Effect of prenatal food supplementation on birth weight: an observational study from Bangladesh[1–3]

Rubina Shaheen, Andres de Francisco, Shams El Arifeen, Eva-Charlotte Ekström, and Lars Åke Persson

ABSTRACT

Background: National nutrition programs in Bangladesh have included prenatal food supplementation to reduce maternal and child malnutrition. The knowledge base is weak regarding the effect of prenatal food supplementation on the birth weight (BW) of infants in populations in whom low BW is prevalent and regarding any variation in effect based on maternal nutritional status.

Objective: We examined whether observational data support an effect of daily prenatal food supplementation on BW by considering the duration of supplementation and whether the effect is modified by maternal postpartum weight (a proxy of prepregnancy weight) groups.

Design: A cohort of undernourished pregnant women ($n = 777$) who received prenatal food supplementation (608 kcal/d) was followed. The association between the uptake of food supplements and BW was analyzed after adjustment for potential confounders ($n = 619$ with complete information). Differential effects in lower and higher maternal postpartum weight groups were examined.

Results: The average BW was 2521 g. On average, the women received daily supplements for 4 mo, which resulted in an increase in BW of 118 g (1.0 g/d). The strongest effect was found for births occurring in January and February. There was a linear dose-response relation between duration of supplementation and BW for women with higher postpartum weights (≥ 42 kg, above the median). In women with lower weights (< 42 kg, below median), a shorter duration of supplementation (< 4 mo) had no such dose-response relation with BW, but there was a linear dose-response relation for longer durations of supplementation.

Conclusions: The association between duration of prenatal food supplementation and BW varies with maternal postpartum weight. A large effect was observed after the season with food insecurity (mid-August to mid-November).   *Am J Clin Nutr* 2006;83:1355–61.

KEY WORDS   Food supplementation, pregnancy, birth weight, maternal weight, season, Bangladesh

INTRODUCTION

Low birth weight (LBW), ie, BW < 2500 g, is a global public health concern (1). The problem is most prominent in South Asia, where one-half of the world's LBW babies are born (2). LBW is a reflection of intrauterine growth restriction and of a high frequency of preterm delivery (3). LBW results in a high occurrence of child morbidity (4), impaired development (5–8), and mortality (9).

Prenatal food supplementation has been used as one of the strategies to improve fetal development in societies where food insecurity, maternal malnutrition, and LBW are prevalent (10–15) as well as in the poor segment of affluent societies (16). Such interventions have reportedly had mixed results (10–19), although due consideration should be given to variations in the amount and composition of supplements, maternal nutrition status, seasonal variation in food security, and other factors that may influence the effect on fetal growth and maternal nutritional status (20). Thus, the knowledge base is still weak regarding the effectiveness of such interventions.

It has been suggested (21), and later supported by empirical data (22), that the effect of food supplementation is partitioned between the mother and the fetus, depending on the nutritional status of the mother, which may be best represented by her prepregnancy weight. Interestingly, the positive effect of food supplementation on fetal growth is suggested to be lower in most malnourished mothers and larger in mothers with moderate malnutrition (22).

Mean BW frequently varies with season (23–26), which reflects variations in household food security and maternal weight over the year (23). Consequently, the effect of prenatal food supplements on BW may vary with season. In the Gambia the effect of food supplements on BW was higher after the season characterized by food insecurity, ie, June to October (11, 12, 14).

