Ann. N.Y. Acad. Sci. ISSN 0077-8923

ANNALS OF THE NEW YORK ACADEMY OF SCIENCES
Special Issue: *Adolescent Women's Nutritional Status*
ORIGINAL ARTICLE

Factors associated with nutritional status and dietary practices of Bangladeshi adolescents in early pregnancy

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Bangladesh has a high prevalence of adolescent pregnancy, but little is known about the nutritional status and dietary practices of Bangladeshi adolescents in early pregnancy or associated factors. We used the baseline data of 1552 pregnant adolescents from a longitudinal, cluster-randomized effectiveness trial conducted in northwest Bangladesh. Forty-four percent of the adolescents were short for their age, 36% had low body mass index, 28% were anemic, 10% had iron deficiency, and 32% had vitamin A deficiency. The mean consumption of animal-source foods was 10.3 times/week. In multivariate analysis, socioeconomic status, education, and food security were generally positively associated with anthropometric indicators and dietary practices but not with iron or vitamin A status. Our findings confirm that there is a high burden of undernutrition among these Bangladeshi adolescents in early pregnancy. Understanding factors related to undernutrition can help to identify adolescent pregnant women at higher risk and provide appropriate counseling and care.

Keywords: adolescents; early pregnancy; nutritional status; dietary practices; Bangladesh

Introduction

Pregnancy during adolescence is a major health and social concern, as it poses risks for both the mother and the baby, including maternal morbidity and mortality, fetal growth restriction, and adverse birth outcomes. The adverse consequences of adolescent pregnancy may be exacerbated by malnutrition. Though nutritional status before and during early pregnancy is an important determinant of maternal and child health,[1] little is known about the factors associated with nutritional status in early pregnancy, particularly among adolescents.

The 2014 Bangladesh Demographic Health Survey indicated a high prevalence of adolescent marriage and pregnancy in Bangladesh.[2] Median age at first marriage among the married women in the 20–49 years age group was 16.1 years. Among these women, median age at first birth was 18.4 years, and 45.3% of them experienced their first childbirth by 18 years of age. Among those in the 15–19 year age group who were already married, 30.8% had begun childbearing, with 24.6% having experienced childbirth and 6.2% being currently pregnant. In these adolescents, 13.4% had short stature (i.e., height less than 145 cm); 31% had body mass index (BMI) less than 18.5 kg/m^2; and 7.1% had BMI $\geq$25 kg/m^2.

The diet quality of many pregnant women in Bangladesh is also poor. In a recently published study, Shamim and colleagues reported that over 60% of pregnant women who were $\leq$19 years old had low or medium dietary diversity (dietary diversity score less than 5 out of a maximum of 8).[3] Among the food groups included in the dietary diversity score, consumption of eggs, dairy products, legumes and nuts, and vitamin A–rich vegetables and fruits (other than dark-green leafy vegetables) was low. Though there are data available for dietary intake of pregnant women as a whole, the dietary practices of pregnant adolescents in Bangladesh are largely unknown.

doi: 10.1111/nyas.13568

There is also little understanding of the factors related to the dietary practices of pregnant adolescents in Bangladesh, though there has been some exploration of factors associated with dietary diversity of rural women. For example, Harris-Fry and colleagues found that women's dietary diversity was associated with homestead vegetable gardens, household wealth, and women's literacy.[4] Because pregnancy may hinder the growth and nutritional status of adolescent girls,[1] more attention to the factors associated with pregnant adolescents' dietary practices is warranted.

Accordingly, our objectives are to describe the nutritional and dietary characteristics of rural Bangladeshi adolescents during early pregnancy and identify factors associated with their nutritional status and dietary practices.

Methods

We used baseline data from the Rang-Din Nutrition Study (RDNS) to address the objectives of our study. The RDNS was a longitudinal cluster-randomized effectiveness trial conducted in rural Bangladesh, designed to evaluate the impact of nutrition interventions during the "1000 days" window on nutritional status of pregnant and lactating women and on growth, nutritional status, and development of their children.[5–7] Of the 4011 pregnant women enrolled in the study, 1552 (39%) were adolescents (13–20 years of age). The RDNS was conducted by three partners: the University of California, Davis; the International Center for Diarrheal Disease Research, Bangladesh; and Lutheran Aid to Medicine in Bangladesh (LAMB), a local nongovernmental organization responsible for supplement distribution. It was conducted in two subdistricts in northwest Bangladesh—Badarganj and Chirirbandar—in one of the poorest regions of Bangladesh. Pregnant women were enrolled between October, 2011 and August, 2012. We implemented the study in 64 clusters (16 per arm), with a cluster defined as the supervision area of a LAMB Community Health Worker. Eligibility criteria included gestational age ≤20 weeks and no plans to move out of the study area during the following 3 years.

At enrollment, women were interviewed at home to collect data on socioeconomic status (SES), diet, food security, and knowledge, attitudes, and practices relevant to nutrition. They were invited to a local LAMB clinic within 1 week, where anthropometric assessments, including height, weight, and mid-upper arm circumference (MUAC), were completed for all women. Dietary assessment was conducted using a short 7-day food frequency questionnaire (FFQ) to capture intake from selected food groups. The FFQ was pretested among 46 pregnant women in areas close to the RDNS areas. It was aimed at collecting data on intake of nutrient-rich foods including animal source foods (seven categories: meat, poultry, eggs, fresh fish, dried fish, milk, and milk products), pulses/beans/lentils, nuts, fruits (five locally available fruits), and vegetables (four locally available vegetables). The subjects were asked on how many days and how many times they had consumed each food item during the previous week.

