

# Rice-based diets in rural Bangladesh: how do different age and sex groups adapt to seasonal changes in energy intake?<sup>1-3</sup>

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## ABSTRACT

**Background:** Seasonality has been recognized as a key determinant of human energy balance, especially in low-income countries.

**Objective:** The objective was to test the hypothesis that, in rural Bangladesh, different age and sex groups adapt similarly to seasonal changes in energy intake (EI).

**Design:** A prospective study was carried out in 2 rural Bangladeshi villages in the lean and peak seasons. Data on anthropometric measures (weight, height, and midupper arm circumference) and dietary food intake (collected with the use of a 24-h food weighing method) were obtained from all subjects from 304 households.

**Results:** The average EI increased from a least-squares mean ( $\pm$  SE) of  $7.87 \pm 0.10$  MJ  $\cdot$  person<sup>-1</sup>  $\cdot$  d<sup>-1</sup> in the lean season to  $9.47 \pm 0.13$  MJ  $\cdot$  person<sup>-1</sup>  $\cdot$  d<sup>-1</sup> in the peak season. In children and adolescents aged < 18 y of age, the prevalence of underweight (weight-for-age) was not significantly different (56%) in the 2 seasons. Among adults, a significantly higher prevalence of chronic energy deficiency [body mass index (in kg/m<sup>2</sup>) < 18.5] was observed in the peak season (67%) than in the lean season (61%), despite a higher EI in the peak season. Other determinants of seasonal nutritional status are presented.

**Conclusions:** Seasonal fluctuations in EI were substantial in all age and sex groups. Children and adolescents showed no significant seasonal changes in the prevalence of underweight, which indicated that they adapted to changes in EI. In adults, the season in which EI was high coincided with average weight loss, which indicated that adults did not adapt fully to seasonal fluctuations in EI and that seasonal energy expenditure is probably a major determinant of nutritional status. *Am J Clin Nutr* 2003;78:406–13.

**KEY WORDS** Seasonality, anthropometry, underweight, chronic energy deficiency, Bangladesh, children, adolescents, adults, physical activity level

## INTRODUCTION

Seasonality has long been recognized as a key determinant of nutritional status in humans in low-income countries because of its role in food production, food access and availability, morbidity, and mortality (1–3). More recently, the role of climatic seasonality on human energetics has been emphasized because of its significant role not only in food and energy intakes (EIs) but also in physical activity and thus energy expenditure (4–9).

Earlier cross-sectional studies on food intake in weanlings in rural Bangladesh suggest that intrahousehold food allocation favored boys more than girls (1). Subsequently, longitudinal studies

on the intrahousehold distribution of foods in rural Bangladesh showed that EI in women and older children remained constant throughout the year when EI was related to body size, whereas young girls had particularly low EIs (2, 10).

One appropriate way to evaluate and compare EI between groups with different body sizes is to express EI as a ratio of EI to basal metabolic rate (BMR). This approach has been used widely in affluent societies, mainly to identify the extent of underreporting (11–13), but can also be used in low-income countries (14).

Body weight is a sensitive nutritional outcome measure that can be used in studies of seasonal fluctuations in energy balance. Seasonal exposure of low EI is reported to cause moderate weight loss in adults, usually not exceeding 10% of the maximum annual value of body weight (3). These values, however, were much lower in short Indian women with an average body mass index (BMI; in kg/m<sup>2</sup>) of 18 (weight loss of 0.3 kg) than in tall Beninese women with an average BMI of 20 (weight loss of 1.0 kg) (4, 6). In children, the nutritional outcome measure of seasonality on energy balance may be further affected by other factors, such as incidence of infectious diseases (15, 16) and lack of care (17).

Most published studies on the relation of seasonality to nutrition security have been carried out in subgroups of a study population, eg, in children aged < 5 y (1, 18) or in adults (4–6). In the present study, the effects of seasonality were studied in the whole population of selected villages. The hypothesis tested was that different age and sex groups in rural Bangladesh adapt to seasonal fluctuations in EI similarly.

## SUBJECTS AND METHODS

### Study area

The fieldwork was conducted in 2 villages. One village was in the Shebalaya thana, Manikganj district, a flooded, double-rice-cropped area west of Dhaka (hereafter called the Manikganj village). The other

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village was located in Fulbaria thana, Mymensingh district, which is a nonflooded, triple-rice-cropped area northeast of Dhaka (hereafter called the Mymensingh village). In the Manikganj village, the agricultural production system can be characterized as traditional, whereas the practiced farming system in the Mymensingh village can be characterized as modern. Both villages have a subtropical monsoon climate, with the *rabi* (dry) season lasting from November to March and the *kharif* (rainy) season lasting from April to October. The monsoon season generally lasts from July to October.

