations the correlation between reported prepregnancy weight and the first measured weight was 0.93; however, a detailed inspection of our data set showed that approximately 7% of adolescents had large differences between the recalled prepregnancy weight and a first measured weight in the first trimester (gains of ±1 kg/wk). The data were therefore adjusted according to the following rules: 1) accept reported prepregnancy weight if the resulting rate of gain was <1 kg/wk during the first trimester; otherwise 2) extrapolate prepregnancy weight if 2 weight gain measures were recorded before 15 wk gestation, from which a first trimester rate of gain could be estimated; 3) replace reported prepregnancy weight with the first measured weight if a measure was recorded by 8 wk gestation but the second measure was recorded after 15 wk; 4) drop observation if the rate of gain was implausible (≥1 kg/wk) and the correction was not feasible.

Subjects were then classified according to the adult references used by the IOM into 4 categories: underweight (BMI <19.8), average weight (BMI =19.8–26.0), overweight (BMI =26.1–29.0), and obese (BMI >29). Because few overweight and obese adolescents delivered small-for-gestational-age infants (n = 12 and n = 14, respectively), and because weight gain recommendations are similar for these 2 groups, the data for these 2 groups were combined for the analysis. In addition, a preliminary analysis indicated that differences in total weight gain and birth weight between these 2 groups were not statistically significant.

The subjects were weighed at each prenatal visit in street clothes and no shoes following standard clinical practice, and total weight gain was calculated as the difference between the final recorded weight within 4 wk of delivery and the prepregnancy weight; 86% of these final weight measures were made within 2 wk of delivery. The number of weeks between the final weight measure and delivery was included in all multivariate analyses. In addition to being examined as a continuous variable, total weight gain at term (≥37 wk) was examined in 4 categories: below the IOM recommendation for BMI, in the lower half of the recommended range (12.5–15.2 for low-, 11.5–13.8 for average-, and 7.0–9.2 kg for high-BMI adolescents), in the upper half of the recommended range (15.3–18 kg for low-, 13.9–16 kg for average-, and 9.3–11.5 kg for high-BMI adolescents), and above the recommendation for BMI. Date of last menstrual period was estimated on the basis of a best obstetrical estimate algorithm using all available data (self-reported last menstrual period, physical examination, and earliest available ultrasound), and length of gestation was calculated as the distance between birth and last menstrual period (15).

Infant birth weight classification and outcome variables

The outcome variables examined included average birth weight and small-for-gestational-age (SGA) size, which was defined as birth weight less than the 10th percentile for gestational age according to a national sex-specific reference for fetal growth based on 1991 natality data (20). SGA birth weight was selected as an outcome variable rather than low birth weight because it adjusts for duration of pregnancy. Large-for-gestational-age (LGA) size according to the same national reference was also examined, but the incidence was too low (2%) to allow for multivariate analysis. Birth weight at term was categorized as suboptimal (<3000 g), optimal (3000–4000 g), and above optimal (>4000 g) on the basis of previous research findings that adverse outcomes are minimized for infants of African American adult and adolescent mothers when birth weights range between 3000 and 4000 g (21).

Other variables in the data set were examined for their association with these outcomes and with gestational weight gain on the basis of findings previously reported in the literature. These variables included young maternal chronological age (<15 y at infant birth), low gynecologic age (≤2 y since the self-reported date of the onset of menses), parity (0 versus ≥1), height, self-reported history of smoking or drug use (any versus none), medical diagnosis of preeclampsia (blood pressure >140/90 mm Hg accompanied by abnormally high urinary protein and symptoms of edema), health insurance status (private, Medicare, or none), iron status (results of hemoglobin and hematocrit screens, typically conducted at entry into prenatal care and at ≥28 wk gestation), gynecologic infections diagnosed at any time during pregnancy (including chlamydia, gonorrhea, bacterial vaginosis, vaginal infections, and urinary tract infections), adequacy of prenatal care as measured by the Kotelchuck index (based on timing of entry, total number of prenatal visits, and gestational age at delivery) (22), and infant sex.

