

Fetal femur length is influenced by maternal dairy intake in pregnant African American adolescents¹⁻³

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ABSTRACT

Background: Pregnant adolescents may compete with their developing fetuses for the nutrients required for optimal bone mineralization.

Objective: The objective of this study was to determine the effect in pregnant African American adolescents of maternal dairy intake at entry into prenatal care on fetal femur development between 20 and 34 wk of gestation.

Design: A 10-y retrospective chart review was carried out in 1120 pregnant African American adolescents (≤ 17 y of age) who had received care at an inner-city maternity clinic between 1990 and 2000. Generalized multiple linear regression models were used to address significant determinants of fetal femur length after control for gestational age, biparietal diameter, maternal age and height, and prepregnancy body mass index. Dairy intake was estimated at entry into prenatal care on the basis of 24-h dietary recall and a food-frequency questionnaire. Data from 350 subjects, for whom data on all variables were available, were included in the model.

Results: In these pregnant adolescents with a mean (\pm SD) age of 15.9 ± 1.1 y (range: 12.7–17.9 y), dairy intake had a significant positive effect on fetal femur growth after adjustment for gestational age, biparietal diameter, maternal age and height, and prepregnancy body mass index ($P = 0.001$, $R^2 = 0.97$). Fetal femur length was significantly lower in the lowest dairy-intake group (< 2 servings/d) than in the highest dairy-intake group (> 3 servings/d), and a dose-response relation was suggested in the intermediate dairy-intake group (2–3 servings/d; $P = 0.089$).

Conclusion: These data suggest that consumption of < 2 servings of dairy products/d by pregnant adolescents may negatively affect fetal bone development by limiting the amount of calcium provided to the fetus. *Am J Clin Nutr* 2003;77:1248–54.

KEY WORDS Fetal femur length, ultrasound, adolescents, calcium, dairy products, pregnancy, African Americans

INTRODUCTION

Maternal nutrition during pregnancy is known to have a significant effect on fetal growth and development (1–3). Under situations of reduced nutrient intake or increased nutrient requirements, competition between the mother and the fetus may limit the availability of the nutrients required for optimal fetal growth (4, 5).

At present, the effect of maternal calcium intake on fetal skeletal development is not well defined. Previous studies found

that maternal malnutrition adversely affects not only the bone density of the mother herself but also that of the newborn (6). Moreover, weak evidence supports an effect of calcium supplementation on fetal growth (7), and calcium supplementation during pregnancy increases the bone density of the neonate in undernourished mothers (8) and women with habitually low dietary calcium intakes (9).

In pregnant adolescents, calcium intakes may be limited by poor maternal diet and by the need to retain enough calcium to support both maternal and fetal skeletal mineralization. A recent study indicated that although female adolescents generally have higher concentrations of indirect markers of bone formation than do adult women, under conditions of limited dietary calcium availability, less pronounced differences were found during pregnancy (10). In addition, heel ultrasound data indicate bone loss at trabecular sites over the course of pregnancy, and the magnitude of this loss is greatest in pregnant adolescents (11). The greater loss among adolescents is consistent with the demands of fetal mineralization and the continued demands of the maternal skeleton during growth (11).

Pregnant adolescents, especially those who have not yet reached peak adult height and peak bone mass, may be particularly vulnerable to calcium insufficiency during pregnancy (12). In this age group, competition for calcium between the adolescent and the fetus may limit optimal bone mineralization in both the mother and the fetus. To address the effect of early child-bearing on fetal bone development, we examined potential predictors of fetal femur development in a cohort of African American adolescents (≤ 17 y of age) who had received care at an inner-city maternity clinic between 1990 and 2000. The effect of maternal factors, particularly dairy intake at entry into prenatal care, on fetal femur development was addressed in this “at risk” population.