In Bangladesh, the 3 rice-harvest seasons are the Aman (November–December), the Aus (March–April), and the Boro (May–June). The Aman harvest is traditionally the most important, but the Boro harvest has become more important during the past decade because of the introduction of high-yielding rice varieties and modern technology. The present study was undertaken during 2 seasons in 1995–1996. The first season, the lean season (October–November), represents the months immediately preceding the main rice harvest and is characterized as a time of few work opportunities, low household food stocks, and increased rice prices. The second season, the peak season (February–March), represents the postharvest months and is characterized as a time of abundant rice, relatively low rice prices, and hard work for both males and females in relation to postharvest activities (17, 19). No food- or nutrient-intervention programs took place in the villages during the study.

#### Study population and sampling design

The study population comprised 152 households in both villages selected from 4 socioeconomic subgroups following the probability proportion to size method. The study population was considered to be rural poor because 45% of the households were landless, and the land size of the remaining households was < 10 acres (average: 2.7 acres, or  $\approx 10\,927\text{ m}^2$ ). The 4 subgroups were characterized on the basis of the Bangladesh rural population tax system: 1) group A represented the poorest, landless group, who were not required to pay any local tax; 2) group B represented the less-poor group, who paid a token tax; 3) group C represented the rural middle class, who paid an appreciable amount of tax; and 4) group D represented the least poor, who paid the highest proportion of tax. The present study used the same techniques to collect anthropometric data, dietary intakes, and information on the general questionnaire as used in the national nutrition surveys of rural Bangladesh in 1962–1964, 1975–1976, and 1981–1982 (19).

Of the 304 households studied in the lean season, data could not be collected from 13 households during the peak season because the household occupants had either migrated to another area or were visiting relatives in neighboring villages. A complete set of data, therefore, was available for 1361 persons during the lean season and for 1281 persons during the peak season. Of this population group, 1030 persons participated in the study during both seasons. The study was approved by the Academic Committee, University of Dhaka, Bangladesh, following the guidelines for study approval. Informed consent was obtained from the heads of all selected households.

#### Anthropometric measures

The height, weight, and midupper arm circumference (MUAC) of all members of the selected households were obtained during house visits in both seasons. A portable beam balance was used to measure weight to the nearest 0.5 kg after the subjects removed their shoes and heavy clothing. The balances were frequently checked with the use of standard weights. Two types of wooden scales were used for measuring height: one

for measuring recumbent length to the nearest centimeter in children aged < 24 mo and the other for measuring height to the nearest centimeter in older children and adults. The investigators collecting the anthropometric data underwent extensive training in the field and at the Institute of Nutrition and Food Science, University of Dhaka; strict control of the measurement procedures was maintained throughout the study.

The nutritional status of children and adolescents was expressed as weight-for-age, which is considered the most appropriate indicator of nutritional status in seasonal studies. The proportion of underweight children was defined as those children having weight-for-age values < -2 SD of the median of the National Center for Health Statistics (NCHS) standards. Furthermore, the proportion of wasted children, defined as children aged  $\leq 24$  mo with weight-for-length values < -2 SD and as children aged > 24 mo with weight-for-height values < -2 SD of the median of the median of the NCHS standards was calculated. The nutritional status of adults (here defined as > 18 y of age) was expressed as BMI and was calculated as weight (kg)/height<sup>2</sup> (m). The international criterion for classification of chronic energy deficiency (CED) was used: BMI < 16.0, severe energy deficiency; BMI between 16.0 and 16.9, moderate CED; BMI between 17.0 and 18.4, mild CED; and BMI > 18.5, no energy deficiency (20).

#### Dietary intake

The dietary intakes of subjects from the selected households were obtained by trained investigators, who were well known to the household occupants, using a 24-h actual food weighing method. All days of the week were equally represented in the collection of dietary intakes. Before the investigation began, the investigators practiced the techniques of food weighing and recording in the laboratory for 2 wk and then conducted a pilot survey in a village close to Dhaka city. The field training continued until the inter- and intrainvestigator variations were minimal. Two investigators were assigned to 2 households, which were situated close to each other, for 1 d and then were moved on to the next 2 households. All foods that went into the household's cooking pots were weighed. Each subject's portions of cooked foods were weighed. Leftover foods (of which there was little) were weighed. During both survey rounds, the same supervisor checked all of the collected data on food intake before data coding. If the subjects from a household were absent from a meal, arithmetic adjustments were made to obtain a full 24-h dietary intake. All children, including breast-fed infants, were included in the study. The breast milk intakes of all children aged 0–24 mo were estimated by using specific data on breast-milk intakes in children in Bangladesh (21). All foods were converted into raw foods before the energy values were computed with the use of tables of nutrient composition of Bangladeshi foods (22).