Blood and urine were collected from a subsample of women, as described elsewhere.[8] Hemoglobin (Hb; g/L) was measured using HemoCue® Hb 301 System (HemoCue America, Brea, CA). Plasma was shipped to an external laboratory for analysis of biomarkers of iron status (serum ferritin and soluble transferrin receptor (sTfR)), vitamin A status (retinol-binding protein (RBP)), and inflammation (α1 acid glycoprotein (AGP) and C-reactive protein (CRP)). Spot urine samples were analyzed for urinary iodine concentration (UIC).

We developed a statistical analysis plan to address specific research questions relevant to the objectives described above. The research questions were: (1) What are the dietary practices, nutritional status indicators (weight, height, and BM), MUAC, Hb, micronutrient status (iron, vitamin A, and iodine), and inflammation indicators (CRP and AGP) of adolescent Bangladeshi women in early pregnancy?; (2) Do these dietary practices, nutritional indicators, or inflammation indicators differ by SES, education, food security, or years since menarche?; and (3) Which factors predict abnormal nutritional status of this cohort in early pregnancy?

The key nutrition-related indices were as follows: (1) short stature, defined as height-adjusted Z-score <-2 or <150.1 cm if 19 years, (2) low BMI, defined as BMI <18.5 kg/m^2,[2] (3) low MUAC, defined as MUAC <21.5 cm,[9] (4) anemia, defined as Hb <110 g/L,[10] (5) low ferritin, defined as serum ferritin < 12 μg/L,[11] (6) high sTfR, defined as sTfR >8.3 mg/L,[12] (7) iron deficiency (ID), defined as ferritin < 12 μg/L or sTfR >8.3 mg/L,[8] (8) vitamin

Table 1. Nutritional status of study participants in early pregnancy ($n = 1486$)

Characteristic	Percentage
Short stature (**HAZ <–2, or < 150.1 cm if 19 years**)	44
BMI < 18.5 kg/m^2	36
MUAC < 21.5 cm	10
Hb < 110 g/L	28
Low serum ferritin (ferritin < 12 μg/L)	4
High sTfR (sTfR > 8.3 mg/L)	7
Iron deficiency (serum ferritin < 12 μg/L or sTfR > 8.3 mg/L)	10
Iron-deficiency anemia	5
Vitamin A deficiency (retinol-binding protein < 1.17 μmol/L)	32
Median urinary iodine concentration (μg/L) (quartile 1, quartile 3)	49.1 (27.1, 91.2)
C-reactive protein > 5 mg/L	8
AGP > 1 g/L	7
Inflammation (C-reactive protein > 5 mg/L or AGP > 1 g/L)	13

HAZ, height-for-age Z score; BMI, body mass index; MUAC, mid-upper arm circumference; Hb, hemoglobin; sTfR, soluble transferrin receptor; AGP, α1 acid glycoprotein.

A deficiency, defined as RBP <1.17 μmol/L,[13] (9) iron-deficiency anemia (IDA), defined as Hb <110 g/L and either ferritin <12 μg/L or sTfR >8.3 mg/L,[8] (10) iodine deficiency, defined as median UIC <150 μg/L,[14] and (11) inflammation, defined as AGP >1 g/L or CRP >5 mg/L.[15] Dietary intake variables included intake of dairy products, animal-source foods (ASFs, including dairy), green leafy vegetables, red leafy vegetables, and vitamin C–rich fruits and vegetables. We did not adjust the ferritin and sTfR values for inflammation, as there is still uncertainty with respect to the best methods of accounting for inflammation.[15]

The key predictor variables included in the analysis were SES, education, food security, and years since menarche. SES quintiles were based on a household asset index created using principal component analysis[5] of individual questions about land ownership, housing quality, toilet type, garbage disposal quality, and ownership of 19 items, including televisions, irrigation pumps, tables, bicycles, sewing machines, and other goods. Education data were collected as "complete years of education," subsequently categorized into five levels: no education, primary incomplete, primary complete, secondary incomplete, and secondary or more. We used the Household Food Insecurity Access Scale to categorize participants into four levels of household food insecurity: severe food insecurity, moderate food insecurity, mild food insecurity, and food security.[16] The age at menarche was determined by asking participants "At what age did you have the first menstruation?" Data for "years since menarche" were collected in completed years and were categorized into two levels: ≤3 years since menarche versus >3 years since menarche. In addition to these key predictor variables, we examined sanitation as another independent variable, categorized as flushing toilet versus no flushing toilet. We also examined how the dietary variables were related to anthropometric and biochemical indices of nutritional status and how maternal BMI and MUAC related to other indices.

To investigate the relationship of categorical SES, education, food security, and time since menarche with nutritional status, biochemical status, and dietary practices, bivariate relationships were assessed for each variable using mixed-model analysis of covariance (ANCOVA) including the study design controls.

To determine which factors predict abnormal anthropometric and biochemical status, we first collapsed factor categories to high-risk and low-risk groups to have adequate sample size in each category and then used mixed-model logistic regression. We first assessed the bivariate relationship with only the study design controls and the individual predictor included in the models to determine associated predictors ($P < 0.05$). Multivariate models were then constructed including maternal age, season at measurement, and all associated predictors to determine the strength of relationships. For all analyses, all

Table 2. **Dietary intake among study participants in early pregnancy ($n = 1552$)**

Food group	Mean ± SD times per week consumed
Dairy products	2.4 ± 3.1
ASF	10.3 ± 7.3
GLV	4.4 ± 4.5
RLV	0.5 ± 1.6
Vitamin C–rich fruits and vegetables	4.0 ± 6.1

ASFs, animal-source foods; GLVs, green leafy vegetables; RLVs, red leafy vegetables.

tests were two-sided, at 5% level of significance, and we accounted for the cluster randomization using a random effect of cluster and union nested within subdistrict.