The Bangladesh Integrated Nutrition Project (BINP) was initiated with the long-term goal of improving nutritional status so that malnutrition would cease to be a public health problem (27). As a part of this initiative, BINP and its successor—the National Nutrition Project (NNP)—have offered a comprehensive health and nutrition program to pregnant and lactating women and children aged <2 y, including prenatal food supplementation to women with a body mass index (BMI; in kg/m^2) < 18.5. Benefiting from this ongoing program, we followed a cohort of 777
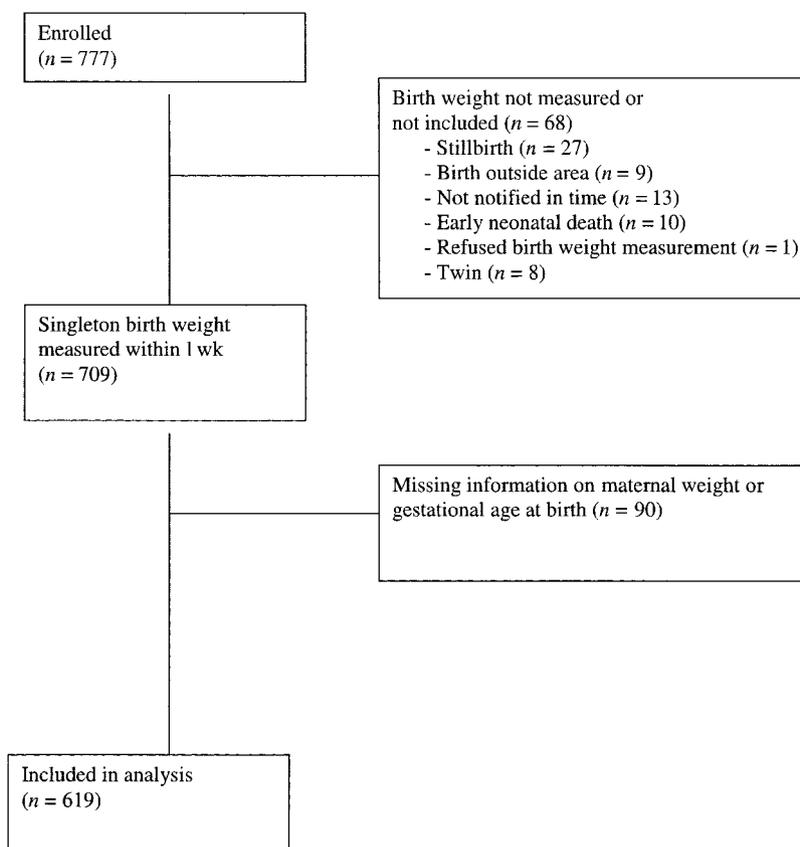
FIGURE 1. Study participation.

pregnant women and examined whether observational data support an effect on BW of a daily prenatal food supplement (608 kcal) that increases the total dose by increasing the number of days of supplementation and is modified by maternal postpartum weight.

SUBJECTS AND METHODS

Study site and subjects

The study was conducted in Shaharasti, one of 7 *upazilas* (subdistricts) in the Chandpur district, Bangladesh. Shaharasti is located adjacent to a river that annually causes moderate to severe flooding in the surrounding area. The main occupation in the area is agriculture, and the main crops are rice, wheat, potatoes, and sugarcane.

The BINP initiated its nutrition-related activities in Shaharasti, including food supplementation during pregnancy, in 1996. Four of 9 unions (administrative units in each subdistrict, each with a population of ≈20 000) in the subdistrict were randomly selected for this study.

The BINP activities were performed at Community Nutrition Centers (CNCs; 52 in the study area) operated by Community Nutrition Promoters, who were women with children and a minimum of about 8 y of schooling. The centers were located in the villagers' houses, and the program activities were run during the morning from Saturday through Thursday. Each CNC covered ≈1200 persons, and the promoter made regular household visits to identify pregnant women and invite them to participate in the activities. Pregnant women with a BMI < 18.5 were eligible to

participate. Usually, Community Nutrition Promoters invited the women to participate in the food supplementation program early in pregnancy. Participating women were invited to visit the CNC 6 d/wk and received health and nutrition education, food supplementation, and iron-folate supplementation (provided monthly, 2 tablets/d; each tablet containing 60 mg Fe and 250 μg folic acid) according to national recommendations. Compliance with the iron-folate supplementation was not monitored.

The preparatory field activities of the study started in November 1998, and BW was measured from December 1998 to October 1999. In 1998 there was a severe flood throughout Bangladesh; the flooding in Shaharasti was excessive through October 1998. BINP activities in the field were stopped during peak flooding and restarted in mid-November 1998. Women participating in the BINP program with calculated probable births (based on last menstrual period) between December 1998 and October 1999 were invited to take part in this study ($n = 777$; **Figure 1**). The fieldworkers regularly visited the 52 CNCs to identify new enrollees. The Ethical Review Committee of ICD-DR,B approved the study. Informed written consent was obtained from each participant.

Food supplementation

Village women employed by the program prepared the food supplements using local products. The prepared food was provided in plastic packets to be mixed with water. The daily supplement contained 80 g roasted rice powder, 40 g roasted pulse powder, 20 g molasses, and 12 mL (6 g) soybean oil, which provided ≈608 kcal and ≈17.9 g vegetable protein (≈11.5% of

total energy). The supplements were usually eaten at the CNC, but were often brought to the participants' homes for consumption in the third trimester.