Statistical analyses

Descriptive analyses included visual examination of distributions, means, and SDs for continuous variables and frequency distributions for categorical variables. Chi-square analysis was applied to test relations between pairs of categorical variables and one-way analysis of variance to test for significant relations between categorical and continuous variables. Significance for bivariate relations was set at P < 0.05. Analysis of covariance (ANCOVA) was used to examine differences in mean birth weight by prenatal weight-gain category (below, in the lower half of, in the upper half of, and above recommended ranges) with adjustment for variables that proved significant in the bivariate analyses and remained significant in the ANCOVA equation. Logistic regression models were developed to examine the effect of weight gain (as a continuous and as indicator variables for the 4 weight-gain categories) on the risk of being born SGA and suboptimal birth weight (<3000 g) after control for covariates and potential confounding factors. Linear regression models
were used to test these effects on birth weight. Associations with SGA and suboptimal and mean birth weights were examined for the group as a whole and stratified by prepregnancy BMI. Because each BMI stratum included a wide range of BMI values, BMI was also included in the multivariate analyses as a continuous variable. All variables for which there was a significant difference for any BMI group or which are known confounders of the relation between weight gain and birth weight were tested in multivariate models. Significance for retention in the multivariate models was defined as \( P < 0.05 \) (ANOVA with Tukey’s multiple comparisons test).

\( i \) IOM, Institute of Medicine. Means in a row with different superscript letters are significantly different, \( P < 0.02 \) (ANOVA with Tukey’s multiple comparisons test).

\( j \) Totals vary because of missing values for some variables.

\( k \) Group differences were significant, \( P < 0.02 \) (chi-square test).

\( l \) Per the Kotelchuck index (22).

\( m \) Defined as \( < 2 \) y at adjusted last menstrual period.

\( n \) Restricted to term births (\( \geq 37 \) wk).

\( o \) Significant interaction between BMI and weight gain, \( P \leq 0.05 \).

\( p \) Low BMI: 12.5–15.2 kg; average BMI: 11.5–13.8 kg; high BMI: 7–9.2 kg.

\( q \) Low BMI: 15.3–18 kg; average BMI: 13.9–16 kg; high BMI: 9.3–11.5 kg.

likely to be older (\( P = 0.02 \)) and multiparous (\( P < 0.01 \)). Overweight adolescents were less likely to undergo weight gain and about twice as likely to overgain weight (\( P < 0.001 \)), similar to the patterns found in adults (23). However, unlike many adult African American populations (14), our teens were more likely to overgain than to undergo weight gain.

Mean (\( \pm \)SD) birth weight in this population was 3062 ± 647 g, and 37% of the newborns had suboptimal birth weights (\(< 3000 \) g) (Table 2). The incidence of SGA birth weight (16%) was elevated and of LGA size (2%) was low compared with the incidence in adult African Americans from the same community (12). Risk of SGA and suboptimal birth weight were significantly and negatively associated with prepregnancy BMI (\( P < 0.02 \) and \( P < 0.001 \), respectively), gestational weight gain (\( P < 0.001 \) for both), and maternal height (\( P = 0.03 \) for both). The rate of smoking was low in this cohort; nevertheless, it was significantly associated with suboptimal birth weight (\( P = 0.05 \)). Preclampsia more frequently coincided with SGA birth weight (\( P < 0.01 \)) but not with suboptimal birth weight (\( P = 0.08 \)).

The actual mean birth weights of infants born at term (\( \geq 37 \) wk) to mothers gaining below, within the lower or upper half, or above the BMI-specific recommended weight gain ranges and birth weights adjusted for potentially confounding factors are shown in Table 3. Also presented are the proportions of infants in each weight-gain category that were of suboptimal birth weight.