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SUBJECTS AND METHODS

Study design

A retrospective cohort study was undertaken of all adolescents aged ≤ 17 y at entry into prenatal care who had received prenatal care between 1990 and 2000 at an inner-city maternity clinic affiliated with Johns Hopkins Hospital in Baltimore. The community surrounding this clinic is predominantly African American and has the highest rates of adolescent pregnancy in Maryland (13). To provide specialized, age-appropriate care to an increasing number of pregnant adolescents (14), the Johns Hopkins Hospital developed an adolescent pregnancy program in 1990; in this program, all adolescents seeking prenatal care are referred to the Maternity Center East Clinic. This clinic was staffed with a registered dietitian who evaluated patterns of dietary intake in each adolescent at entry into prenatal care. Medical records of these subjects were stored at the clinic and were accessible for review.

Study population

To evaluate predictors of fetal bone growth, medical records were included only for adolescents that self-reported their racial group as African American, had a singleton pregnancy, had no self-reported history of smoking or alcohol abuse, and had no positive drug screen during pregnancy. Furthermore, all adolescents included in this study had sonogram data available (between 20 and 34 wk of gestation). This period was chosen because 20 wk is the beginning of the period of peak femur growth velocity (15) and because very few ultrasound data were available after 35 wk of gestation in our population. In addition, adolescents with serious medical complications during pregnancy (such as diabetes) or those with HIV infection were excluded from this study. The study was approved by the Joint Committee of Clinical Investigation at Johns Hopkins Hospital.

Data management

A statistical software program (STATVIEW, version 5.01; SAS Institute, Cary, NC) was used to enter data from the charts in a standardized manner. Information extracted from the medical chart review in this study included the following: patient's date of birth, gestational age at entry into prenatal care, date of last menstrual period, self-reported prepregnancy weight, self-reported height, prepregnancy body mass index (BMI; in kg/m^2), duration of pregnancy, birth weight, Apgar score, type of delivery, parity, and ultrasound data. To ensure the quality of data, periodic quality control of the data was performed by randomly choosing identification numbers of the patients and pulling their medical charts for cross-checking study variables. If errors were identified, data from all charts entered on the same day were also reviewed. A codebook was created before any data were entered to maintain data quality and to ensure that the definition of results for each specific categorical variable was uniform throughout the data entry period.

Determination of gestational age

Gestational age was determined by best obstetric estimate, taking into account self-reported menstrual history, physical examination, and the earliest available ultrasound data. If the gestational age determined by self-reported menstrual history was within 10 d of that derived from the physical examination and the ultrasound, the gestational age was based on self-reported menstrual history.

If these 2 measures differed by > 10 d, the ultrasound estimate of gestational age was used.

Ultrasound measures

Ultrasound measures during pregnancy were available for 84% of the 1120 adolescents seen during this 11-y interval. All ultrasound measures were made at the Johns Hopkins Hospital by a certified ultrasonographer. Measures of fetal biparietal diameter (cm), femur length (cm), abdominal circumference (cm), and head circumference (cm) were obtained with the use of standard techniques. Biparietal diameter was calculated as the distance from the outer margin to the inner margin of the fetal skull, and fetal femur length was determined by measuring along the femur diaphysis but excluding the distal femoral epiphysis (16).

Pattern of fetal femur development

Data on femur development in our population was compared with normative data published by Chitty et al (17) in a cross-sectional study of 649 fetuses studied between 12 and 42 wk of gestation in the United Kingdom. We applied a linear-cubic regression model to estimate the mean femur length at different weeks of gestation. The SDs of mean femur length for each gestational week were obtained by a separate linear regression and were weighted by the sample size at each week as described by Altman and Chitty (18). Femur length was measured for 929 of the 943 fetuses in our study. To compare fetal femur development in our adolescent population with that expressed in this large normative database, a graph presenting mean femur length in relation to gestational age was developed by using our data and those of Chitty et al (17). For the purpose of this comparison of fetal growth only, measurements of femur length in our study were extrapolated to 12–42 wk. Data are presented as centiles 2.5, 50, and 97.5.

