Pregnancy and Lactation Hinder Growth
and Nutritional Status of Adolescent Girls
in Rural Bangladesh$^{1,2}$

Jee H. Rah,$^3$ Parul Christian,$^4$ Abu Ahmed Shamim,$^4$ Ummeh T. Arju,$^4$ Alain B. Labrique,$^3$
and Mahbubur Rashid$^4$

$^3$Center for Human Nutrition, Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD 21205 and $^4$JiVitA Maternal and Child Research Project, 5400 Rangpur, Bangladesh

Abstract

Adolescent pregnancy is associated with adverse birth outcomes. Less is known about its influence on maternal growth and nutritional status. We determined how pregnancy and lactation during adolescence affects postmenarcheal linear and ponderal growth and body composition of 12–19 y olds in rural Bangladesh. In a prospective cohort study, anthropometric measurements were taken among primigravidae ($n=229$) in the early first trimester of pregnancy and at 6 mo postpartum. Randomly selected never-pregnant adolescents ($n=458$) of the same age and time since menarche were measured within 1 wk of these assessments. Annual changes in anthropometric measurements were compared between the 2 groups adjusting for confounders using mixed effects regression models. The mean ± SD age and age at menarche of adolescents were 16.3 ± 1.6 y and 12.7 ± 1.2 y, respectively. Unlike pregnant girls who did not grow in height ($-0.09 ± 0.08 $ cm/y), never-pregnant girls increased in stature by $0.35 ± 0.05$ cm/y. The adjusted mean difference between the 2 groups was $0.43 ± 0.1$ cm ($P<0.001$). Similarly, whereas never-pregnant girls gained BMI, mid-upper arm circumference, and percent body fat, pregnant girls declined in every measurement by 6 mo postpartum, resulting in adjusted mean ± SD differences in annual changes of $0.62 ± 0.11$ kg/m$^2$, $0.89 ± 0.12$ cm, and $1.54 ± 0.255\%$, respectively ($\forall P<0.001$). Differences in changes in all anthropometric measurements except height were greater among adolescents whose first pregnancy occurred <24 mo vs. ≥24 mo since menarche (BMI, $-1.40 ± 0.18$ vs. $-0.60 ± 0.11$ kg/m$^2$; all interaction terms, $P<0.05$). Pregnancy and lactation during adolescence ceased linear growth and resulted in weight loss and depletion of fat and lean body mass of young girls. J. Nutr. 138: 1505–1511, 2008.

Introduction

Adolescent pregnancy is a worldwide concern, particularly in areas of poverty and social disadvantage. Nearly two-thirds of women in Sub-Saharan Africa and a few countries in South Asia have their first child before the age of 20 y (1). Pregnancy during adolescence has been shown to increase the risk of adverse birth outcomes, poor fetal growth, and infant and maternal health and mortality (2,3). Less is known about how pregnancy and lactation affect the growth and nutritional status of adolescent girls.

Adolescence is a period of rapid growth and development. Approximately 50% of adult body weight and 15% of final adult height is attained during adolescence, along with changes in body shape and composition (4,5). In South Asian countries such as Bangladesh, chronic undernutrition can delay physical maturation and extend the adolescent growth period beyond 20 y of age, coinciding with the age of first pregnancy (6). Adolescents in developing countries exhibit poor growth and nutritional status. A study of rural Bangladeshi teenagers showed that stunting (height-for-age <3rd percentile of the National Center for Health Statistics/WHO reference) and thinness (BMI-for-age <5th percentile of the National Center for Health Statistics/WHO reference) were prevalent among 48 and 60% of adolescent girls, respectively (7). Other than genetic factors, adverse environmental conditions such as low socioeconomic status (SES) and poor quality diets explain the suboptimal growth of teenagers (8,9).