#### Calculation of estimated basal metabolic rate and the ratio of basal metabolic rate to energy intake

BMR was estimated for each subject aged 18–60 y by using Schofield's age- and sex-specific equations, which are based on body weight, as adapted by the FAO/WHO/UNU in 1985 (23). Ratios of EI to BMR were calculated for each adult as described by Goldberg et al (11) and Black (24).

#### General questionnaire

A pretested questionnaire was completed by each head of household. The questionnaire included information on the main

**TABLE 1**  
Height, body weight, and midupper arm circumference (MUAC) of children and adolescents, by sex and age group<sup>1</sup>

Age group (y) <sup>3</sup>	Height		Body weight		MUAC <sup>2</sup>
	Lean season	Peak season	Lean season	Peak season	
	cm		kg		mm
<b>Female</b>					
0 to <3 (n = 43 and 42)	68.9 ± 9.45	69.0 ± 9.06	7.1 ± 2.0	7.3 ± 2.0	125 ± 13.7
3 to <6 (n = 54 and 50)	93.2 ± 8.73	93.1 ± 8.38	12.0 ± 2.4	12.3 ± 2.0	143 ± 11.2
6 to <10 (n = 88 and 85)	114.6 ± 10.9	114.7 ± 10.4	18.2 ± 3.9	18.2 ± 3.7	156 ± 13.3
10 to <18 (n = 100 and 99)	139.4 ± 11.4	140.7 ± 11.2	32.4 ± 8.7	33.1 ± 8.4	198 ± 27.7
<b>Male</b>					
0 to <3 (n = 55 and 48)	73.5 ± 8.25	74.6 ± 9.20	8.1 ± 2.0	8.7 ± 2.0	133 ± 17.7
3 to <6 (n = 62 and 60)	95.0 ± 7.03	95.2 ± 8.56	12.9 ± 2.2	13.2 ± 2.1	144 ± 10.9
6 to <10 (n = 89 and 82)	115.0 ± 10.4	115.6 ± 11.4	18.3 ± 3.9	18.7 ± 4.3	154 ± 12.9
10 to <18 (n = 126 and 120)	145.5 ± 13.9	146.2 ± 14.1	34.0 ± 9.3	34.7 ± 9.6	196 ± 26.7
<b>P<sup>4</sup></b>					
Season	<0.001		<0.001		NS
Age group	<0.001		<0.001		<0.001
Sex	<0.005		<0.001		NS
Village	<0.005		NS		NS
Socioeconomic group	<0.001		<0.001		<0.001
Season × age group	<0.001		NS		<0.01
Season × sex	<0.001		<0.01		NS

<sup>1</sup> $\bar{x} \pm \text{SD}$ .

<sup>2</sup>Average of the 2 seasons.

<sup>3</sup>n values are for the lean and peak seasons, respectively.

<sup>4</sup>Univariate ANOVA.

occupation and education of the head of the household as well as housing conditions.

### Data analysis

All analyses were performed with the Statistical Analysis System statistical software package version 8 (25). Univariate analysis of variance was performed with the MIXED procedure (26). In the statistical model, anthropometric measures, EI, energy contribution from rice (as a percentage), and the ratio of EI to BMR were evaluated as dependent variables. Village, season, socioeconomic group, age group, and sex were included as independent fixed variables. Households nested within village and subjects nested within both household and village were included as random effects in the statistical model. All main effects were evaluated as well as two-factor interactions between all fixed effects; three-factor interactions between season, sex, and age group; four-factor interactions of season, sex, age group, and village; and five-factor interactions between season, village, sex, age, and socioeconomic group. Tukey's test was used for the post hoc detection of significant pairwise comparisons.

Age groups were defined by using the WHO's classification in equations for prediction of BMR (23). In the analyses of anthropometric measures, children aged 3–10 y were further divided into 2 age groups: 3–6 and 6–10 y. Analyses of anthropometric measures were done separately for children and adolescents (0–18 y) and for adults (>18 y) to separate the effect of growth between seasons. Likewise, women who were pregnant, lactating, or pregnant and lactating were excluded from the analyses of anthropometric measures to avoid the confounding effects of pregnancy and lactation.

Plots and histograms of residuals were used to investigate homogeneity of variance and normal distribution among random effects. Depending on the number of observations, the Shapiro-Wilk's or Kolmogorov-Smirnov's test for normal distribution was

performed. The analyses showed it necessary to transform both EI and the ratio of EI to BMR with square root and to square the energy contribution from rice. Least-squares means and SEs were estimated and transformed back where necessary before presentation. Only P values for main effects and significant interactions are presented.