Dairy intake and dietary survey information

The dairy intake of each pregnant adolescent was estimated at her first prenatal visit during an initial consultation with a registered dietitian at the Maternity Center East Clinic. All dietary information was collected by the same registered dietitian (MSN), who has worked at this clinic since 1990. Both 24-h dietary recall and food-frequency methods were used to characterize habitual dietary intake. The adolescents filled out their own 24-h recall, which was then reviewed with the registered dietitian. The food-frequency questionnaire required the adolescents to circle foods that they consumed, and the frequency of consumption of these foods was discussed with the registered dietitian. Dietary dairy intake was estimated on the basis of the number of servings of dairy products.

The registered dietitian initially rated each adolescent's calcium intake as "adequate" (4 servings/d), "fair" (2–3 servings/d), or "poor" (0–1 serving/d) on the basis of the 24-h dietary recall by using the number of dairy products consumed daily. Each serving size of dairy products contributed ≈ 300 mg Ca. The food-frequency questionnaire was then administered to determine how representative the recall data were of the adolescents' usual intake, and 2 intermediate categories ("fair plus" and "poor plus") were then added if the data from the food-frequency questionnaire were slightly higher than those determined from the 24-h dietary recall. Dairy intake was classified into 1 of the 5 categories for each adolescent. For the purposes of our study, we defined the high dairy-intake group as those adolescents with an "adequate" or "fair plus"

TABLE 1
Criteria for rating dairy intake in pregnant African American adolescents

Original rating	Intake ¹ servings/d	Combined rating in this study ²
Adequate (<i>n</i> = 66)	≥4	High [84]
Fair plus (<i>n</i> = 18)	3 to <4	
Fair (<i>n</i> = 86)	2 to <3	Medium [86]
Poor plus (<i>n</i> = 11)	1 to <2	Low [180]
Poor (<i>n</i> = 169)	0 to <1	

¹Determined from 24-h recall and a food-frequency questionnaire.

²*n* in brackets.

intake, the medium dairy-intake group as those with a “fair” intake, and the low dairy-intake group as those with a “poor plus” or “poor” intake. The criteria for rating intakes are shown in **Table 1**. Additional dietary information on intakes of energy, protein, iron, vitamin A, and vitamin C was obtained during the initial interview by the registered dietitian using similar methods.

Statistical analyses

Statistical analyses were performed with the STATA software package (version 7.0; Stata Corporation, College Station, TX). Analysis of variance was used to test for significant differences between the 3 maternal intake groups in age, height, weight, prepregnancy BMI, birth weight, duration of pregnancy, and Apgar score. Potential differences in rates of cesarean delivery and preterm birth between the 3 maternal intake groups were analyzed statistically by using 2 × 3 contingency table analysis with calculation of chi-square statistics. In addition, 3 × 3 contingency table analysis with calculation of chi-square statistics was used to test for significant differences between the intake groups in the intakes of other nutrients, including energy, protein, vitamin A, iron, and vitamin C. The relation between fetal femur length and gestational age was linear between 20 and 34 wk. Multiple linear regression analysis was used to determine the relative contribution of categorical and continuous variables to fetal femur length. Because there were 13 patients who contributed 2 pregnancies in our study, we also used a generalized estimating equation method (19, 20) to control for the possible effect of within-group correlation from these 13 patients on associations between maternal factors and fetal femur length. Because the pattern and significance of the results did not change, we present only the results of the multiple linear regression analysis. In all statistical analyses, significance was defined as *P* < 0.05. Only adolescents with no missing values for any of the other covariate and outcome variables were included in these analyses.