Conventionally, it has been accepted that growth is largely completed by the time adolescents become pregnant, because preg-
nancy occurs subsequent to menarche, when growth rate drops to a nadir (10,11). However, in a recent study conducted in Camden, NJ, it was demonstrated that a large proportion of pregnant adolescents were still growing (using knee height changes as a measure of growth), reflecting continuing growth in stature during and following pregnancy (12). This finding may be particularly relevant to malnourished adolescent girls in developing countries whose physical growth period is extended and in whom pregnancy occurs at an early age.

A large proportion of adolescents in developing countries enters pregnancy with a poor nutritional status and is likely to have suboptimal dietary intake during pregnancy and lactation (13–15). Consequently, in severely undernourished pregnant adolescents, maternal nutritional depletion and impaired growth of the fetus are likely to occur concurrently due to the competition for nutrients between the growing teenage mother and the fetus (13).

The present study was conducted to investigate how pregnancy and lactation during adolescence affects postmenarcheal linear and ponderal growth and body composition of young mothers in rural Bangladesh. We hypothesized that annual changes in stature, weight, BMI, lean body mass, and body fat measures among adolescents who experienced a pregnancy and were followed through 6 mo postpartum would be lower compared with annual changes in these anthropometric indicators among never-pregnant adolescents.

Materials and Methods

**Study area and subjects.** We conducted a prospective cohort study in which 2 groups of adolescent girls, 12–19 y old primigravidae and never-pregnant subjects at the same age and time since menarche, were concurrently followed for 1 y. The study was carried out in rural northwestern Bangladesh where a double-masked, randomized, controlled trial was ongoing (2001–2007) to examine the impact of vitamin A and β-carotene supplementation on maternal and infant mortality (the JiVitA trial). The trial area comprised 596 community units, called sectors, in the districts of Gaibandha and Rangpur, encompassing an area of 580 km² with an estimated total population of 650,000. This densely populated (~1000 per km²) study area is typical of rural Bangladesh with respect to SES, health service utilization, childhood malnutrition and morbidity, and reproductive health.

In July 2004, 96 contiguous sectors in the western part of the JiVitA study area were purposively selected for conducting the present study. A census was conducted at the outset in these selected sectors to enumerate all married and unmarried female adolescents. Data on date of birth, month and year of menarche, marital status, and pregnancy history were collected from all enumerated adolescents. The self-reported month and year of birth, checked against the home records of date of birth or the parents, was used to calculate age. Data on menarcheal status was gathered by asking the adolescent the year and month of the onset of menstruation. Help from the mother or other female relatives living in the household was sought. Those who were pregnant at the time of census, had a previous pregnancy, were premenarcheal, or were <12 y or >19 y of age were excluded. A total of 2605 married nulligravid (n = 2220) adolescents aged 12–19 y who had reached menarche were identified. Subsequently, over a period of 1 y, newly married women who were enumerated and registered into the study by the JiVitA project were added to the list of enumerated adolescents if they met the above criteria (n = 419).

Married adolescents were visited once every 5 wk to identify incident pregnancies as part of the JiVitA project. At each of these visits, women who reported being amenstrual in the past 30 d were administered an human chorionic gonadotropin-based urine test to detect pregnancy. As part of the present study, each time an adolescent was ascertained as being pregnant for the first time, 2 never-pregnant adolescents were randomly selected from the pool of enumerated adolescents matched on age (in years) and time since menarche (in months).

Data collection. After obtaining consent, within 1 ± 1.5 wk of pregnancy ascertainment, pregnant adolescents were interviewed at home regarding their dietary intake and physical activity in the preceding week, morbidity in the previous month, and smoking and alcohol consumption. An FFQ was used to determine intake of 30 different food items. Physical activity was assessed by self-reported performance of 15 common work activities. Height, weight, mid-upper arm circumference (MUAC) and triceps (TSF) and subcapsular (SSF) skinfolds were measured during this visit. Interviews and measurements were conducted at a mean ± SD gestational age of 10.1 ± 2.8 wk and at 6 mo postpartum for pregnant adolescents. Never-pregnant adolescents were also assessed within a week of the assessments conducted in their pregnant counterparts. Information on SES was collected at the first interview for both groups. At 3 and 6 mo postpartum, women were asked whether they were breast-feeding and were asked to recall the number of times had they breast-fed in the past 24 h. Timing of initiation of breast-feeding at birth and feeding of prelacteals was determined soon after birth during a home visit to conduct newborn anthropometry.