### Results

The distribution of selected anthropometric and sociodemographic variables in the group as a whole, and stratified by prepregnancy BMI, is presented in Table 1. Underweight adolescents were more likely to be taller (\( P < 0.01 \)) and of low gynecologic age (\( P < 0.001 \)); overweight adolescents were more

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>(&lt; 19.8)</th>
<th>19.8–26.0</th>
<th>(&gt;26.0)</th>
<th>Mean (range) for group</th>
<th>No. of subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects [n (%)]</td>
<td>193 (23.7)</td>
<td>431 (52.9)</td>
<td>191 (23.4)</td>
<td>---</td>
<td>815</td>
</tr>
<tr>
<td>Primiparous (%)</td>
<td>83.9</td>
<td>85.2</td>
<td>74.9</td>
<td>82.5</td>
<td>815</td>
</tr>
<tr>
<td>Private insurance (%)</td>
<td>11.9</td>
<td>10.8</td>
<td>9.5</td>
<td>10.8</td>
<td>809</td>
</tr>
<tr>
<td>Medical assistance (%)</td>
<td>44.0</td>
<td>46.6</td>
<td>56.6</td>
<td>48.3</td>
<td>809</td>
</tr>
<tr>
<td>Uninsured (%)</td>
<td>44.0</td>
<td>42.6</td>
<td>33.9</td>
<td>40.9</td>
<td>809</td>
</tr>
<tr>
<td>Inadequate prenatal care (%)</td>
<td>39.3</td>
<td>38.1</td>
<td>25.5</td>
<td>35.4</td>
<td>810</td>
</tr>
<tr>
<td>Height (in)</td>
<td>64.2 ± 2.7</td>
<td>63.6 ± 2.8</td>
<td>63.9 ± 3.0</td>
<td>(49.0–73.0)</td>
<td>815</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>18.3 ± 1.1</td>
<td>22.4 ± 1.6</td>
<td>30.9 ± 4.6</td>
<td>(14.8–49.0)</td>
<td>815</td>
</tr>
<tr>
<td>Mother’s age at infant birth (y)</td>
<td>16.9 ± 1.2</td>
<td>16.8 ± 1.1</td>
<td>17.0 ± 1.1</td>
<td>(12.9–18.8)</td>
<td>815</td>
</tr>
<tr>
<td>Low gynecologic age (%)</td>
<td>14.5</td>
<td>5.7</td>
<td>6.1</td>
<td>7.9</td>
<td>697</td>
</tr>
<tr>
<td>Gestational weight gain (%)</td>
<td>30.3</td>
<td>31.3</td>
<td>16.5</td>
<td>27.6</td>
<td>711</td>
</tr>
<tr>
<td>&lt; IOM recommendation</td>
<td>18.1</td>
<td>16.1</td>
<td>9.4</td>
<td>14.9</td>
<td>711</td>
</tr>
<tr>
<td>Lower half of IOM recommendation</td>
<td>21.9</td>
<td>17.6</td>
<td>10.6</td>
<td>16.9</td>
<td>711</td>
</tr>
<tr>
<td>Upper half of IOM recommendation</td>
<td>29.7</td>
<td>35.0</td>
<td>63.5</td>
<td>40.6</td>
<td>711</td>
</tr>
<tr>
<td>&gt; IOM recommendation</td>
<td>14.8 ± 5.8</td>
<td>14.3 ± 6.3</td>
<td>14.4 ± 8.9</td>
<td>14.5 ± 6.9</td>
<td>711</td>
</tr>
<tr>
<td>Total weight gain within 4 wk of delivery (kg)</td>
<td>4.2–43.1</td>
<td>-1.4 to 40.9</td>
<td>-10.4 to 41.3</td>
<td>(-10.4 to 43.1)</td>
<td>711</td>
</tr>
<tr>
<td>Range of total weight gain (kg)</td>
<td>11.4</td>
<td>9.7</td>
<td>10.5</td>
<td>10.3</td>
<td>815</td>
</tr>
<tr>
<td>Smokers (%)</td>
<td>7 (3.6)</td>
<td>26 (6.0)</td>
<td>15 (7.9)</td>
<td>48 (5.9)</td>
<td>815</td>
</tr>
</tbody>
</table>

1 IOM, Institute of Medicine. Means in a row with different superscript letters are significantly different, \( P < 0.02 \) (ANOVA with Tukey’s multiple comparisons test).