Results

We included 1552 pregnant adolescents in the analysis. Average age was 17.4 ± 1.3 years, average gestational age at enrollment was 13.0 ± 3.4 weeks, and average schooling was 6.5 ± 2.7 years. Eighty percent were pregnant for the first time and 47.5% were living in food insecure households.

As shown in Table 1, 44% of the pregnant adolescents were short for their age, and 36% had low BMI, whereas a smaller percentage had low MUAC (10%). Although 28% were anemic, only 4% had low serum ferritin and 7% had elevated sTfR (markers of ID), suggesting that a large proportion of anemia was not due to ID. The prevalence of IDA was 5%. About one-third had vitamin A deficiency, and median UIC was 49.1 μg/L, suggesting a high level of iodine deficiency. Prevalence of inflammation was 13%.

Table 2 shows that ASFs were consumed an average of 10 times per week, with dairy products comprising about one-fourth of the total for ASF. Green leafy vegetables were consumed 4.4 times per week, and vitamin C–rich fruits and vegetables were consumed four times per week, whereas red leafy vegetables were rarely consumed (less than once per week).

Tables 3–6 show the bivariate results for the key predictors of nutrition-related indices and dietary intake. SES was positively associated with maternal height, weight, BMI, MUAC, CRP, and consumption of dairy products, ASF, and green leafy vegetables (Table 3). For example, comparing the lowest versus highest SES quintiles, mean height was 149.4 versus 151.4 cm, the percentage with low BMI was 41.4% versus 28.7%, and the consumption of ASF was 7.1 versus 11.0 times/week. There was no association of SES with maternal Hb, ferritin, sTfR, RBP, UIC, AGP, or consumption of vitamin C–rich fruits or red leafy vegetables.

Maternal education was positively associated with maternal height, weight, BMI, MUAC, and consumption of ASF, dairy products, and vitamin C–rich fruits and vegetables (Table 4). For instance, comparing those with no education to those who completed secondary education, the mean height was 147.0 versus 152.5 cm, and consumption of ASFs was 7.1 versus 10.0 times/week. There was no association of education with maternal Hb, ferritin, sTfR, RBP, UIC, CRP, AGP, or consumption of red leafy vegetables.

Higher food security was positively associated with maternal height, weight, AGP, and consumption of ASFs, dairy products, and vitamin C–rich fruits and vegetables (Table 5). For example, comparing those with severe food insecurity to those considered food secure, the mean height was 149.0 versus 150.6 cm, and the consumption of ASF was 6.2 versus 10.1 times/week. There was no association of food security with maternal BMI, MUAC, Hb, ferritin, sTfR, RBP, UIC, CRP, or consumption of green leafy vegetables or red leafy vegetables.

Time since menarche >3 years was positively associated with maternal BMI and negatively associated with consumption of vitamin C–rich fruits and vegetables (Table 6). For instance, the mean BMI was 19.0 kg/m^2 among those whose time since menarche was ≤3 years compared with 19.5 kg/m^2 among those whose time since menarche was >3 years. There was no association of this variable with average maternal height, weight, MUAC, Hb, ferritin, sTfR, RBP, UIC, CRP, AGP, or consumption of ASFs, dairy products, green leafy vegetables, or red leafy vegetables. However, the prevalence of anemia and vitamin A deficiency was lower among those whose time since menarche was ≤3 years.

Table 7 shows the bivariate relationships with the dichotomous indicators of nutritional status, as well as those that remained significant when all of the significant predictive factors were included in a multivariate model. In the multivariate models, short

Table 3. Bivariate association of SES quintile with anthropometric, dietary, and biochemical indicators of pregnant adolescents

Indicator	SES category: Lowest ($n = 309$)	Low ($n = 311$)	Middle ($n = 311$)	High ($n = 310$)	Highest ($n = 311$)	P value
Height (cm)	149.4 ± 5.5	149.6 ± 5.6	150.3 ± 5.6	150.7 ± 5.2	151.4 ± 5.3	<0.0001
Weight (kg)	42.8 ± 5.6	43.0 ± 5.4	43.6 ± 5.7	44.2 ± 5.5	46.1 ± 6.0	<0.0001
BMI (kg/m^2)	19.2 ± 2.2	19.2 ± 2.0	19.3 ± 2.2	19.5 ± 2.2	20.1 ± 2.4	<0.0001
Low BMI (%)[a]	41.4	39.6	36.5	31.8	28.7	0.0057
MUAC (cm)	23.7 ± 2.2	23.8 ± 2.0	23.9 ± 2.2	24.1 ± 2.0	24.8 ± 2.2	<0.0001
Hb (g/L)	115.7 ± 11.2	114.1 ± 13.5	115.9 ± 13.4	115.9 ± 11.8	116.6 ± 11.3	0.7390
Anemia (%)[a]	28.2	30.4	29.5	27.4	26.4	0.9834
Ferritin (μg/L)[b]	63.5 (41.4, 86.8)	62.2 (39.5, 99.7)	72.0 (40.8, 99.4)	67.6 (35.1, 99.5)	65.2 (34.0, 93.7)	0.7520
sTfR (mg/L)[b]	4.8 (4.2, 5.9)	4.8 (4.0, 5.8)	4.7 (4.0, 5.7)	4.8 (4.1, 5.9)	5.1 (4.0, 6.0)	0.5000
RBP (μmol/L)[b]	1.3 (1.2, 1.6)	1.3 (1.1, 1.6)	1.3 (1.2, 1.6)	1.3 (1.0, 1.6)	1.3 (1.2, 1.6)	0.1584
Vitamin A deficiency	27.1	39.1	28.4	42.1	24.1	0.0529
UIC (μg/L)[b]	51.0 (30.1, 96.0)	45.5 (27.8, 83.2)	46.8 (20.1, 86.1)	50.9 (26.6, 89.8)	55.5 (28.9, 121.9)	0.2080
CRP (mg/L)[b]	0.6 (0.2, 1.6)	0.9 (0.4, 1.8)	0.6 (0.4, 1.5)	0.8 (0.4, 2.5)	0.9 (0.5, 2.4)	0.0188
AGP (g/L)[b]	0.6 (0.5, 0.8)	0.6 (0.5, 0.8)	0.6 (0.5, 0.8)	0.6 (0.5, 0.8)	0.6 (0.5, 0.7)	0.8229
Dairy products (times/week)[c]	0 (0, 2)	0 (0, 4)	0 (0, 4)	1 (0, 6)	3 (0, 7)	<0.0001
ASF (times/week)[c]	7 (3, 12)	9 (5, 13)	9 (5, 14)	10 (6, 15)	11 (7, 16)	<0.0001
GLV (times/week)[c]	2 (1, 5)	3 (2, 6)	3 (2, 6)	3 (1, 6)	4 (2, 6)	0.0006
RLV (times/week)[c]	0 (0, 0)	0 (0, 0)	0 (0, 0)	0 (0, 0)	0 (0, 0)	0.4772
Vitamin C–rich fruits and vegetables (times/week)[c]	1 (0, 4)	1 (0, 5)	2 (0, 7)	1 (0, 7)	2 (0, 7)	0.1713