All interviews and measurements were conducted by 8 trained and standardized female interviewers/anthropometrists. Anthropometric measurements were taken following standard procedures as described by Gibson (16). Height was measured to the nearest 0.1 cm using a Harpenden stadiometer (Shorr Productions) and weight was measured to the nearest 0.1 kg using a digital scale (UNICEF scale S0141015, by SECA). Both TSF and SSF were measured to the nearest 0.2 mm using Holtain calipers and MUAC to the nearest 0.1 cm using a nonstretch locally manufactured insertion tape (JiVitA) based on the Ross nonelastic tape design (Ross Laboratories). All measurements except weight were taken 3 times and the median value for each measurement was used for this analysis.

Standardization for each anthropometric measurement was conducted every 3 mo throughout the data collection period. During the sessions, each female interviewer measured a group of 10–15 women twice with an hour between measurements. Both intra- and interobserver reliability were assessed by calculating the technical error of measurement (TEM) as described by Ulijaszek and Kerr (17). The mean ± SD intra- and interobserver TEM of 8 female interviewers was 0.21 ± 0.03 and 0.25 ± 0.07 cm, respectively, for height; 0.17 ± 0.02 and 0.20 ± 0.05 cm, respectively, for MUAC; 0.52 ± 0.10 and 0.69 ± 0.14 mm, respectively, for TSF; 0.5 ± 0.09 and 0.5 ± 0.08 mm, respectively, for SSF. Throughout the study, the TEM for all of the measurements were maintained at approximately one-half the acceptable intra- and interobserver TEM values suggested by Shorr (18): 0.69 and 0.95 cm for height; 0.33 and 0.43 cm for MUAC; 0.8 and 1.89 mm for TSF; and 1.83 and 1.53 mm for SSF.

Sample size. The sample size was calculated using α = 0.05 and β = 0.2 to detect a difference of ≥0.5 cm in annual height increments between pregnant and never-pregnant adolescents using a SD of an annual change in height of 1.5 cm (19). A 1:2 ratio of pregnant to never-pregnant adolescents was used to ensure at least 1 never-pregnant comparison in each case 1 of the 2 were to become pregnant during the course of the study. This sample size was increased by 35% to account for pregnancy loss and loss to follow-up, resulting in a required (rounded) sample of 220 pregnant and 440 never-pregnant adolescents. A total of 229 pregnant and 456 never-pregnant adolescents was enrolled into the study between April and November 2005.

Although the 5-weekly pregnancy surveillance allowed us to identify most pregnancies early in gestation, some women who later became pregnant were not met at each round and were identified later in gestation. A total of 19 pregnant girls enrolled after 16 wk of gestation were not met at each round and were identified later in pregnancy. As part of the present study, each time an adolescent was ascertained as being pregnant for the first time, 2 never-pregnant adolescents were randomly selected from the pool of enumerated adolescents matched on age (in years) and time since menarche (in months).
annual changes in anthropometric measurements differed by pregnancy status.

Calculations and statistical analyses. BMI was defined as weight (kg)/height$^2$ (m). Upper-arm-muscle and fat areas were derived from MUAC and TSF as described by Frisancho (20) and percent body fat from TSF and SSF [1.33 × (SSF + TSF) − 0.013 × (SSF + TSF)$^2$ − 2.5] as described by Slaughter et al. (21). Stunting and underweight were defined as height-for-age and weight-for-age Z-scores < −2, respectively, using the CDC (22) reference standards in EpiInfo 2005 software. Descriptive statistics were employed to examine the distributions of the full range of variables. We created categorical variables using meaningful cutoffs: dietary intake variables were classified into 6 food groups and dichotomized using a cut-off of ≤3 times/wk; work activities were classified into strenuous vs. light-to-moderate groups and dichotomized using a cutoff of ≥2 activities/d; morbidity variables were grouped and dichotomized into no morbidity and any day of illness in the past 30 d. A wealth index was developed based on dwelling characteristics, land ownership, productive and durable assets, and human capital (S. Gunnsteinsson, A. B. Labrique, K. P. West, Jr, P. Christian, S. Mehra, A. A. Shamin, M. Rashid, J. Katz, and R. Klemm, unpublished data) using principal components analysis (23).