RESULTS

Subject characteristics

In total, 1120 medical charts were reviewed from pregnant African American adolescents who had received prenatal care between 1990 and 2000. Ultrasound measures were available for 943 of the 1120 patients. A total of 467 records were not included because ultrasound measures were not made between 20 and 34 wk of gestation, and 74 records were removed because the adolescents had a self-reported history of drug use and cigarette smoking. A total of 402 patients met the inclusion criteria. Among these 402

patients, we further eliminated 52 patients who either had missing values for any of the covariates in our multiple regression analyses or gave birth to a stillborn infant. These 52 eliminated patients included 24 patients who had no dietary evaluation data, 22 patients whose prepregnancy BMI was not available, 1 patient who did not have biparietal diameter information in the medical record, and 5 patients whose infants were stillborn. A final sample size of 350 patients was obtained. No significant differences in maternal age, prepregnancy BMI, height, dairy-intake distribution, and birth outcomes were observed between this subset population of 350 adolescents and the excluded population of 770 adolescents.

The characteristics of the total study group and of the 3 dairy-intake groups are shown in **Table 2**. The rate of preterm delivery (<37 wk of gestation) in this population (14%) was similar to that reported among young African American mothers aged <19 y (13.8%) in *National Vital Statistics Reports* from data in 2000 (21).

There were no significant differences between the 3 dairy-intake groups in maternal age, height, prepregnancy weight, prepregnancy BMI, infant birth weight, or 1- and 5-min Apgar scores. The adolescents in the medium intake group had marginally lower prepregnancy BMI than did the other groups, but this difference was not significant (*P* = 0.06). No significant differences between the 3 intake groups were evident in the rates of maternal cesarean delivery or preterm birth.

Effect of dairy intake on fetal femur length

High maternal dairy intake at entry into prenatal care was associated with significantly greater fetal femur length after adjustment for gestational age, maternal age, maternal height, prepregnancy BMI, and fetal biparietal diameter (**Table 3**). A dose-response relation was also suggested because patients with intermediate dietary dairy intakes had moderately greater fetal femur lengths (*P* = 0.089) than did those in the low dairy-intake group.

No significant associations of dairy intake with fetal biparietal diameter (*P* for trend = 0.381), fetal head circumference (*P* for trend = 0.713), and fetal abdominal circumference (*P* for trend = 0.196) were present after correction for gestational age, maternal age, maternal height, and prepregnancy BMI. In addition, no significant relations were found between fetal head circumference and fetal abdominal circumference by using the same regression model, which corrected for fetal biparietal diameter, as was used to examine the relation between fetal femur length and maternal dairy intake. Mean values of all fetal growth measures are shown in **Table 2** by maternal dairy-intake group.

Other determinants of fetal femur length

As expected, gestational age and fetal biparietal diameter were the strongest predictors of fetal femur length (**Table 3**). Maternal height and prepregnancy BMI were also positively associated with fetal femur length (*P* = 0.002 and 0.018, respectively). Every 1-cm increase in maternal height was associated with a 0.0044-cm increase in fetal femur length after control for dairy intake, gestational age, fetal biparietal diameter, maternal age, and prepregnancy BMI. Similarly, an increase of 1 in maternal prepregnancy BMI was associated with a 0.005-cm increase in fetal femur length after control for dairy intake, gestational age, fetal biparietal diameter, maternal age, and maternal height.

Relation between other nutrients and fetal femur length

Diets high in dairy products (as determined by the number of servings of dairy products) may also be of better overall nutritional

TABLE 2

Characteristics of the pregnant African American adolescents in the 3 dairy-intake groups and in the total study group