The prevalence of underweight children and adolescents (0–18 y) and the prevalence of CED (BMI < 18.5) for adults aged > 18 y were analyzed by logistic regressions with the use of the SAS macro GLIMMIX (26). The same fixed and random variables were included as in the analysis of variance.

## RESULTS

### Study population

All calculations and statistical analyses included the total study population (1361 subjects in the lean season and 1281 in the peak season) and were compared with the same calculations and statistical analyses conducted on the subgroup of 1030 subjects who participated during both rounds. Because no significant differences were obtained, the results for the total group are presented.

The persons who participated in the study were evenly divided by sex (Tables 1 and 2). Preliminary data from socioeconomic groups C and D were not significantly different; therefore, the data for these groups were merged for all subsequent statistical analyses. The main occupation of the heads of households, share cropping and wage labors, was related to farming. All households with access to land grew rice, the principal crop.

### Nutritional status

The descriptive anthropometric data are presented as means ± SDs for age and sex groups (Tables 1 and 2). The univariate analyses of variance on the data for children and adolescents showed

TABLE 2

Height, body weight, BMI, and midupper arm circumference (MUAC) of adults, by sex and age group<sup>1</sup>

Age group (y) <sup>3</sup>	Height <sup>2</sup> <i>cm</i>	Body weight		BMI		MUAC	
		Lean season	Peak season	Lean season	Peak season	Lean season	Peak season
		<i>kg</i>		<i>kg/m<sup>2</sup></i>		<i>mm</i>	
Female							
18 to <30 ( <i>n</i> = 74 and 74)	149.8 ± 5.3	41.0 ± 5.1	40.8 ± 5.2	18.1 ± 2.1	18.2 ± 2.0	225 ± 18.3	223 ± 19.8
30 to <60 ( <i>n</i> = 148 and 143)	150.5 ± 5.5	41.0 ± 6.5	40.5 ± 6.8	18.4 ± 2.6	18.3 ± 2.7	228 ± 23.3	225 ± 24.6
≥60 ( <i>n</i> = 45 and 40)	155.2 ± 5.9	37.1 ± 7.0	36.4 ± 6.5	17.8 ± 2.6	17.4 ± 2.4	216 ± 22.1	212 ± 22.0
P and L <sup>4</sup> ( <i>n</i> = 101 and 87)	150.1 ± 5.3	41.6 ± 5.9	40.9 ± 4.1	18.7 ± 2.2	18.3 ± 1.6	221 ± 17.8	218 ± 17.9
Male							
18 to <30 ( <i>n</i> = 120 and 108)	161.5 ± 6.2	47.3 ± 5.5	47.2 ± 5.6	18.1 ± 1.7	18.0 ± 1.6	237 ± 16.7	236 ± 17.7
30 to <60 ( <i>n</i> = 206 and 187)	159.6 ± 6.8	48.8 ± 7.1	48.3 ± 7.2	18.8 ± 2.7	18.7 ± 2.7	245 ± 21.1	243 ± 20.7
≥60 ( <i>n</i> = 60 and 55)	155.2 ± 5.6	44.7 ± 6.9	44.4 ± 7.0	17.7 ± 2.3	17.6 ± 2.2	232 ± 25.4	231 ± 26.3
<i>P</i> <sup>5</sup>							
Season	NS	0.001		0.001		0.001	
Age group	0.001	0.001		0.001		0.001	
Sex	0.001	0.001		NS		0.001	
Village	NS	0.01		0.01		0.01	
Socioeconomic group	NS	0.01		0.01		0.001	
Season × age group	NS	NS		NS		0.05	
Season × village	NS	0.05		0.05		NS	
Sex × age group	0.001	NS		NS		NS	

<sup>1</sup> $\bar{x} \pm$  SD.<sup>2</sup>Average of the 2 seasons.<sup>3</sup>*n* values are for the lean and peak seasons, respectively.<sup>4</sup>Pregnant and lactating females, excluded from the statistical analyses.<sup>5</sup>Univariate ANOVA.

significant seasonal effects on height and weight (Table 1). The age effect was significant for height, body weight, and MUAC, whereas the sex effect was significant only for height and weight. A significant effect of village on height was also observed. The effect of socioeconomic group was significant for all anthropometric measurements. Height was significantly affected by season × age and by season × sex. Weight was significantly affected by season × sex and MUAC by season × age (Table 1).

In the adults, the univariate analyses of variance showed no seasonal effects on height but significant effects on weight, BMI, and MUAC (Table 2). The mean weight of all adults, excluding all pregnant and lactating women, declined by 0.8 ± 0.2 kg from the lean to the peak season (data not shown). The mean weight of adults in the Manikganj village was 2.1 kg higher than the mean weight of adults in the Mymensingh village (data not shown). The effect of age was significant for all anthropometric measures. Sex

significantly affected all anthropometric measures in adults, except for BMI. Weight was significantly affected by village, socioeconomic group, and season × village. BMI was significantly affected by village, socioeconomic group, and season × village, whereas MUAC was significantly affected by village, socioeconomic group, and season × age (Table 2).