We compared baseline characteristics between pregnant and never-pregnant adolescents using $t$ tests and chi-square tests. The Kruskal-Wallis test was used to compare the means of continuous variables that were not normally distributed, such as TSF and SSF. Changes in height, weight, BMI, and body composition indicators were annualized after being divided by the actual number of days between measurements and tested for significance using paired $t$ tests. Mean annual changes in anthropometric measurements were compared by pregnancy status using $t$ tests.

Changes in anthropometric measurements over time were compared by pregnancy status adjusting for confounders using linear mixed effects regression models (24,25). The mixed effects regression models permit accounting for the within-subject correlation of repeated measurements (in this case, only 2) in estimation of the regression parameters and their standard errors (24). Dependent variables included anthropometric measures; separate models were constructed for height, weight, BMI, MUAC, TSF, SSF, upper-arm muscle and fat area, and percent body fat. Independent variables included time of measurement in years since the baseline visit, pregnancy status, interaction between time and pregnancy status, age, time since menarche, and other potential confounders. Confounding factors included characteristics that differed by pregnancy status at the baseline and 12-mo follow-up and were associated with annual change in each anthropometric measurement in the bivariate analyses ($P < 0.05$). The robust estimates of standard errors were computed. The interaction between time of measurement and pregnancy status reflected the difference in annual change in anthropometric measures between pregnant and never-pregnant adolescents.

We hypothesized that differences in changes in anthropometric measures between pregnant and never-pregnant adolescents would be larger among adolescents with a shorter time since menarche. Thus, a 3-way interaction between time of measurement, pregnancy status, and age since menarche as a dichotomous variable was tested at the 5% significance level. If there was a significant interaction, linear mixed effects regression models were fitted separately for adolescents with time since menarche <24 mo and ≥24 mo. We also tested a 3-way interaction between time of measurement, pregnancy status, and age as a dichotomous variable. All analyses were performed using STATA version 9.0 (Stata Corp). Results are presented as means ± SD and percentages and the significance level throughout was $P < 0.05$.

This study was carried out between July 2004 and December 2006. The study was approved by the Bangladesh Medical Research Council, Dhaka, Bangladesh and the Committee on Human Research at the Bloomberg School of Public Health, Johns Hopkins University, Baltimore, MD.

Results

Of 210 pregnant adolescents who were enrolled within 16 wk of gestation, 162 (77%) who had live births completed the baseline and 12-mo assessments (Fig. 1). Among a total of 456 never-pregnant adolescents who were enrolled, 385 (83%) were measured at the 12-mo follow-up visit (Fig. 1). The girls who did not complete the study due to migration, pregnancy, and refusal were comparable to those who remained in the study by baseline characteristics (data not shown).

The age at the time of entry into the study and age at menarche of the subjects in both groups combined was 16.3 ± 1.6 y and 12.7 ± 1.2 y, respectively. All pregnant and only 9.4% of never-pregnant adolescents were married at the time of interview (Table 1). The height and weight at baseline did not differ between pregnant and never-pregnant adolescents (Table 1). However, TSF, upper-arm fat area, and percent body fat were higher ($P < 0.05$) and BMI and upper-arm muscle area were lower ($P < 0.05$) among pregnant compared with never-pregnant adolescents at baseline (Table 1).

Frequency of food intake did not differ between pregnant and never-pregnant adolescents, but a higher proportion of pregnant than never-pregnant adolescents reported experiencing morbidity symptoms such as painful urination or lower abdominal pain and symptoms of anemia in the month preceding the interview (Table 1). A greater proportion of never-pregnant adolescents came from households with higher SES compared with pregnant adolescents.