	Dairy-intake group			Total (n = 350)	P ¹
	Low (<2 servings/d) (n = 180)	Medium (2 to <3 servings/d) (n = 86)	High (>3 servings/d) (n = 84)		
Maternal age (y)	16.0 ± 1.1 (12.71–17.81) ²	15.8 ± 1.1 (13.12–17.99)	15.9 ± 1.3 (12.17–17.75)	15.9 ± 1.1 (12.17–17.99)	0.31
Height (cm)	161.7 ± 7.6	163.2 ± 6.3	163.0 ± 6.6	162.4 ± 7.1	0.15
Weight (kg)	61.7 ± 13.3	59.2 ± 11.4	61.4 ± 14.3	61.0 ± 13.1	0.34
Prepregnant BMI (kg/m ²)	23.7 ± 5.2	22.2 ± 3.7	23.0 ± 5.0	23.2 ± 4.8	0.06
Infant birth weight (g) ³	3090 ± 580	3101 ± 574	3129 ± 538	3102 ± 567	0.88
Gestation (wk) ⁴	39.0 ± 2.4	39.0 ± 2.4	38.8 ± 2.4	38.9 ± 2.4	0.85
Cesarean delivery (% [n]) ⁴	12.7 [22]	12.0 [10]	12.7 [10]	12.5 [42]	0.55
Preterm birth (% [n]) ^{4,5}	12.7 [22]	13.3 [11]	17.7 [14]	14.0 [47]	0.99
Apgar score ³					
1 min	7.9 ± 1.4	7.7 ± 1.5	7.5 ± 2.0	7.8 ± 1.5	0.40
5 min	8.8 ± 0.6	8.8 ± 0.5	8.7 ± 0.8	8.8 ± 0.6	0.56
Fetal femur length (cm)	4.46 ± 1.0	4.69 ± 1.0	4.59 ± 1.1	4.54 ± 1.0	0.66
Fetal biparietal diameter (cm)	6.02 ± 1.2	6.23 ± 1.2	6.06 ± 1.2	6.08 ± 1.2	0.81
Fetal head circumference (cm)	22.44 ± 4.1	23.15 ± 4.2	22.74 ± 4.5	22.69 ± 4.2	0.72
Fetal abdominal circumference (cm)	19.82 ± 4.3	20.78 ± 4.6	20.41 ± 4.7	20.20 ± 4.5	0.67

¹Chi-square test with 2 df for cesarean delivery and preterm birth, and ANOVA for the other characteristics.² $\bar{x} \pm SD$; range in parentheses.³Total n = 168, 78, 78, and 324 in the low, medium, and high dairy-intake groups and the total group, respectively.⁴Total n = 173, 83, 79, and 335 in the low, medium, and high dairy-intake groups and the total group, respectively.⁵Less than 37 wk of gestation.

quality. Therefore, we also examined the relation between dairy intake and other nutrients screened for at entry into prenatal care by using a chi-square test. The results in **Table 4** show that high dairy consumption was associated with overall better nutrition in these inner-city, pregnant, African American adolescents. The subjects in the high dairy-intake group had significantly higher protein ($P = 0.001$), vitamin A ($P = 0.001$), and iron ($P = 0.002$) intakes than did those in the lower intake groups. Similar trends were also evident for total energy and vitamin C intakes, although these results were not significant ($P = 0.096$ and 0.061 , respectively).

To examine whether the effect of dairy intake on fetal femur length was confounded by intakes of other nutrients present in dairy products, we further examined the effect of each nutrient intake on fetal femur length by using generalized multiple

regression models and controlling for gestational age, maternal age, maternal height, prepregnancy BMI, and fetal biparietal diameter. No significant relations of fetal femur length with intakes of protein, vitamin A, iron, energy, and vitamin C were evident.

TABLE 4

Dietary intake patterns in relation to dairy-intake groups in 350 pregnant African American adolescents