Values are mean ± SD, except where otherwise indicated.
BMI, body mass index; MUAC, mid-upper arm circumference; Hb, hemoglobin; sTfR, soluble transferrin receptor; RBP, retinol-binding protein; UIC, urinary iodine concentration; CRP, C-reactive protein; AGP, α1 acid glycoprotein; ASFs, animal-source foods; GLVs, green leafy vegetables; RLVs, red leafy vegetables.
[a]Values are percentage, $n = 1486$.
[b]Log transformed for analysis. Values are median (quartile 1, quartile 3), $n = 454$.
[c]Square root transformed for analysis. Values are median (quartile 1, quartile 3), $n = 1552$.

stature was predicted by low SES, low education, and more years since menarche. Low BMI was predicted by low SES. Anemia was related to higher intake of dairy products and was less likely in adolescents with low BMI. No variables were predictive of low MUAC, low ferritin, high sTfR, ID, IDA, or low RBP.

Discussion

There is a high burden of undernutrition among these Bangladeshi adolescents in early pregnancy. More than one-third were underweight, and 28% were anemic. On average, they had relatively low consumption of dairy products, green and red leafy vegetables, and vitamin C–rich fruit and vegetables. SES, education, and food security were generally positively associated with anthropometric status and dietary intake in early pregnancy, but not with iron, vitamin A, or iodine status.

Though research among pregnant adolescents is rare, several studies in Bangladesh also reported a high burden of undernutrition in adolescent girls. In a nearby study area, 49% of adolescent girls were stunted (height-for-age Z-score <–2) and 40% were underweight (weight-for-age Z-score <–2).[17] Another earlier study in rural Bangladesh showed that 59% of adolescent girls were thin (defined as BMI <fifth percentile of World Health Organization (WHO)-recommended reference) and 48% were stunted (height for age < third percentile NCHS/WHO).[18] Among adolescent female factory workers, 65% were short (height-for-age < third percentile of NCHS reference values).[19] Rah *et al.* showed that pregnant adolescent girls in Bangladesh did not grow in height, and their BMI, MUAC, and

Table 4. Bivariate association of education with anthropometric, dietary, and biochemical indicators of pregnant adolescents

Indicator	No education ($n = 64$)	Primary incomplete ($n = 255$)	Primary complete ($n = 234$)	Secondary incomplete ($n = 821$)	Secondary complete or higher ($n = 178$)	P value
	Education category					
Height (cm)	147.0 ± 6.2	148.8 ± 6.0	149.8 ± 4.9	150.7 ± 5.2	152.5 ± 5.3	<0.0001
Weight (kg)	42.4 ± 5.6	42.5 ± 5.5	43.6 ± 5.5	44.2 ± 5.6	46.2 ± 6.4	<0.0001
BMI (kg/m^2)	19.6 ± 2.3	19.2 ± 2.0	19.4 ± 2.3	19.4 ± 2.2	19.9 ± 2.4	<0.0001
Low BMI (%)[a]	34.9	39.5	36.3	35.3	30.2	0.5534
MUAC (cm)	24.1 ± 2.2	23.7 ± 2.1	24.1 ± 2.1	24.1 ± 2.1	24.5 ± 2.3	0.0030
Hb (g/L)	115.7 ± 13.7	115.8 ± 12.4	114.7 ± 13.3	115.8 ± 12.5	115.6 ± 9.3	0.9769
Anemia (%)[a]	33.3	26.2	35.2	26.4	29.6	0.6108
Ferritin (μg/L)[b]	71.4 (57.3, 114.1)	61.2 (43.7, 99.4)	70.9 (40.4, 100.0)	62.4 (36.0, 93.1)	80.5 (43.2, 113.1)	0.1803
sTfR (mg/L)[b]	5.3 (4.5, 6.3)	4.9 (4.0, 6.0)	4.7 (4.2, 5.6)	4.8 (4.1, 5.8)	4.8 (3.9, 6.0)	0.6454
RBP (μmol/L)[b]	1.3 (1.2, 1.7)	1.3 (1.2, 1.5)	1.3 (1.1, 1.6)	1.3 (1.1, 1.6)	1.3 (1.1, 1.5)	0.9085
Vitamin A deficiency	27.8	23.1	36.6	34.1	31.5	0.2369
UIC (μg/L)[b]	61.5 (43.6, 95.7)	56.1 (27.6, 105.0)	47.3 (27.1, 88.0)	43.9 (26.1, 87.7)	57.3 (24.0, 121.7)	0.0970
CRP (mg/L)[b]	1.4 (0.6, 2.6)	0.6 (0.2, 1.8)	0.7 (0.3, 1.6)	0.7 (0.4, 1.9)	0.8 (0.5, 1.7)	0.2745
AGP (g/L)[b]	0.7 (0.6, 0.9)	0.6 (0.5, 0.9)	0.6 (0.5, 0.8)	0.6 (0.5, 0.8)	0.6 (0.5, 0.8)	0.3835
Dairy products (times/week)[c]	0 (0, 3)	0 (0, 2)	0 (0, 4)	1 (0, 7)	3 (0, 7)	<0.0001
ASF (times/week)[c]	7 (4, 13)	8 (4, 14)	9 (4, 14)	9 (6, 15)	10 (7, 15)	0.0078
GLV (times/week)[c]	3 (2, 6)	3 (1, 6)	3 (1, 5)	3 (2, 6)	4 (2, 8)	0.1213
RLV (times/week)[c]	0 (0, 0)	0 (0, 0)	0 (0, 0)	0 (0, 0)	0 (0, 0)	0.5584
Vitamin C–rich fruits and vegetables (times/week)[c]	0 (0, 3)	1 (0, 5)	1.5 (0, 7)	1 (0, 6)	2 (0, 8)	0.0195