All pregnant adolescents (100%) who had live births and whose infants were alive reported breast-feeding at 3 and 6 mo postpartum. Among adolescents who were breast-feeding and reported the frequency of breast-feeding in the past 24 h, the median frequency was 12 at both 3 and 6 mo postpartum.

Pregnant adolescents did not gain height during the follow-up period, whereas never-pregnant adolescents increased their stature by 0.35 ± 0.85 cm/y ($P < 0.001$) (Table 2). Whereas
TABLE 1 Characteristics of pregnant and never-pregnant adolescents at baseline

<table>
<thead>
<tr>
<th></th>
<th>Pregnant adolescents</th>
<th>Nonpregnant adolescents</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>162</td>
<td>385</td>
</tr>
<tr>
<td>Chronological age, y</td>
<td>16.4 ± 1.6</td>
<td>16.3 ± 1.6</td>
</tr>
<tr>
<td>Age at menarche, y</td>
<td>12.6 ± 1.2</td>
<td>12.7 ± 1.2</td>
</tr>
<tr>
<td>Time since menarche, mo</td>
<td>43.4 ± 20</td>
<td>43.0 ± 20</td>
</tr>
<tr>
<td>Married, %</td>
<td>100</td>
<td>94</td>
</tr>
<tr>
<td>Baseline anthropometry</td>
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<td></td>
</tr>
<tr>
<td>Height, cm</td>
<td>149.1 ± 5.4</td>
<td>148.4 ± 5.1</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>43.1 ± 5.0</td>
<td>42.4 ± 5.5</td>
</tr>
<tr>
<td>MUAC, cm</td>
<td>23.4 ± 1.7</td>
<td>23.2 ± 2.0</td>
</tr>
<tr>
<td>TSF, mm</td>
<td>10.8 ± 3.0</td>
<td>11.6 ± 3.5</td>
</tr>
<tr>
<td>SSF, mm</td>
<td>9.5 ± 2.3</td>
<td>9.8 ± 2.7</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>19.3 ± 1.7</td>
<td>19.0 ± 2.0</td>
</tr>
<tr>
<td>Upper-arm-muscle area, cm²</td>
<td>32.2 ± 4.2</td>
<td>30.7 ± 4.5</td>
</tr>
<tr>
<td>Upper-arm-fat area, cm²</td>
<td>11.8 ± 3.8</td>
<td>12.6 ± 4.5</td>
</tr>
<tr>
<td>Body fat, %</td>
<td>18.8 ± 3.6</td>
<td>19.6 ± 0.2</td>
</tr>
<tr>
<td>Stunting, %</td>
<td>58.0</td>
<td>47.0*</td>
</tr>
<tr>
<td>Underweight, %</td>
<td>40.1</td>
<td>40.1</td>
</tr>
<tr>
<td>Past 7-d dietary intake, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meat and eggs</td>
<td>26.7</td>
<td>22.0</td>
</tr>
<tr>
<td>Fish</td>
<td>54.1</td>
<td>52.9</td>
</tr>
<tr>
<td>Milk and dairy</td>
<td>34.6</td>
<td>28.2</td>
</tr>
<tr>
<td>Dark green leafy vegetables</td>
<td>8.0</td>
<td>9.1</td>
</tr>
<tr>
<td>Fruits</td>
<td>35.8</td>
<td>34.7</td>
</tr>
<tr>
<td>Nuts and beans</td>
<td>5.6</td>
<td>5.7</td>
</tr>
<tr>
<td>Past 30-d morbidity, %</td>
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<tr>
<td>Diarrhea or dysentery</td>
<td>8.7</td>
<td>15.6*</td>
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<td>Productive cough or rapid breathing</td>
<td>24.4</td>
<td>24.8</td>
</tr>
<tr>
<td>Painful urination or lower abdominal pain</td>
<td>50.3</td>
<td>31.5*</td>
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<td>Nausea or vomiting</td>
<td>74.5</td>
<td>18.8*</td>
</tr>
<tr>
<td>Hepatitis</td>
<td>12.0</td>
<td>6.3*</td>
</tr>
<tr>
<td>Anemia</td>
<td>50.9</td>
<td>21.0*</td>
</tr>
<tr>
<td>Past 7-d history of activities, %</td>
<td>14.8</td>
<td>13.3</td>
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<tr>
<td>Carried heavy objects (&gt;20 kg)</td>
<td>14.2</td>
<td>11.4</td>
</tr>
<tr>
<td>Husked, ground, or pounded grain</td>
<td>12.4</td>
<td>6.2*</td>
</tr>
<tr>
<td>Chopped loads of firewood</td>
<td>4.9</td>
<td>12.2*</td>
</tr>
<tr>
<td>Carried a child a long distance</td>
<td>98.2</td>
<td>93.0*</td>
</tr>
<tr>
<td>Swept the floor or courtyard</td>
<td>7.4</td>
<td>16.9*</td>
</tr>
<tr>
<td>Washed dishes</td>
<td>96.9</td>
<td>83.1*</td>
</tr>
<tr>
<td>Cared for a child</td>
<td>20.4</td>
<td>34.6*</td>
</tr>
<tr>
<td>Cooked</td>
<td>96.9</td>
<td>66.8*</td>
</tr>
</tbody>
</table>