2 Totals vary because of missing values for some variables.

3 Group differences were significant, \( P < 0.02 \) (chi-square test).

4 Per the Kotelchuck index (22).

5 \( \pm \) SD (all such values).

6 Defined as \( < 2 \) y at adjusted last menstrual period.

7 Restricted to term births (\( \geq 37 \) wk).

8 Significant interaction between BMI and weight gain, \( P \leq 0.05 \).

9 Low BMI: 12.5–15.2 kg; average BMI: 11.5–13.8 kg; high BMI: 7–9.2 kg.

10 Low BMI: 15.3–18 kg; average BMI: 13.9–16 kg; high BMI: 9.3–11.5 kg.
TABLE 3

Unadjusted birth weight outcomes for African American adolescents by prepregnancy BMI (in kg/m²)¹

<table>
<thead>
<tr>
<th>BMI</th>
<th>&lt; 19.8 (n = 193)</th>
<th>19.8–26.0 (n = 431)</th>
<th>&gt; 26.0 (n = 191)</th>
<th>Overall value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of pregnancy (wk)</td>
<td>38.4 ± 2.8²</td>
<td>38.9 ± 3.1</td>
<td>39.1 ± 3.1</td>
<td>38.8 ± 3.0</td>
</tr>
<tr>
<td>Birth weight (g)</td>
<td>2899 ± 595</td>
<td>3083 ± 645⁴</td>
<td>3181 ± 673⁴</td>
<td>3062 ± 647</td>
</tr>
<tr>
<td>Size-for-gestational-age (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>22.3 (43)</td>
<td>15.6 (67)</td>
<td>11.5 (22)</td>
<td>16.2 (132)</td>
</tr>
<tr>
<td>Average</td>
<td>77.2 (149)</td>
<td>82.1 (354)</td>
<td>85.4 (163)</td>
<td>81.7 (666)</td>
</tr>
<tr>
<td>Large</td>
<td>0.5 (1)</td>
<td>2.3 (10)</td>
<td>3.1 (6)</td>
<td>2.1 (17)</td>
</tr>
<tr>
<td>Birth weight category</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suboptimal, &lt;3000 g (%)</td>
<td>50.8 (98)</td>
<td>33.6 (145)</td>
<td>29.3 (56)</td>
<td>36.7 (299)</td>
</tr>
<tr>
<td>Optimal, 3000–4000 g (%)</td>
<td>48.2 (93)</td>
<td>62.9 (271)</td>
<td>66.5 (127)</td>
<td>60.3 (491)</td>
</tr>
<tr>
<td>Above optimal, &gt;4000 g (%)</td>
<td>1.0 (2)</td>
<td>3.5 (15)</td>
<td>4.2 (8)</td>
<td>3.1 (25)</td>
</tr>
</tbody>
</table>

¹ n in parentheses.
² Significant interactions between BMI and weight gain for birth weight and suboptimal birth weight outcomes.
³ ± SD (all such values).
⁴ Significantly different from BMI < 19.8, P < 0.005 (ANOVA with Tukey’s multiple comparisons test).
⁵ Group differences were significant, P < 0.01 (chi-square test).

weight. In general, the most biologically and statistically significant reductions in birth weight were found in comparisons of gains below the recommended range with those in the lower half of the recommended range. The significance of further improvements in birth weight from gains in the upper half of the recommended ranges was inconsistent; the data adjusted for confounders suggested biologically modest additional increases in birth weight, with the highest increases (88.4 g) seen in the average-BMI group. Further increases in birth weight were achieved from weight gains above the recommended ranges, but the mean gestational weight gain in this category for all 3 BMI groups was > 20 kg.