Values are mean ± SD, except where otherwise indicated.
BMI, body mass index; MUAC, mid-upper arm circumference; Hb, hemoglobin; sTfR, soluble transferrin receptor; RBP, retinol-binding protein; UIC, urinary iodine concentration; CRP, C-reactive protein; AGP, α1 acid glycoprotein; ASFs, animal-source foods; GLVs, green leafy vegetables; RLVs, red leafy vegetables.
[a]Values are percentage, $n = 1486$.
[b]Log transformed for analysis. Values are median (quartile 1, quartile 3), $n = 454$.
[c]Square root transformed for analysis. Values are median (quartile 1, quartile 3), $n = 1552$.

percent body fat declined over time when compared with a group of nonpregnant adolescents.[1] Taken together, these studies indicate that a significant proportion of rural and urban adolescent Bangladeshi girls suffer from undernutrition, which may be made worse by pregnancy.

The positive associations that we observed between anthropometric indicators and both SES and education are not surprising and suggest that these indicators will improve with socioeconomic development and better education. Fewer years since menarche was associated with lower BMI. This implies that increasing the time to first pregnancy since menarche may improve birth outcomes, consistent with other evidence showing a potentially higher risk of poor pregnancy outcomes among adolescents who become pregnant within a few years of menarche, compared with those who become pregnant later.[20]

The high prevalence of anemia among these pregnant adolescents is consistent with other studies in Bangladesh. For example, in a study that assessed anemia and iodine deficiency among children, adolescents, and pregnant women in a nationally representative sample, 25% of adolescent girls were anemic.[21] In our study, anemia was associated with higher intake of dairy products. One possible mechanism is the inhibition of nonheme iron absorption by calcium and casein present in dairy products.[22] However, only, 10% of our study

Table 5. Bivariate association of food security with anthropometric, dietary, and biochemical indicators of pregnant adolescents

	Food security category				
Indicator	Severely food insecure ($n = 114$)	Moderately food insecure ($n = 402$)	Mildly food insecure ($n = 221$)	Food secure ($n = 815$)	P value
Height (cm)	149.0 ± 5.5	150.2 ± 5.5	150.0 ± 5.6	150.6 ± 5.4	0.0265
Weight (kg)	42.9 ± 5.7	43.6 ± 5.8	43.5 ± 5.4	44.4 ± 5.7	0.0111
BMI (kg/m^2)	19.3 ± 2.1	19.3 ± 2.2	19.3 ± 2.0	19.6 ± 2.3	0.1760
Low BMI (%)[a]	38.5	39.3	34.9	33.5	0.3262
MUAC (cm)	23.8 ± 2.0	23.9 ± 2.2	24.1 ± 2.0	24.2 ± 2.2	0.1017
Hb (g/L)	116.1 ± 11.4	116.2 ± 12.2	115.8 ± 11.7	115.2 ± 12.7	0.9490
Anemia (%)[a]	20.0	29.5	27.0	29.7	0.5206
Ferritin (μg/L)[b]	57.4 (40.1, 104.4)	57.7 (36.7, 96.2)	61.9 (29.3, 107.6)	72.1 (40.7, 96.5)	0.5080
sTfR (mg/L)[b]	4.5 (4.0, 6.8)	4.8 (4.1, 5.8)	5.1 (4.1, 6.6)	4.9 (4.0, 5.8)	0.5035
RBP (μmol/L)[b]	1.2 (1.0, 1.6)	1.3 (1.2, 1.6)	1.3 (1.1, 1.7)	1.3 (1.1, 1.6)	0.1735
Vitamin A deficiency	42.5	23.2	31.7	35.1	0.0755
UIC (μg/L)[b]	51.2 (25.3, 85.1)	40.3 (23.5, 68.8)	44.0 (27.1, 84.7)	54 .0 (28.0, 108.1)	0.1637
CRP (mg/L)[b]	0.5 (0.3, 1.8)	0.6 (0.3, 1.2)	1.3 (0.5, 2.4)	0.8 (0.4, 1.9)	0.0766
AGP (g/L)[b]	0.6 (0.5, 0.8)	0.6 (0.5, 0.8)	0.7 (0.5, 0.9)	0.6 (0.5, 0.8)	0.0259
Dairy products (times/week)[c]	0 (0, 2)	0 (0, 4)	1 (0, 6)	1 (0, 7)	<0.0001
ASF (times/week)[c]	6 (3, 11)	8 (4, 12)	8 (5, 13)	10 (6, 15)	<0.0001
GLV (times/week)[c]	2 (1, 6)	3 (2, 6)	3 (1, 6)	3 (1, 6)	0.1288
RLV (times/week)[c]	0 (0, 0)	0 (0, 0)	0 (0, 0)	0 (0, 0)	0.2775
Vitamin C–rich fruits and vegetables (times/week)[c]	0 (0, 3)	1 (0, 6)	1 (0, 6)	2 (0, 7)	0.0174