SES indicators

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
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<tbody>
<tr>
<td>Literate</td>
<td>74.1</td>
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<tr>
<td>Currently enrolled in school</td>
<td>0</td>
</tr>
<tr>
<td>Highest grade completed (&gt;5th grade)</td>
<td>65.4</td>
</tr>
<tr>
<td>Income earning job</td>
<td>25.9</td>
</tr>
<tr>
<td>Religion</td>
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<tr>
<td>Muslim</td>
<td>90.7</td>
</tr>
<tr>
<td>Hindu</td>
<td>8.0</td>
</tr>
<tr>
<td>Other</td>
<td>1.3</td>
</tr>
<tr>
<td>Wealth index (&gt;0.5)</td>
<td>38.3</td>
</tr>
</tbody>
</table>

1 Values are means ± SD or percent. Symbols indicate different from pregnant adolescents, P < 0.05: * Kruskal-Wallis test; t test; # chi-square test.
2 Missing values existed for: weight (n = 1), BMI (n = 1), MUAC (n = 1), TSF (n = 1), SSF (n = 1), upper-arm muscle area (n = 1), upper-arm-fat area (n = 1), % body fat (n = 2), underweight (n = 1), and meat and eggs (n = 4), fish (n = 21), milk and dairy (n = 2), fruits (n = 42), diarrhea and dysentery (n = 2), productive cough (n = 18), painful urination (n = 19), nausea and vomiting (n = 20), hepatitis (n = 7), anemia (n = 1), swept floor (n = 2), washed dishes (n = 1), cared for a child (n = 1).

3 Mean ± SD gestational age for pregnant adolescents at baseline measurement was 10.1 ± 2.8 wk.
4 Stunting and underweight were defined as height-for-age and weight-for-age Z-scores < -2, respectively.
5 Percentage of adolescents who consumed each food group more than 3 times in the past 7 d.
6 Percentage of adolescents who had at least one morbidity symptom at least once in the past 30 d.
7 Percentage of adolescents who had at least 1 clinical symptom of hepatitis, including ash-colored/gray stool, tea-colored urine, liver pain, jaundice, and yellow eyes.
8 Percentage of adolescents who had at least 3 clinical symptoms of anemia in the past 30 d.
9 Percentage of adolescents performing each work activity at least once in the past 7 d.
10 Adolescents with wealth index score >0.5 are from higher SES.
of the same age and time since menarche. Although peak height velocity occurs prior to menarche, linear growth continues during late adolescence and most girls grow 5–7.6 cm after the onset of menarche (4,26). In developing countries, chronic undernutrition can delay puberty and extend the adolescent growth period beyond 20 y of age (6). Using cross-sectional data on height of rural Bangladeshi primigravidae enrolled in the JiVitA study conducted in Mexico City in which pregnant adolescents <18 y of age did not grow in height between the 2nd trimester of pregnancy and 1 mo postpartum, whereas never-pregnant adolescents matched for age, menarche age, BMI, and SES grew 0.94 ± 0.3 cm during the 5-mo period (28). There is evidence from developed countries suggesting that teenagers continue to grow in height during pregnancy (29). In a study from Camden, NJ, Scholl et al. (12,29) noted a tendency for most gravidas to measure slightly less in stature during pregnancy as a result of vertebral compression or weight gain. However, using knee height measurement, which is less susceptible to the shrinkage effects of pregnancy, the study found a significant increase in knee height, reflecting gains in stature among pregnant adolescents (12). In the present study, we measured maternal height not during pregnancy but at 6 mo postpartum when a rebound in maternal height is expected (10). Thus, change in height between