Measurements

Information on participation in the food supplementation program was retrospectively collected by the fieldworkers, who conducted 3 structured interviews at the participants' homes. The respondents were requested to report how many days they had consumed the supplement. Different important events in the preceding months were used to improve recall. Additional questions were asked to resolve any missing information on supplement intakes. Information on general dietary intakes was not collected.

Standard procedures were followed for anthropometric measurements, and the training of fieldworkers included standardization of measurements (28). The women's weights were measured after birth with a precision of 100 g (model 770; SECA, Hamburg, Germany), and length was measured by using a portable scale with a precision of 1 mm. Ninety-seven percent of the analyzed maternal postpartum weights were assessed within 7 d after birth, at the same time as BWs were measured. A notification system was established for births. Efforts were made to measure BW as soon as possible, preferably within 72 h; 23% were measured within 24 h and 85% within 72 h. BW was measured by using a SECA beam scale (model 725) with a precision of 10 g. BWs measured later than 24 h after delivery, but within 7 d of delivery, were transformed to SD scores by using the distribution in this material as standard. The SD scores obtained were transformed back to the corresponding BWs.

Gestational age at birth was determined on the basis of the date of the last menstrual period. A local calendar sharing Bangla, Arabic, and Gregorian months and dates in parallel and special religious events was used to ensure the accuracy of the dates. Information on maternal age, parity, work (working hours per day), education, and household income was collected in the first interview.

Analyses

Participation in the supplementation program was analyzed by including characteristics of women with and without complete data on days of supplementation, BW, and maternal postpartum weight. Descriptive information on distribution of days of supplementation and BW was presented, and differences in mean values by season of birth were analyzed by analysis of variance with an F test. Associations between these 2 variables were analyzed by linear regression, and stratification for season was done. The main goal was to determine possible dose-response relations between days of supplementation and BW and to determine whether any dose-response relations varied by maternal weight, in this case by postpartum weight. BW was plotted as a function of days of supplementation, and lowess moving average lines (29) were fitted for higher and lower maternal postpartum weight groups (postpartum weight median value <42 = 1, ≥42 = 0). This was followed by multivariate linear regression analyses based on the observations made on the lowess curves, and statistical analysis was done to test the dose-response relation between days of supplementation and BW. Adjustments were made for potential confounding of the dose-response relation. Potential confounding was considered for any cofactor with a P value < 0.20 for any linear or nonlinear association with BW and

total days of supplementation. Confounding by the measured variable was excluded if its influence on the effect estimate was <10%. Analyses were done by using the STATISTICAL PACKAGE FOR SOCIAL SCIENCE (version 12.01; SPSS Inc, Chicago).

RESULTS

Participation

Of 777 women in the supplementation program, 619 with complete information on supplementation during pregnancy, BW, postpartum maternal weight, and gestational age at birth were included in the analysis. No differences in maternal, infant, or socioeconomic characteristics were found between those with or without complete data, except for some differences in maternal height (women with complete data were slightly taller), month or season of birth (women with complete data were better represented in the period from December to February), and days of supplementation (women with complete data had slightly shorter periods of supplementation) (**Table 1**).

Supplementation

On average, the women started to receive food supplementation at week 15, and the mean (±SD) number of days of food supplement intake was 116 ± 40. Provided that the whole daily supplement was consumed (intake not supervised), the average intake was 70 000 kcal. Compliance with supplementation varied considerably over the year; the lowest values were for those born between January and February (83 d). For 201 (32%) of 619 women, the measurements for supplement intake were based on 3 interviews (2 during pregnancy and one after childbirth); for 173 (28%) of 619 women, the measurements were based on 2 interviews (1 during pregnancy and 1 after childbirth); and for 245 (40%) of 619 women, the measurements were based on 1 interview after childbirth. The number of interviews did not vary by maternal postpartum weight group (< 42 and ≥ 42 kg; P = 0.60).

Birth weight

Mean (±SD) BW was 2521 ± 382 g, and 48% of the infants had a low BW (<2500 g). The boys had a mean (±SD) BW of 2556 ± 399 g, and the girls had a mean (±SD) BW of 2486 ± 358 g. There was a marked seasonal variation in BW; the lowest mean (±SD) weights were in the period from January to February (2424 ± 397 g), and the highest weights were in the period from March to October (2550 ± 373 g) (P = 0.001).