The incidence of SGA and suboptimal birth weight in mothers who gained less than the recommended range for their BMI compared with those who gained within or above their recommended ranges were significantly higher in the low-BMI group (P < 0.0001) and average-BMI (P < 0.01) groups but not in the high-BMI group (P > 0.30), although it should be noted that only 16.5% of these high-BMI teens gained below the recommended range. Differences in the rates of these outcomes between those who gained in the lower half and those who gained in the upper half of the recommended ranges were also inconsistent; however, the number of subjects in some categories was relatively small. For example, in the high-BMI teens, the incidence of SGA birth weight did not differ significantly between those who gained in the lower half of the recommended range and those who gained in the upper half of the recommended range, whereas the incidence of suboptimal birth weight increased in low-BMI

TABLE 3

Actual and adjusted birth weights (g) for term deliveries of African American adolescents (n = 705) by low, average, and high prepregnancy BMI (in kg/m²) and gestational weight gain category⁴

<table>
<thead>
<tr>
<th>Prepregnancy BMI and birth weight²</th>
<th>&lt; IOM recommendation</th>
<th>Lower half of IOM recommendation</th>
<th>Upper half of IOM recommendation</th>
<th>&gt; IOM recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (&lt;19.8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td>2852 ± 391 (47)ᵃ</td>
<td>3115 ± 425 (28)ᵇ</td>
<td>3143 ± 360 (34)ᵇ</td>
<td>3264 ± 376 (46)ᵇ</td>
</tr>
<tr>
<td>Adjusted⁴</td>
<td>2986 ± 94 (47)ᵃ</td>
<td>3167 ± 81 (28)ᵇ</td>
<td>3198 ± 103 (33)ᵇ</td>
<td>3277 ± 79 (45)ᵇ</td>
</tr>
<tr>
<td>&lt;3000 g (%)</td>
<td>66ᵃ</td>
<td>39ᵇ</td>
<td>32ᵇ</td>
<td>20ᵇ</td>
</tr>
<tr>
<td>Average (19.8–26.0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td>3089 ± 355 (121)ᵃ</td>
<td>3186 ± 423 (62)ᵇ</td>
<td>3297 ± 400 (68)ᵇ</td>
<td>3330 ± 440 (135)ᵇ</td>
</tr>
<tr>
<td>Adjusted⁴</td>
<td>3018 ± 82 (117)ᵃ</td>
<td>3166 ± 86 (62)ᵇ</td>
<td>3255 ± 83 (67)ᶜ</td>
<td>3318 ± 86 (134)ᵈ</td>
</tr>
<tr>
<td>&lt;3000 g (%)</td>
<td>39ᵃ</td>
<td>32ᵇ</td>
<td>21ᵇ</td>
<td>17ᵇ</td>
</tr>
<tr>
<td>High (&gt;26.0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td>3037 ± 389 (28)ᵃ</td>
<td>3366 ± 303 (16)ᵇ</td>
<td>3355 ± 345 (18)ᵇ</td>
<td>3412 ± 442 (108)ᵇ</td>
</tr>
<tr>
<td>Adjusted⁴</td>
<td>3127 ± 85 (28)ᵃ</td>
<td>3351 ± 67 (16)ᶜ</td>
<td>3384 ± 80 (17)ᵇ</td>
<td>3434 ± 120 (106)ᵇ</td>
</tr>
<tr>
<td>&lt;3000 g (%)</td>
<td>36</td>
<td>15</td>
<td>22</td>
<td>19</td>
</tr>
</tbody>
</table>

¹ n = 705. IOM, Institute of Medicine. Means in a row with different superscript letters are significantly different, P < 0.02 (ANOVA with Tukey’s multiple comparisons test).
² Significant interaction between BMI and weight gain for both actual and suboptimal birth weight outcomes.
³ All values are ± SD; n in parentheses.
⁴ ANCOVA analysis including adjustment for smoking (yes or no), time between last weight measure and delivery, maternal BMI, height, parity, preeclampsia, and infant sex.
The vast majority of the heavier teens (64%) gained above the IOM recommended range. The additional benefits from weight gain were only seen in those who gained above their recommended range (data not shown).