Values are mean ± SD, except where otherwise indicated.
BMI, body mass index; MUAC, mid-upper arm circumference; Hb, hemoglobin; sTfR, soluble transferrin receptor; RBP, retinol-binding protein; UIC, urinary iodine concentration; CRP, C-reactive protein; AGP, α1 acid glycoprotein; ASFs, animal-source foods; GLVs, green leafy vegetables; RLVs, red leafy vegetables.
[a]Values are percentage, $n = 1486$.
[b]Log transformed for analysis. Values are median (quartile 1, quartile 3), $n = 454$.
[c]Square root transformed for analysis. Values are median (quartile 1, quartile 3), $n = 1552$.

population exhibited ID, so this potential mechanism may not play a major role. The relatively low rate of ID and IDA in our study is consistent with the most recent micronutrient survey in Bangladesh, which indicated that 7.1% of nonpregnant, nonlactating women were iron deficient, and only 4.8% had IDA—nearly identical to our prevalence of 5%.[23] The low prevalence of ID in our study may be attributable to the high iron content of groundwater in this area of Bangladesh.[24] The lack of association of anemia or biomarkers of ID with SES, education, and food security suggests that these outcomes may have other causes not investigated in our study.

With regard to other micronutrient deficiencies, our cohort had a relatively high prevalence of vitamin A deficiency (32%) and a very low median UIC (49.1 μg/L), indicative of iodine deficiency. Other studies in Bangladesh have reported similar results. In a study implemented in central Bangladesh, 51% of pregnant women were found to have low vitamin A status (serum retinol <1.05 μmol/L).[25] That study also revealed that gestational age was negatively associated with serum retinol concentration and per-capita household expenditure on food, MUAC, and SES was positively associated with serum retinol concentration. Other investigators have reported that BMI and sanitation condition were associated with vitamin A deficiency in rural pregnant women in Bangladesh.[26] With respect to iodine deficiency, other studies in Bangladesh have also found a high level of iodine deficiency among pregnant women. For example, in the study by Harun-Or-Rashid *et al.*,

Table 6. **Bivariate association of time since menarche with anthropometric, dietary, and biochemical indicators of pregnant adolescents**

Indicator	Menarche category: ≥3 years since menarche ($n = 1443$)	Menarche category: <3 years since menarche ($n = 105$)	P value
Height (cm)	150.3 ± 5.4	150.1 ± 6.4	0.7433
Weight (kg)	44.0 ± 5.7	42.9 ± 5.4	0.0583
BMI (kg/m^2)	19.5 ± 2.2	19.0 ± 1.9	0.0430
Low BMI (%)[a]	35.1	43.2	0.1394
MUAC (cm)	24.1 ± 2.2	23.8 ± 1.9	0.2119
Hb (g/L)	115.4 ± 12.4	118.6 ± 10.3	0.1642
Anemia (%)[a]	29.5	13.3	0.0304
Ferritin (μg/L)[b]	64.9 (36.8, 97.9)	76.1 (45.2, 100.0)	0.1307
sTfR (mg/L)[b]	4.8 (4.1, 5.9)	4.9 (4.2, 5.8)	0.9282
RBP (μmol/L)[b]	1.3 (1.1, 1.6)	1.5 (1.3, 1.7)	0.2446
Vitamin A deficiency	33.3	20.0	0.0424
UIC (μg/L)[b]	49.1 (26.9, 92.5)	52.0 (28.6, 73.6)	0.7716
CRP (mg/L)[b]	0.8 (0.4, 1.9)	0.6 (0.3, 1.2)	0.1332
AGP (g/L)[b]	0.6 (0.5, 0.8)	0.7 (0.6, 0.8)	0.6505
Dairy products (times/week)[c]	1 (0, 6)	1 (0, 4)	0.7966
ASF (times/week)[c]	9 (5, 14)	8 (4, 15)	0.6114
GLV (times/week)[c]	3 (1, 6)	4 (2, 6)	0.2653
RLV (times/week)[c]	0 (0, 0)	0 (0, 0)	0.9851
Vitamin C–rich fruits and vegetables (times/week)[c]	1 (0, 6)	2 (0, 8)	0.0270

Values are mean ± SD, except where otherwise indicated.

BMI, body mass index; MUAC, mid-upper arm circumference; Hb, hemoglobin; sTfR, soluble transferrin receptor; RBP, retinol-binding protein; UIC, urinary iodine concentration; CRP, C-reactive protein; AGP, α1 acid glycoprotein; ASFs, animal-source foods; GLVs, green leafy vegetables; RLVs, red leafy vegetables.

[a]Values are percentage, $n = 1486$.

[b]Log transformed for analysis. Values are median (quartile 1, quartile 3), $n = 454$.

[c]Square root transformed for analysis. Values are median (quartile 1, quartile 3), $n = 1552$.