### Dietary energy intake and food consumption

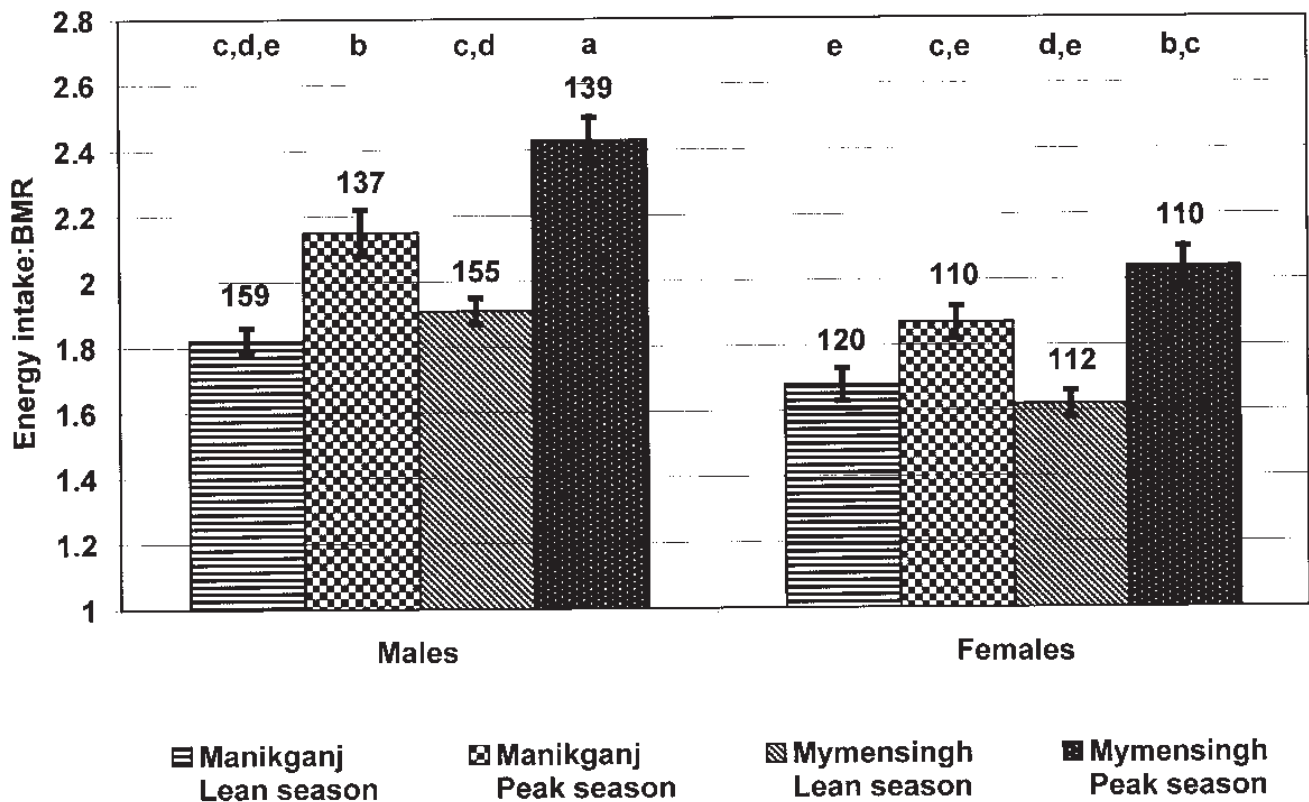
Dietary EI was affected significantly by season, age, sex, village, season × village, and sex × age (Table 3). The average EI (least-squares mean ± SE) for all subjects increased by 20% from 7.87 ± 0.10 MJ · person<sup>-1</sup> · d<sup>-1</sup> in the lean season to 9.47 ± 0.13 MJ · person<sup>-1</sup> · d<sup>-1</sup> in the peak season. Except for the age group 0–3 y, EI was consistently lower in females than in males. The energy contribution from rice, expressed as a percentage of total EI, was 80.3 ± 0.82% for all age groups, excluding the 0–3 y age