	Dairy intake group			Total	P ¹
	Low	Medium	High		
	n (%)			n (%)	
Energy intake					
Low	67 (39.7)	35 (43.8)	19 (24.4)	121 (37.0)	0.096
Medium	58 (34.3)	28 (35.0)	36 (46.1)	122 (37.3)	
High	44 (26.0)	17 (21.2)	23 (29.5)	84 (25.7)	
Protein intake					
Low	64 (35.7)	17 (19.8)	12 (14.5)	93 (26.7)	0.001
Medium	59 (33.0)	40 (46.5)	16 (19.3)	115 (33.0)	
High	56 (31.3)	29 (33.7)	55 (66.2)	140 (40.3)	
Vitamin A intake					
Low	87 (51.8)	27 (31.8)	24 (30.0)	138 (40.3)	0.001
Medium	47 (28.0)	26 (30.6)	16 (20.0)	89 (25.9)	
High	44 (26.2)	32 (37.6)	40 (50.0)	116 (33.8)	
Iron intake					
Low	66 (36.9)	21 (24.4)	18 (21.7)	105 (30.2)	0.002
Medium	70 (39.1)	41 (47.7)	27 (32.5)	138 (39.6)	
High	43 (24.0)	24 (27.9)	38 (45.8)	105 (30.2)	
Vitamin C intake					
Low	87 (49.2)	26 (30.6)	31 (37.8)	144 (41.9)	0.061
Medium	24 (13.6)	16 (18.8)	15 (18.3)	55 (16.0)	
High	66 (37.2)	43 (50.6)	36 (43.9)	145 (42.1)	

¹Chi-square test with 4 df.**TABLE 3**Generalized multiple linear regression of maternal dairy intake, maternal age, maternal height, prepregnancy BMI, gestational age, and fetal biparietal diameter on fetal femur length in 350 pregnant African American adolescents¹

	$\beta \pm SE$	P
Dairy intake ²		
Medium	0.041 ± 0.024 (−0.006, 0.089)	0.089
High	0.077 ± 0.024 (0.030, 0.125)	0.001
Maternal age (y)	−0.002 ± 0.009 (−0.020, 0.015)	0.783
Maternal height (cm)	0.0044 ± 0.0014 (0.0017, 0.0072)	0.002
Prepregnancy BMI (kg/m ²)	0.005 ± 0.002 (0.001, 0.009)	0.018
Gestational age (wk)	0.141 ± 0.011 (0.119, 0.162)	0.001
Fetal biparietal diameter (cm)	0.373 ± 0.039 (0.297, 0.449)	0.001

¹95% CI in parentheses. The medium and high dairy-intake groups were compared with the low dairy-intake group.²P for trend = 0.004.

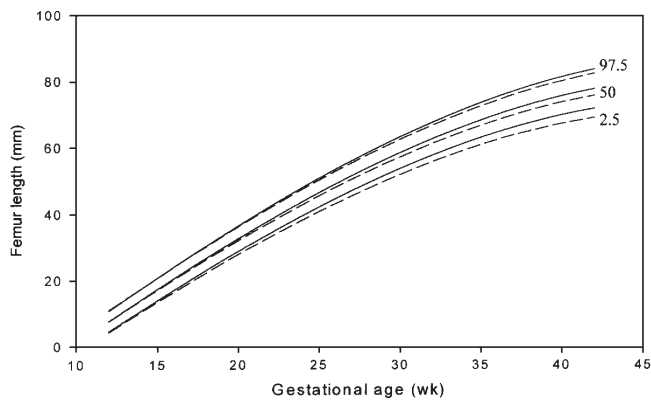


FIGURE 1. A comparison of fetal femur length development in our group of 929 fetuses (—) and in 649 fetuses studied by Chitty et al (---; 17). Data are presented as centiles 2.5, 50, and 97.5; a linear-cubic regression model and a separate linear regression were fitted to estimate the mean femur length and the SD, respectively, as described in the studies by Altman and Chitty (18) and Chitty et al (17). The regression equations generated between fetal femur growth and week of gestation in our study were as follows: mean femur length = $-33.26 + 3.489w - 0.000482w^3$, and SD = $1.065 + 0.04906w$, where w is exact gestational age in weeks. These equations were similar to those reported by Chitty et al (17): mean femur length = $-32.43 + 3.416w - 0.000479w^3$, and SD = $1.060 + 0.05833w$. These data indicate that overall femur growth in our adolescent population was similar to that observed in adult women.