38% of adolescent girls were reported to be iodine deficient (UIC < 100 μg/L).[21] In a study conducted in northwest Bangladesh, the reported median UIC was 65.9 μg/L (quartile 1, 33.6 and quartile 3, 133.1), and median UIC was positively associated with higher levels of iodine in the household salt samples.[14] Given that 77–79% of household salt samples in that study had less than 15 ppm iodine (the lowest cutoff of the WHO recommendation),[14] improving the iodine content in iodized salt is a must for improving iodine status in the Bangladeshi population. In addition, iodine supplementation of pregnant and lactating women may be necessary to meet their extra needs.[27]

Our findings also align with other studies that reported poor dietary and nutrient intake of nonpregnant and pregnant adolescent girls in Bangladesh. In a recent study among pregnant women in southwest Bangladesh, the reported overall dietary diversity was low, and consumption of dairy foods, legumes and nuts, eggs, and vitamin A–rich vegetables and fruits was poor.[3] That study also found that dietary diversity was associated with education, husband's occupation, number of family members, and number of rooms in the home, and that consumption of eggs was associated with SES.[3] Another study in rural Bangladesh revealed that mean intakes of energy, iron, zinc, calcium, magnesium, folate, and vitamins D and E were below recommended levels in both pregnant adolescents and adults.[28] In a comparison of low-income urban and rural adolescents in Bangladesh, the percentage who never ate meat or fish was higher in urban areas than in rural areas.[29] In our study, we found that SES and food security were associated with ASF intake. SES was not associated with intake of red

Table 7. **Bivariate and multivariate relationships between key factors and nutritional status of adolescents in early pregnancy**

Outcome	Type of relation	No flushing toilet	Lowest socioeconomic status tertile	No or incomplete primary education	Severe or moderate food insecurity	Menarche within last 3 years	Low BMI	Animal source foods per week below median	Dairy per week below median
Short stature[a]	Bivariate	1.38 (0.99, 1.93)	1.58 (1.27, 1.96)	2.17 (1.68, 2.80)	1.20 (0.97, 1.50)	0.64 (0.41, 0.99)	—	1.15 (0.93, 1.41)	1.18 (0.96, 1.45)
	Multivariate	—	1.33 (1.05, 1.68)	1.97 (1.50, 2.58)	—	0.80 (0.49, 1.32)	—	—	—
Low weight[b]	Bivariate	1.58 (1.14, 2.20)	1.86 (1.47, 2.35)	1.72 (1.31, 2.26)	1.39 (1.10, 1.75)	1.20 (0.77, 1.86)	—	1.25 (1.01, 1.55)	0.95 (0.77, 1.18)
	Multivariate	1.25 (0.89, 1.76)	1.60 (1.24, 2.05)	1.37 (1.02, 1.83)	1.21 (0.95, 1.55)		—	—	—
Low BMI[c]	Bivariate	1.37 (0.96, 1.97)	1.40 (1.11, 1.75)	1.19 (0.91, 1.54)	1.22 (0.97, 1.53)	1.38 (0.90, 2.12)	—	0.93 (0.75, 1.15)	1.07 (0.86, 1.34)
	Multivariate	—	1.39 (1.11, 1.75)	—	—	—	—	—	—
Low MUAC[d]	Bivariate	1.59 (0.86, 2.97)	1.23 (0.86, 1.74)	1.15 (0.77, 1.73)	1.15 (0.81, 1.65)	0.93 (0.45, 1.90)	—	1.03 (0.73, 1.44)	1.23 (0.87, 1.74)
	Multivariate	—	—	—	—	—	—	—	—
Inflammation[e]	Bivariate	0.79 (0.35, 1.78)	1.10 (0.62, 1.95)	1.40 (0.73, 2.69)	0.50 (0.26, 0.95)	0.99 (0.33, 2.95)	0.90 (0.51, 1.60)	0.56 (0.32, 0.97)	0.62 (0.36, 1.07)
	Multivariate	—	—	—	0.47 (0.24, 0.93)	—	—	0.62 (0.35, 1.11)	
Low ferritin[f]	Bivariate	1.98 (0.25, 15.49)	1.29 (0.46, 3.65)	1.54 (0.48, 4.96)	1.66 (0.60, 4.60)	0.57 (0.07, 4.44)	0.83 (0.30, 2.27)	1.15 (0.42, 3.15)	0.82 (0.30, 2.25)
	Multivariate	—	—	—	—	—	—	—	—
High sTfR[g]	Bivariate	2.05 (0.47, 8.98)	1.28 (0.61, 2.66)	1.47 (0.63, 3.43)	0.94 (0.44, 2.01)	0.86 (0.19, 3.87)	0.70 (0.32, 1.52)	0.97 (0.47, 1.96)	0.98 (0.48, 2.00)
	Multivariate	—	—	—	—	—	—	—	—
Iron deficiency[h]	Bivariate	1.76 (0.51, 6.01)	1.26 (0.64, 2.45)	1.26 (0.57, 2.78)	1.10 (0.56, 2.15)	0.66 (0.15, 2.94)	0.83 (0.42, 1.63)	1.05 (0.55, 1.99)	1.12 (0.59, 2.14)
	Multivariate	—	—	—	—	—	—	—	—
Anemia[i]	Bivariate	0.82 (0.43, 1.56)	0.89 (0.57, 1.40)	0.94 (0.55, 1.61)	0.90 (0.58, 1.41)	0.38 (0.13, 1.12)	0.61 (0.39, 0.95)	0.83 (0.55, 1.25)	0.57 (0.37, 0.86)
	Multivariate						0.59 (0.37, 0.94)		0.58 (0.38, 0.90)
Iron-deficiency anemia[j]	Bivariate	1.51 (0.33, 6.93)	0.71 (0.27, 1.86)	1.27 (0.45, 3.59)	0.86 (0.34, 2.17)	0.55 (0.07, 4.37)	0.58 (0.22, 1.53)	0.95 (0.41, 2.22)	1.04 (0.45, 2.43)
	Multivariate	—	—	—	—	—	—	—	—
Vitamin A deficiency[k]	Bivariate	0.44 (0.14, 1.40)	0.73 (0.26, 2.07)	0.51 (0.12, 2.28)	0.52 (0.17, 1.59)	1.71 (0.37, 7.81)	0.80 (0.30, 2.15)	0.96 (0.38, 2.40)	1.24 (0.49, 3.14)
	Multivariate	—	—	—	—	—	—	—	—