TABLE 3

Seasonal energy intake, by sex and age group<sup>1</sup>

Age group (y)	Female		Male	
	Lean season	Peak season	Lean season	Peak season
	<i>MJ · person<sup>-1</sup> · d<sup>-1</sup></i>			
0 to <3	2.5 ± 0.5 [43]	3.1 ± 0.5 [42]	2.7 ± 0.4 [55]	2.8 ± 0.4 [48]
3 to <10	4.4 ± 0.2 [142]	5.9 ± 0.2 [135]	5.3 ± 0.2 [151]	6.4 ± 0.2 [142]
10 to <18	6.5 ± 0.2 [100]	8.3 ± 0.3 [99]	8.6 ± 0.3 [126]	10.6 ± 0.3 [120]
18 to <30	6.9 ± 0.2 [74]	9.1 ± 0.3 [74]	11.4 ± 0.3 [120]	13.3 ± 0.3 [108]
30 to <60	7.3 ± 0.2 [148]	9.1 ± 0.2 [143]	10.6 ± 0.2 [206]	13.1 ± 0.3 [187]
≥60	6.3 ± 0.4 [45]	8.8 ± 0.4 [40]	9.3 ± 0.2 [60]	11.3 ± 0.4 [55]
P and L <sup>2</sup>	8.5 ± 0.4 [101]	9.6 ± 0.3 [87]	—	—

<sup>1</sup>Least-squares  $\bar{x} \pm$  SE; *n* in brackets.<sup>2</sup>Pregnant and lactating, excluded from the statistical analyses. Significant effect of season (*P* < 0.001), age (*P* < 0.001), sex (*P* < 0.001), village (*P* < 0.01), season × village (*P* < 0.001), and sex × age (*P* < 0.001).



**FIGURE 1.** Least-squares mean ( $\pm$  SE) ratios of energy intake to basal metabolic rate (BMR) in the adult population by sex, season, and village. The *n* values for each group are given above each bar. Bars with different letters are significantly different,  $P < 0.05$ .

group. The univariate analysis of variance showed no significant differences between seasons, sex, or socioeconomic groups. However, the energy contribution from rice was significantly ( $P < 0.01$ ) higher in the Mymensingh village ( $79.0 \pm 0.82\%$ ) than in the Manikganj village ( $75.9 \pm 0.82\%$ ).

#### Ratio of energy intake to predicted basal metabolic rate

The ratios of EI to BMR in the adult population between 18 and 60 y disaggregated by sex, season, and village ( $P = 0.790$ ) are shown in **Figure 1**. The univariate analysis of variance showed significant effects of sex ( $P < 0.001$ ), village ( $P = 0.005$ ), season  $\times$  village ( $P < 0.001$ ), and socioeconomic group  $\times$  village ( $P < 0.05$ ). No significant differences were observed between age groups, socioeconomic groups, or seasons. Neither the three-factor (season, sex, and age group), the four-factor (sex, season, age, and village), or the five-factor (sex, season, age, village, and socioeconomic status) interactions were significant.

#### Seasonal changes in nutritional status

##### Children

The average prevalence of underweight in children and adolescents was 56.5%, and no seasonal or sex differences were observed (**Table 4**). The risk of being classified as underweight was significantly higher in the young age groups (0–3, 3–6, and 6–10 y) than in 10–18 y age group. Socioeconomic status of the head of households also significantly affected the risk of being classified as underweight ( $P < 0.001$ ), and the prevalence of underweight children was higher in socioeconomic groups A and

B than in groups C and D. Village did not affect the prevalence of underweight significantly.

##### Adults

A significant effect of season on the prevalence of CED ( $P < 0.001$ ) was observed in adults, the prevalence being higher in the peak season (67%) than in the lean season (61%) (**Table 5**). Sex had no effect on the prevalence of CED, whereas the effects of age ( $P < 0.05$ ), socioeconomic group ( $P < 0.05$ ), and village ( $P < 0.005$ ) were significant. A reduction in the cutoff value for CED from 18.5 to 17.0 in the statistical analysis did not alter these results.

#### DISCUSSION

The results of the present study do not fully support our hypothesis that different age and sex groups in this population (rural poor with a high dependency on the local agricultural seasonal pattern) adapt to seasonal changes in EI similarly. Seasonal fluctuations in EI varied considerably in all groups. Adults with a high EI had a significantly lower average body weight and a significantly higher prevalence of CED in the peak season than in the lean season, which indicated that the adults were not capable of adapting fully to the seasonal fluctuations. The weight loss was probably due to the high physical activity level in the peak season due to heavy postharvest activities. On the contrary, children and adolescents showed no seasonal changes in the prevalence of underweight.