Dose-response analyses

Overall, a longer supplementation period was associated with a higher BW (**Figure 2**). For each day of supplementation, BW increased by 1.0 g/d (adjusted for gestational age at birth; P = 0.007). The subset of women who gave birth during January and February had an increase in BW of 2.2 g/d of supplementation (n = 140; adjusted for gestational age; P = 0.053).

The lowess curve from a scatter plot of days of supplementation and BW showed a clear dose-response relation (Figure 2). This was also the case for the subset of women with a postpartum weight above the median (≥42 kg). Women with a postpartum weight below the median (<42 kg) showed no effect of daily

TABLE 1
Characteristics of the participants with complete and incomplete information on days of supplementation, infant birth weight, postpartum maternal weight, and gestational age at birth[1]

Characteristic	Complete data ($n = 619$)[2]	Incomplete data ($n = 158$)[3]
Maternal		
Age (y)	25.7 ± 5.9[4] (615)	26.1 ± 5.8 (155)
Parity (%)		
1	20 (125/615)	21 (33/155)
2	24 (147/615)	21 (32/155)
≥3	56 (343/615)	58 (90/155)
Work (h/d)	8.0 ± 2.1 (584)	7.7 ± 2.1 (139)
Weight after childbirth (kg)	42.4 ± 4.4 (619)	42.3 ± 5.9 (39)
Height (cm)	150.7 ± 4.8 (616)	149.8 ± 5.6[5] (144)
Duration of education (y)	4.2 ± 3.6 (619)	4.4 ± 3.7 (151)
Month of childbirth (%)		
December–February	23 (142/619)	9[6] (14/154)
March–April	22 (138/619)	25[6] (39/154)
May–July	26 (161/619)	28[6] (43/154)
August–October	29 (178/619)	38[6] (58/154)
Duration of supplementation (d)	116.5 ± 40.4 (619)	124.9 ± 41.3[7] (151)
Infant		
Birth weight (g)	2521 ± 382 (619)	2564 ± 354 (91)
Gestational age at birth (d)	273 ± 17 (619)	273 ± 18 (132)
Household		
Income quartiles (taka)[8]	1500, 2500, 4000 (613)	1800, 2500, 4000 (155)

[1] Values in parentheses are *n* or *n* of total *n*.

[2] The number of women may vary because of missing values.

[3] The number of women varies because of missing values; for 3 women, no information was available.

[4] $x \pm$ SD (all such values).

[5,7] Significantly different from the subjects with complete data (Student's *t* test): [5]$P = 0.05$, [7]$P = 0.02$.

[6] Significantly different from the subjects with complete data, $P = 0.001$ (chi-square test).

[8] US$1 = 48.06 Bangladeshi taka (1999). Values represent quartiles 1, 2, and 3, respectively.

The American Journal of Clinical Nutrition

food supplementation on BW unless it was continued beyond 4 mo.

In a regression analysis based on the pattern of effects visualized in Figure 2, we first considered supplementation up to 120 d
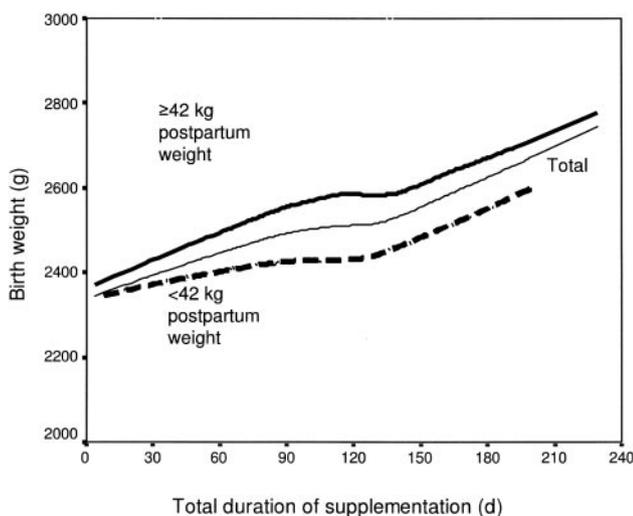