Fetal femur growth chart

The comparison between our fetal femur length centiles and those reported by Chitty et al (17) is shown in **Figure 1**. Overall, the pattern of femur length growth was similar between the 2 studies, although our population had slightly greater fetal femur length in later pregnancy than did the population of Chitty et al. The outer centiles were also similar between these 2 populations in early pregnancy, but our population had a narrower distribution during late pregnancy. The regression equations used to generate the centiles in the present study were

$$\text{Mean femur length} = -33.26 + 3.489w - 0.000482w^3 \quad (1)$$

$$\text{SD} = 1.065 + 0.04906w \quad (2)$$

where w is the exact gestational age in weeks. These equations were similar to those reported by Chitty et al (17; Figure 1).

DISCUSSION

This is the first study to examine the effect of maternal anthropometric measures and nutrient intakes on fetal femur length in adolescent females during pregnancy. After adjustment for numerous maternal factors, dairy intake at entry into prenatal care had a significant effect on fetal femur length in this group of pregnant African American adolescents.

Adequate calcium intake, particularly during growth, is known to be an important determinant of bone mineralization and thus bone density in the growing adolescent (22). This rapid period of bone mineralization is accommodated by increased calcium absorption and retention and increased rates of bone calcium deposition during adolescence (23–26). To ensure that calcium intakes are sufficient to meet the physiologic demands during this key growth period, the recommended dietary allowance was recently increased from 800 mg/d (27) to 1300 mg/d (28). In part because of a scarcity of

data, no additional increase in dietary calcium intake was recommended for pregnant or lactating adolescents.

At present, many adolescents do not consume the recommended amounts of calcium. A nutrient-intake survey based on 14-d food-consumption records collected from 4 national, representative samples of 4000 US households found that adolescents, particularly females, were at greatest risk for inadequate calcium intake (29). Dietary calcium consumption among 15–18-y-olds has also decreased significantly over the past 10 y, and during all data-collection periods, >90% of all adolescent females (aged 11–18 y) consumed less than the recommended dietary allowance (29). The self-reported intakes of dairy products in our pregnant, African American, adolescent population suggested that this group consumed slightly more dietary calcium than did the subjects in previous surveys (29), on the basis of the assumption that each serving of dairy product contained 300 mg Ca. Even so, one-half of our population probably consumed <600 mg Ca/d (which corresponds to <50% of the current adequate intake for calcium).

Insufficient maternal calcium intake has been found to influence neonatal bone density. The radiodensities of bones studied in 21 paired Indian mothers and neonates from a poor community with limited food access were significantly lower than those of 15 paired mothers and neonates of high-income groups with adequate access to food (6). The same group of investigators also found that supplementation of poorly nourished pregnant women with ≥ 300 mg Ca/d increased the bone density of their neonates (8). Moreover, a study by Koo et al (9) indicated that maternal calcium supplementation (up to 2 g/d) during the second and third trimesters increased neonatal bone density in women with habitually low calcium intakes but not in women with adequate dietary calcium intake. These data suggest that insufficient calcium consumption in women during pregnancy may have a negative effect on fetal skeletal mineralization.

Fetal femur length measurements are routinely made during prenatal ultrasounds because this measure is one of the combined factors used to estimate fetal age and weight (16). The femur is the longest and most rapidly growing long bone of the fetus. Normal values for each week of pregnancy and growth curves of ultrasound femur length were established previously among a population in the United Kingdom (17, 18). The femur lengths of our population were similar to but slightly longer than those observed in the United Kingdom. This comparison suggests that although femur development in the pregnant African American adolescents in the present study was influenced by maternal dairy intake, the overall growth of this long bone was comparable to that reported in a primarily adult white population.

In the present study, we found that pregnant adolescents with high dairy intake at entry into prenatal care had fetuses with significantly longer femurs than did those with low dairy intake. Moreover, a dose-response relation was suggested across intake groups. This effect was specific for femur length and was not evident for overall fetal growth. No significant associations of dairy intake with fetal biparietal diameter, head circumference, or abdominal circumference were present when the same model used for fetal femur measures was used.