In the present study, the measurements of EI from the dietary survey were evaluated and compared between groups by applying

TABLE 4

Logistic regression analysis of determinants of underweight in children and adolescents<sup>1</sup>

Determinant	Underweight %	Odds ratio (95% CI)	P
Season			0.111
Peak (n = 586)	57	1.10 (0.98, 1.26)	
Lean (n = 617)	56	1.00	
Age group (y)			<0.001
0 to <3 (n = 188)	72	2.98 (1.91, 4.64)	
3 to <6 (n = 226)	66	2.08 (1.37, 3.12)	
6 to <10 (n = 344)	56	1.51 (1.05, 2.16)	
10 to <18 (n = 445)	46	1.00	
Sex			0.419
Male (n = 642)	57	1.13 (0.84, 1.51)	
Female (n = 561)	56	1.00	
Socioeconomic group			<0.001
A (n = 508)	65	2.27 (1.56, 3.29)	
B (n = 367)	56	1.67 (1.13, 2.48)	
C and D (n = 328)	45	1.00	
Village			0.142
Manikganj (n = 583)	57	1.26 (0.92, 1.71)	
Mymensingh (n = 620)	56	1.00	

<sup>1</sup>n = 1203. Underweight is defined as a weight < -2 SD of the median of the National Center for Health Statistics weight-for-age standards.

the ratio of EI to BMR. In evaluations of group mean EI in studies with > 100 subjects, EI:BMR can be compared directly with values of physical activity level (24). Application of the EI:BMR to the group of adults between 18 and 60 y of age showed that the average EI:BMR for the rural Bangladeshi women ranged from  $1.62 \pm 0.04$  (least-squares  $\bar{x} \pm SE$ ) in the lean season in the Mymensingh village to  $2.04 \pm 0.07$  in the peak season in the same village (Figure 1). The EI:BMR for men showed the same pattern, ranging from  $1.82 \pm 0.04$  in the lean season in the Manikganj village to  $2.43 \pm 0.07$  in the peak season in the Mymensingh village. According to international recommendations, EI:BMR values for women of 1.64 and for men of 1.78 correspond to moderate occupational work, whereas ratios of 1.82 for women and of 2.10 for men correspond to heavy occupational work (23, 27, 28). The lack of significant differences in EI:BMR values between socioeconomic groups was surprising but was mainly explained by the fact that EI was not affected significantly by the socioeconomic groups studied. In the present study, the high EI:BMR values for both men and women in the peak season were well above international recommendations for heavy occupational work. The true EI:BMR values may be even higher because it is recognized that Schofield's equations for estimating BMR (23) may overestimate BMR in small persons, such as those included in the present study. Therefore, these results raise the question of whether the ratios of EI to BMR for heavy occupational work suggested in the abovementioned study are appropriate for women and men of low body mass living in rural areas of developing countries.

In an earlier analysis of the dietary energy sharing index in rural Bangladesh, Wheeler (10) concluded that sex differences in EI were related to differences in body size and that the women's energy needs were met to the same degree as were the men's. EI:BMR values in the present study were higher for men than for women, which suggests that the men had a higher share of the dietary energy in the household. However, in comparisons of the outcome measures of nutritional status, the prevalence of underweight children and adolescents, and

TABLE 5

Logistic regression analysis of determinants of chronic energy deficiency (CED) in adults<sup>1</sup>

Determinant	CED %	Odds ratio (95% CI)	P
Season			<0.001
Peak (n = 607)	67	1.23 (1.07, 1.40)	
Lean (n = 653)	61	1.00	
Age group (y)			0.028
>60 (n = 200)	71	1.14 (0.72, 1.79)	
30 to <60 (n = 684)	60	0.69 (0.50, 0.95)	
18 to <30 (n = 376)	68	1.00	
Sex			0.988
Male (n = 736)	64	1.00 (0.75, 1.33)	
Female (n = 524)	64	1.00	
Socioeconomic group			0.023
A (n = 465)	71	1.41 (0.98, 2.02)	
B (n = 419)	61	0.95 (0.66, 1.36)	
C and D (n = 376)	60	1.00	
Village			0.004
Mymensingh (n = 618)	70	1.60 (1.12, 2.02)	
Manikganj (n = 642)	59	1.00	

<sup>1</sup>n = 1260. Pregnant and lactating females were excluded from the statistical analyses.

the prevalence of CED in the adults, no sex differences were observed in the present study, which supports Wheeler's earlier conclusion.

In the present study, the dietary energy contribution from rice (on average  $\approx 80\%$ ) was constant in both seasons. However, rice contributed significantly more energy in the Mymensingh village, which has a modern rice production system, than in the Manikganj village, which has a more traditional farming system. The high rice intake confirms the strong dependency on this one food item in rural Bangladesh.