For the group as a whole, the risk of SGA birth weight after control for potentially confounding variables was found to be significant (Table 4), which indicated that the largest benefits were achieved with gains from below to within the lower half of the recommended ranges. Regression analyses of birth weight outcomes estimated separately by BMI category suggested that the effect on birth weight of increasing gains from below to within the recommended range was most significant for low- and for high-BMI teens (birth weight increased by $\approx 260$ g in both groups).

### DISCUSSION

In this cohort of pregnant African American adolescents, birth weight outcomes markedly improved in teens in all BMI groups when weight gain increased from below to within the lower half of the IOM recommended range. The additional benefits from gains in the upper half of the recommended range were modest or equivocal. Additional weight gain conferred the greatest benefit on infants of low- and average-BMI teens and had the least effect on overweight teens, most of whom had infants of healthy birth weight regardless of the level of weight gain. Furthermore, there appeared to be a tendency for higher weight gains to be associated with a higher proportion of adverse outcomes in this BMI group.

The vast majority of the heavier teens (64%) gained above the recommended range, which likely increased their risk of obesity and its associated chronic diseases. Moreover, whereas 23% of the study sample entered pregnancy overweight ($n = 191$), an additional 18.5% ($n = 151$) entered pregnancy with low or average BMIs but gained $>40$ kg; 22.5% ($n = 183$) entered pregnancy with low or average BMIs and gained more than the IOM recommended range and therefore were at increased risk of overweight after pregnancy. These risks may be considerable in light of research indicating that African American women have elevated rates of postpartum weight retention (9, 24).

These findings are consistent with a number of other recent studies that recommend a reconsideration of the IOM weight recommendations for adolescents and African Americans (12, 14, 25, 26). A study by Schieve et al (25), which examined a much larger population of African American adult women ($n = 33,101$), reported adjusted birth weights that were slightly higher than ours and a considerably lower incidence of low birth weight but very similar trends. With greater power than the current study, Schieve et al also found that increases in gestational gains had a somewhat contradictory effect on the birth weight outcomes examined (mean birth weight and risk of low birth weight) in African Americans and concluded that gains in the upper half of the recommended range were of questionable benefit. Hickey et al (26) came to similar conclusions after examining a cohort of 2,219 African American adults. Another study, which examined adult gravidas in Baltimore (12), calculated that among black women of average and high BMI, the gains required to reduce their risk of SGA birth weight to levels observed among white women would be excessive (25 kg for women of average prepregnancy BMI) and thus ill-advised. All 3 studies, as well as an expert panel convened in 1996 by the Federal Maternal and Child Health Bureau (14), cited the lack of clear evidence of benefits and the increased risk of postpartum weight retention and obesity among black women as reason to be cautious about recommending higher gestational weight gains. Our study was the first to examine the effect of weight gain below, within, and above the IOM recommendations in a sample of adolescents.

The African American teens in our study showed less tendency to undergain than did African American women in other studies (14, 26), but these findings were consistent with studies of adolescents (2, 14). In our study population, 29% of the adolescents who delivered at term gained excessive amounts of weight ($>18$ kg, or gains above the highest upper limit recommended by the IOM), a similar proportion to that reported for other adolescent cohorts (2, 6). Despite their higher weight gains, the median birth weight of 3,151 g for this cohort was below the 1991 reference of 3,495 g for infants of similar gestational age (20), below the reference birth weight for African Americans of 3,330 g (27), but similar to the birth weight reported for other adolescents (28). Thus, as did other researchers who studied pregnancy during adolescence, we observed that higher maternal weight gains did not necessarily contribute to higher infant birth weights.