The annual growth rate in ponderal and body composition measures of never-pregnant adolescents was higher among those who were enrolled within a shorter time since menarche (all P < 0.05). Adolescents who had their first pregnancy <24 mo since menarche had to have similar reductions in weight and BMI and slightly higher reductions in percent body fat by 6 mo postpartum compared with those whose first pregnancy occurred >24 mo after the onset of menarche. This implies that the depletion of maternal fat stores during pregnancy and early stages of lactation was more profound among adolescents who became pregnant at an earlier gynecological age.

Our results indicating the cessation of linear growth among pregnant adolescents correspond with the recent findings from a study conducted in Mexico City in which pregnant adolescents <18 y of age did not grow in height between the 2nd trimester of pregnancy and 1 mo postpartum, whereas never-pregnant adolescents matched for age, menarche age, BMI, and SES grew 0.94 ± 0.3 cm during the 5-mo period (28). There is evidence from developed countries suggesting that teenagers continue to grow in height during pregnancy (29). In a study from Camden, NJ, Scholl et al. (12,29) noted a tendency for most gravidas to measure slightly less in stature during pregnancy as a result of vertebral compression or weight gain. However, using knee height measurement, which is less susceptible to the shrinkage effects of pregnancy, the study found a significant increase in knee height, reflecting gains in stature among pregnant adolescents (12). In the present study, we measured maternal height not during pregnancy but at 6 mo postpartum when a rebound in maternal height is expected (10). Thus, change in height between

### TABLE 3

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Pregnant (Adjusted β-coefficient (SE))</th>
<th>Never pregnant (Adjusted β-coefficient (SE))</th>
<th>Differences² P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height, cm</td>
<td>-0.09 (0.08)</td>
<td>0.00</td>
<td>-0.43 (0.10)</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>-0.94 (0.20)</td>
<td>&lt;0.00</td>
<td>-1.48 (0.22)</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>-0.41 (0.09)</td>
<td>&lt;0.00</td>
<td>-0.62 (0.11)</td>
</tr>
<tr>
<td>MUAC, cm</td>
<td>-0.76 (0.10)</td>
<td>&lt;0.00</td>
<td>-0.89 (0.12)</td>
</tr>
<tr>
<td>TSF, mm</td>
<td>-1.69 (0.17)</td>
<td>&lt;0.00</td>
<td>-1.16 (0.30)</td>
</tr>
<tr>
<td>SSF, mm</td>
<td>-0.03 (0.14)</td>
<td>0.84</td>
<td>-0.45 (0.19)</td>
</tr>
<tr>
<td>Upper-arm muscle area, cm²</td>
<td>-0.61 (0.24)</td>
<td>0.01</td>
<td>-1.54 (0.25)</td>
</tr>
<tr>
<td>Upper-arm fat area, cm²</td>
<td>-2.13 (0.24)</td>
<td>&lt;0.00</td>
<td>-1.96 (0.32)</td>
</tr>
<tr>
<td>Body fat, %</td>
<td>-1.41 (0.20)</td>
<td>&lt;0.00</td>
<td>-1.16 (0.30)</td>
</tr>
</tbody>
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1 Values are mean adjusted β-coefficients (SE) and associated P-values.
2 Differences in annual changes in anthropometric measurements were calculated between pregnant vs. nonpregnant adolescents using the linear mixed effects regression models adjusting for confounders.
early pregnancy and 6 mo postpartum in the present study is less likely to be affected by the downward bias in maternal height.