Relations between the growth of the fetal femur and its degree of mineralization are not known. Koo et al (9) previously reported that the effect of calcium supplementation on neonatal bone density was evident only in women with habitually low calcium intakes. The effect of calcium supplementation on fetal skeletal

mineralization may be smaller and harder to detect in women with sufficient or high calcium intakes or in adult women, for whom linear growth has already stopped and skeletal mass has already been consolidated.

We hypothesized that the effect of dairy products on fetal bone was due primarily to calcium. Dairy products constitute approximately two-thirds of the daily calcium intake of US adolescent females (30). However, this effect may also be partially attributed to other nutrients in dairy, such as phosphorus, magnesium, zinc, and vitamin D. Higher dairy intake at entry into prenatal care was significantly associated with higher protein, vitamin A, and iron intakes; there was also a trend for higher dairy intake to be associated with higher energy and vitamin C intakes, but those results were not significant. However, none of the other dietary variables collected at entry into prenatal care, including iron, vitamin A, vitamin C, energy, and protein, were significantly related to fetal femur length, and dairy intake was the only significant dietary predictor of fetal femur length. From our study, we are unable to draw further conclusions on whether the observed effect was due to calcium alone or to a combination of calcium and additional nutrients present in dairy foods.

As expected, in our study, gestational age and biparietal diameter, which are indicators of fetal femur growth, were the strongest predictors of fetal femur length, and these variables explained most (90%) of the variability in fetal femur growth in our generalized multiple linear regression model. In addition to maternal dairy intake at entry into prenatal care, maternal height and prepregnancy weight were also significantly positively associated with fetal femur length. The effect of maternal characteristics, such as maternal height, on fetal femur length has been previously described. Fetal femur length in second-trimester fetuses has been reported to be lower in Asians and Hispanics than in African Americans and whites (31). Pierce et al (31) also found maternal height to correlate with femur length at later gestational ages (18–19 wk) but not at earlier gestational ages. Currently, there are no data addressing the effect of maternal prepregnancy BMI on fetal femur development; however, we found evidence to suggest that high maternal BMI was associated with greater fetal femur length in pregnant adolescents.

In addition to consuming dietary sources of calcium, all the adolescents in the present study were encouraged to take daily prenatal vitamins containing 200 mg CaCO₃. Because no information was available from the medical charts on compliance or use of prenatal vitamins in this population, we assumed that no significant differences in prenatal vitamin use existed among these adolescents. Moreover, because dairy intake was assessed only at entry into prenatal care, we assumed that this level of intake remained somewhat consistent across gestation. By estimating the intake of dairy products only at entry into prenatal care, we probably increased the variation (random error) in the measure. However, random error usually diminishes the strength of observed associations, and an even stronger association might be expected if the variability in the dairy-intake measurement had been reduced. From our data, it is not clear whether the observed differences in femur length during the third trimester were maintained at delivery, whether they corresponded with differences in birth length, or whether these changes in femur length were caused by alterations in the timing of the growth and development of this long bone. Further studies are needed to clarify these questions.

In conclusion, in this population of pregnant African American adolescents, the intake of <2 servings of dairy products/d was associated with significantly lower fetal femur lengths. Increasing the dairy intake of adolescents during pregnancy may benefit both maternal bone mass and fetal bone development. Future studies are needed to address the mechanisms and long-term effect of nutrient intakes during pregnancy on fetal femur development and neonatal bone mineral density in vulnerable populations such as pregnant adolescents. 

S-CC was responsible for study coordination, data analysis, and manuscript preparation. KOO was the principal investigator of the study, was responsible for the design of the study, and oversaw its progress. MSN collected the dietary information from the adolescents and assisted in the interpretation of the data. LEC assisted in data interpretation and analysis. JM provided medical care to the subjects attending the clinic, facilitated the medical chart review, and assisted in interpretation of the data. FRW is the Director of the Labor and Delivery Suite and assisted with the study design and data interpretation. None of the authors had any financial or personal relationships with the sponsor of this research.

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