The 1990 IOM report noted that the limited data available suggest that young adolescents ($<2$ y postmenarche) may give birth to smaller infants for a given weight gain than do older women (5). We found this to be the case in our African American cohort. In the subjects who delivered at term for whom we had data on age at menarche ($n = 607$), those of low gynecologic age had infants with significantly lower mean birth weights than did those of higher gynecologic age ($3079 \pm 347$ compared with $3237 \pm 437$ g; $P = 0.02$), despite similar mean weight gains ($15.1 \pm 7.4$ compared with $14.8 \pm 7.1$ kg; $P > 0.10$). This reduction in birth weight remained significant after control for smoking, prepregnancy BMI, parity, preeclampsia, gestation duration, and weight gain. However, total gestational gain and birth weight of infants born to mothers of young chronologic age ($<15$ y at infant birth) who delivered at term were not significantly different from those of older mothers ($16.1 \pm 6.5$ compared with $14.8 \pm 7.1$ kg; $P > 0.20$) and (3269 $\pm 464$ compared with $3218 \pm 427$ g; $P > 0.40$), respectively. The incidence of SGA and suboptimal birth weight did not differ significantly by either gynecologic or chronologic age.
Our adolescents were recruited from a disadvantaged community. According to the 2000 census, the median income in their neighborhood was <$27,000; 30.8% of the households with children aged <18 y were below the poverty level, 96.4% of the population was African American, and violent crime rates were high (29). A growing body of literature shows that neighborhood poverty and violence, racial discrimination, and associated psychological stress are associated with the risk of poor birth outcomes, particularly among African Americans (30, 31). It is possible that such adversity contributed, in ways that we did not measure, to the elevated rates of growth restriction and suboptimal birth weight observed.

Some limitations to our study should be considered when interpreting these results. Prepregnancy weight was self-reported, and we do not know whether the adolescents were willing and able to report their prepregnancy weight accurately. We adjusted 6.6% of the reported weights, and it is possible that additional inaccurate weights were undetected, which could have led to misclassification by both prepregnancy BMI and weight-gain category. Our adjustments tended to increase estimates of prepregnancy weight and decrease estimates of gestational weight gain but did not affect our overall findings or conclusions. Missing data on prepregnancy weight, weight gain, or birth weight reduced our power to detect differences in these variables when subjects were stratified by BMI and weight-gain category.

Our data did not allow us to determine which adolescents may have gained fat, lean mass, and height as a necessary part of their own maturation in addition to the gain supporting fetal growth. Also, we could not identify those adolescents that possibly retained excess maternal weight postpartum. Longitudinal research suggests that most female teens continue to grow in stature to age 18 y and beyond (32) and to gain weight as part of this growth until age 18 y (33), although there is evidence that black girls may grow taller and heavier (34). In our cohort we noted no biologically or statistically significant differences in gestational weight gain among those with early (<11 y) or late (≥12.9 y) onset of menses, which are potential markers of different rates of growth. It is noteworthy that teens who had given birth previously were significantly more likely to be overweight than were primiparas. Moreover, preliminary evidence from our research suggests that dietary quality among these teens is low (16) and, thus, poor eating habits may contribute to inappropriate weight gain. In conclusion, our data suggest no clear benefit from gestational weight gains at the upper limits of the IOM recommendations, particularly in teens who enter pregnancy overweight. The long-term costs to these mothers of additional weight gain may overshadow the modest improvements in birth weight. Other risk factors—such as poverty, racial discrimination, or dietary quality—may play a more important role than do higher levels of weight gain in optimizing birth weight in this population.

JNN was responsible for the statistical analyses and manuscript preparation with the guidance of KOO and LEC. S-CC compiled the original data set, conducted extensive analyses of the data, and reviewed these analyses for consistency. JM and MSN provided prenatal care and nutrition counseling, respectively, to the subjects included in the data set and were responsible for much of the data entered into the medical charts. FRW reviewed all medical aspects of the analyses, including calculations of adjusted last menstrual period, adjustments of prepregnancy weights, and interpreting birth weight differences, and assisted with manuscript preparation and interpretation.

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