Weight loss and depletion of fat and lean body mass observed among pregnant girls in our study contrast with findings from studies in well-nourished populations in which adolescent pregnancy has been associated with large gestational weight gains (15.2 ± 0.6 kg) and postpartum weight retention (6.9 ± 0.5 kg) and continuing accrual of fat mass during late pregnancy through 6–8 wk postpartum (30,31). Adolescents appeared to continue to synthesize maternal tissues instead of mobilizing maternal nutrient stores for fetal nutritional demands in late pregnancy and early postpartum (30,31). Maternal prepregnancy nutritional status affects nutrient partitioning (13). In a well-nourished population and overnourished rapidly growing adolescent ewes, a preferential compartmentalization of nutrients to promote rapid maternal growth at the expense of the fetus has been observed (31–33) compared with both maternal weight loss and poor fetal growth that may occur among severely undernourished adolescents (13).

We assumed the burden of lactation to be similar among pregnant women, because all pregnant adolescents who had live births and whose infants were alive were breast-feeding at 3 and 6 mo postpartum. The rate of exclusive breast-feeding was low at 8% at 3 mo and 4% at 6 mo, but this can be explained by the universal practice of prelacteal feeding (>90%) in this population. Breast-feeding, however, was predominant through 6 mo of age as determined by its median frequency of 12 as determined by the 3- and 6-mo visits.

It is essential to consider why pregnancy and lactation during adolescence ceased linear growth of these young girls. One explanation may be the inadequate nutrient supply to support maternal growth due to the competition for nutrients between the teenage mother and the fetus (13). In severely undernourished adolescents, competition for nutrients between the mother and her conceptus is likely to result in both cessation of maternal linear growth and poor fetal growth. Another potential mechanism, which remains to be examined, is the acceleration of epiphyseal closure due to the increased estrogen concentration during pregnancy (34). Epiphyseal closure is normally induced by an increased secretion of estrogen during puberty (34). In pregnant adolescents, further elevation of estrogen level during pregnancy may accelerate the termination of bone growth by stimulating epiphyseal closure (34).

A few limitations to this study need to be considered. Although the present study had a 1-y follow-up period, which was longer than that of comparable studies, pregnant adolescents were measured up to 6 mo postpartum when the burden of lactation was still high. Therefore, this study was unable to determine whether a catch-up growth in stature, weight, fat mass, and muscle mass occurred after 6 mo postpartum when the frequency and intensity of lactation decrease. We did not assess energy, protein, and other macro and micronutrient intakes and our estimates or the level of physical work activity were based on the frequency of a few work activities. Information on the duration and intensity of physical activity was not collected. Future studies of energy intake and expenditure among pregnant adolescents in these malnourished settings would enhance our understanding of energy balance in this population.

In conclusion, childbearing during adolescence may hamper postmenarcheal linear and ponderal growth of young girls, a potential window of opportunity for catch-up growth in an undernourished population. The cessation of linear growth in adolescents due to an early pregnancy may result in an overall loss ranging between 0.6 and 2.7 cm in attained height in rural Bangladeshi women, which may contribute to stunting and increased obstetric risk. The depletion of maternal fat stores and lean body mass during pregnancy and an early stage of lactation, especially among adolescents who become pregnant at an earlier gynecological age, may exacerbate the outcome of future pregnancies and increase the risk of maternal morbidity and mortality. Similar studies with a longer follow-up period need to be conducted in other developing country settings, where marriage and pregnancy occur early and where undernutrition is common, to better understand the risk of early pregnancy to the young mother.

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Literature Cited