Values are OR (95% CI). First row per outcome is bivariate analyses adjusting for study design controls. Second row per outcome is multivariate analyses including significant ($P < 0.05$) covariates, maternal age, season at measurement, and study design controls. Low MUAC, green leafy vegetables per week below median, red leafy vegetables per week below median, and vitamin C–rich foods per week below median were also tested as covariates but were not significant in any bivariate results (data not shown). Missing cells for the bivariate models are because anthropometric variables are not used for association with other anthropometric variables at the same time point. Missing cells in multivariate rows are because the association was not significant for the bivariate relationship.

[a]Short stature, defined as height-for-age Z score <–2, or <150.1 cm if 19 years.

[b]Low weight, defined as weight <45 kg.

[c]Low BMI, defined as body mass index <18.5 kg/m^2.

[d]Low MUAC, defined as MUAC <21.5 cm.

[e]Inflammation, defined as α1 acid glycoprotein >1 g/L or CRP > 5 mg/L.

[f]Low ferritin, defined as serum ferritin <12 μg/L.

[g]High sTfR, defined as soluble transferrin receptor >8.3 mg/L.

[h]Iron deficiency, defined as ferritin <12 μg/L or sTfR > 8.3 mg/L.

[i]Anemia, defined as hemoglobin <110 g/L.

[j]Iron-deficiency anemia, defined as Hb <110 g/L and either ferritin <12 μg/L or sTfR > 8.3 mg/L.

[k]Vitamin A deficiency, defined as retinol-binding protein <1.17 μmol/L.

leafy vegetables, which suggests that affordability of these foods is not a constraint to their consumption, and that they may be an underutilized source of some key nutrients. However, as we used a short version of a 7-dayFFQ, we could not report on some food groups (e.g., nuts and legumes).

Our study has a number of limitations. Because we included only adolescents who were pregnant, this study should not be generalized to all female adolescents. Moreover, we used a short FFQ that was primarily developed to understand whether the women were eating less of some specific food items during pregnancy, and therefore it did not include certain food groups (e.g., carbohydrate-rich foods and seeds). Lastly, we did not adjust the ferritin and sTfR values for inflammation, because the best methods for doing so are still under discussion; as a result, our estimate of the prevalence of ID may be an underestimate. However, this is not likely to make a large difference, because only 13% of the study population had inflammation.

Given that adolescent pregnant girls in Bangladesh have a high prevalence of low BMI, micronutrient deficiency, and poor dietary quality, interventions targeted toward improving diets of adolescents and preventing micronutrient and macronutrient deficiencies are urgently needed. Such interventions need to address the accessibility, affordability, and demand for nutrient-rich foods for this target group. On the demand side, behavior change communication directed toward adolescents is essential, and at the social environmental level, parents of adolescents can promote healthy eating by providing advice and modeling appropriate food selection and home-cooked meals.[30] Household vegetable gardens are also associated with improved dietary diversity scores.[31] Fortification of oil with vitamin A has the potential to address vitamin A deficiency, as oil is consumed widely and in significant amounts,[32] and universal salt iodization and/or provision of additional iodine supplements for pregnant adolescents are also critical. Understanding factors that predict nutritional status can help to identify pregnant adolescents at highest risk, facilitating the targeting of appropriate interventions. Because pregnancy is a time when women are engaged with the health system and are receptive to health messages, it is a window of opportunity for improving health outcomes among adolescents and their future children.

Acknowledgments

We thank Camila Chaparro, Megan Deitchler, and Zeina Maalouf-Manasseh from the Food and Nutrition Technical Assistance Project (FANTA); Rina Rani Paul, Sohrab Hossain, Dhiman Dutt, Laura Reichenbach, Anisur Rahman, Sushil Kanta Dasgupta, Ahmedul Hasan Khan, Showkat Ali Khan, Zakia Siddiqui, Atikul Islam Shah, Jyotish Chadra Mallik, Swapan Kumar Chanda, Rubhana Raqib, Md. Rabiul Islam, AEM Motiur Rahman, Md. Nurunnabi Ashakhy, Golam Sarwar, and other research team members and collaborators at icddr,b; Stacy Saha, Louise Tina Day, Swapan Pahan, Altaf Hossain, Shafiul Alam, Pronoy Ganguly, and other collaborators from LAMB; and Md. Barkat Ullah, Kassandra Harding, Christine Stewart, Janet M. Peerson, Rebecca Young, and Stephen A. Vosti from UC Davis for their technical input and support during the implementation of the study. We also thank Juergen Erhardt from the VitMin Lab, Willstaett, Germany for the analysis of blood samples. Our research intervention was incorporated into the community heath and development program of LAMB, which was supported by Plan-Bangladesh in six of the 11 study unions. We also acknowledge funding support from the Sackler Foundation for writing the manuscript.

Competing interests

The authors declare no competing interests.

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