The values for the anthropometric indexes height-for-age and weight-for-age in children and adolescents agreed with earlier data from The Nutrition Survey of Rural Bangladesh 1981–1982 (19) and from several minor studies of rural children (1, 2). Weight-for-age is moderately sensitive to seasonal changes and, thus, is often used as a short-term indicator of undernutrition (29). In Bangladesh, the Bangladesh Bureau of Statistics (BBS) conducts nutrition surveys of young children between 6 and 71 mo of age at 2–3-y intervals. The BBS reports that the prevalence of malnutrition in this age group is decreasing by  $\approx 0.5\%$  annually and that the prevalence of weight-for-age of 71.5% in 1985–1986 had decreased to 68.3% in 1992 and to 62.4% in 1995–1996 (30). Thus, the BBS data on prevalence of underweight are similar to the data from the present study (Table 4). However, weight-for-age may underestimate malnutrition in a stunted population, such as the one described in the present study. On the basis of weight-for-height in the present study, the prevalence of wasting (defined as < -2 SD of the median of the NCHS weight-for-height standards) in the 0–3 y age group was 17%, a value similar to that of 15.8% reported by the BBS for 1995–1996. Thus, both the BBS data and the WHO data are comparable with the prevalence of both underweight and wasting observed in the present study (30, 31).

The dietary EIs for children and adolescents were significantly higher in the peak season (when food was abundant and rice prices were low) than in the lean season. However, it has been shown in

other studies that dietary seasonality may have less bearing on nutritional status in children aged 1–5 y than in older age groups because of the seasonality of infections (3) and other sociocultural characteristics. In Bangladesh, strong seasonal differences in diarrheal disease and other infectious illnesses have been observed, which may lead to malabsorption, reduced appetite, or both (32). Furthermore, the nutritional status of children is particularly sensitive to the care provided by the mother (33). Seasonality of the workload of the women in the household may thus be another important determinant of the nutritional status of the children. In the present study, no seasonal differences in the prevalence of underweight children or adolescents were observed, which confirms that the weight of children and adolescents is determined by several factors other than EI. The logistic regression analysis showed that the risk of underweight was 3 times higher in children aged 0–3 y than in those aged 10–18 y. In addition, the risk of being underweight in the lower socioeconomic group was 2.3 times that in the more well-off socioeconomic groups.


The statures of the adult population in the present study are similar to those reported in earlier studies in this and similar population groups (15, 17); the mean ( $\pm$ SD) BMI of nonpregnant and nonlactating females was  $18.2 \pm 0.24$  and of males was  $18.4 \pm 0.27$ . As expected, no seasonal differences were found in height, whereas significant seasonal differences were found in body weight and thereby BMI (Table 2). MUAC was affected significantly by season, age, sex, village, and socioeconomic group (Table 2) in the same way as was body weight. MUAC has been proposed as a selective indicator of the peripheral wasting of muscle and subcutaneous adipose tissue (34).

Contrary to the findings of other studies on seasonality and human energetics in adults in Bangladesh (2, 17), India (35), and Africa (6, 36), the present study showed a lower average body weight in the peak season than in the lean season. An earlier study in rural Bangladesh showed lower morbidity in adult men and women in the peak season than in the lean season (17). However, morbidity was not measured in the present study. The decrease in the prevalence of CED in adults in the present study is thus mainly explained by the failure of these adults to compensate for the amount of energy expenditure related to the high level of physical activity.

The functional implications of the high prevalence of CED in the present study may be critical for rural populations. Earlier studies have shown that work performance (measured as maximum oxygen consumption per kilogram body weight) is lower under conditions of chronic malnutrition, probably because of a disproportionate reduction in lean tissue than in fat tissue in the more severely malnourished subjects (37). In a group of urban adult Bangladeshi men, a significant inverse association was found between a BMI  $< 18.5$  and work-disabling morbidity (38). Thus, the functional productive and reproductive consequences of the seasonal pattern of high EI associated with increased CED in adults should be explored further.

The accepted focus of the nutritional status of children in this population group (rural poor with a high dependency on the local agricultural seasonal pattern) turned out to be a poor indicator of seasonal changes in dietary EI. In population groups involved in agriculture and with high seasonal changes in energy expenditure, the present results suggest that seasonal changes in the body weight of adult women and men with a high prevalence or a high risk of CED are the best indicators of inadequate EI.

On the basis of the findings from the present study, we conclude that in rural Bangladesh—where livelihoods depend on the local agricultural pattern—seasonal fluctuations in EI vary substantially

in all age and sex groups. However, the results also indicate that an increase in EI was not sufficient to improve the nutritional status of this population. Energy expenditure resulting from heavy workloads has such a large effect on energy balance, and thereby on body weight, that it cannot be compensated for by increases in EI. 

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IT, SHT, and NH codeveloped the study and were responsible for the study design. NIK and NH were responsible for the fieldwork and data collection. OH was mainly responsible for the statistical analyses. IT drafted the first manuscript and incorporated all comments from the other contributors in the final manuscript.

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