FIGURE 2. Duration of prenatal food supplementation plotted against infant birth weight. Lowess curves for higher (≥42 kg, above median) and lower (<42 kg, below median) maternal postpartum weight groups are shown. For total duration of supplementation <120 d, there was an interaction between duration of supplementation and maternal postpartum weight group ($P = 0.059$); for total duration of supplementation above the median, the lines are parallel when assessed by multiple regression analyses.

and the effects on BW in women with higher and lower postpartum weights (**Table 2**). Potential confounders were evaluated according to the analysis plan. Women with higher postpartum weights (≥42 kg) had an increase in BW of 3 g/d of supplementation, whereas no positive effect on BW was observed in the women with lower postpartum weights. For a longer duration of supplementation (>4 mo), women in both postpartum weight groups showed a dose-response relation of an increase in BW of 1.8 g/d of supplementation. Women with a lower postpartum weight, however, had a linear dose-response relation in parallel with but 113 g lower than the other group.

DISCUSSION

On the basis of this observational study of pregnant women participating in a food supplementation program in Bangladesh, there was an overall dose-response relation of daily food supplementation (608 kcal) that resulted in an increase in BW of 1 g/d, which varied considerably by postpartum weight. BW was least affected in the most malnourished women. Greater effects were found for births during January and February after a period of food insecurity in the community.

Data were collected prospectively by trained fieldworkers. Information on compliance with the supplementation regimen was obtained by repeated dietary recalls, including logical controls of information by questioning about missing information and by using a local calendar of events. Anthropometric information was collected after proper training, standardization of instruments, and retraining over the study period. Most BWs

TABLE 2
Dose-response analyses for subgroups defined by duration of prenatal food supplementation: outcome variable is birth weight (g)[1]

	Supplementation <120 d (n = 312)			Supplementation ≥120 d (n = 307)		
	Coefficient	SEE[2]	P	Coefficient	SEE[2]	P
Intercept	1428.78	323.96	0.000	642.06	365.91	0.080
Supplement (d)	3.12	1.22	0.011	1.75	1.00	0.081
Maternal postpartum weight (<42 = 1, ≥42 = 0)	84.94	142.97	0.553	−112.46	40.58	0.006
Maternal postpartum weight (<42 = 1, ≥42 = 0) × supplement (d)	−3.09	1.63	0.059	—	—	
Gestational age at birth (d)	3.24	1.19	0.007	6.17	1.28	0.001
Adjusted R[2]	0.10	—	—	0.10	—	

[1] As a justification for the stratified analysis presented above, a multiple regression analysis was performed in the total sample (n = 619). The interaction duration of supplementation × maternal postpartum weight group × supplementation duration group was significant (P = 0.077).

[2] Determined by multiple regression (all such values).

were measured within 72 h of childbirth. Efforts were made to obtain the accurate date of the last menstrual period, including the use of different calendars and a list of local events.

The issue of reverse causality, ie, that women who had longer pregnancies had the chance to consume the supplement for a longer time, was addressed by adjusting the multivariate analyses by gestational age at birth.

The external validity of the demonstrated effect size was limited; we showed that factors such as maternal nutritional status and season (most likely a proxy of food security) influenced the size of the effect. Thus, the program may have another effect in a different setting or in another year in the same geographic area. However, the finding of differential effects in women on the basis of postpartum weight is most likely to be shown in other settings and other seasons.

The average effect of supplementation (≈70 000 kcal; no supervised intake) was an increase in BW of 118 g. This effect is comparable with the 136-g overall improvement in BW observed in a study in the Gambia (14) and with the 100-g improvement in BW observed in a study in East Java (13). The average effect found in our study is somewhat lower than the estimates calculated by Lechtig et al (10) a few decades ago: an increase in BW of 25–85 g/10 000 kcal of a balanced supplementation. The lower effect may have been because the actual consumption was lower than the average of 70 000 kcal. Nevertheless, the overall effect obtained in this study was reasonably large, which has potentially significant positive consequences for child health.

Several explanations are possible for the results found in this study. First, for the effect of food supplementation on BW to be visible, the distribution of risk in terms of giving birth to LBW babies and responsiveness in terms of the potential for improvement in BW was favorable in the study population, ie, maternal weight was low, there were enough women who were considered marginally malnourished in the local context, and food was insecure in the study area. Second, the food supplement offered by the BINP was a low-protein, high-calorie food that was found to be more effective at improving BW than were the alternatives (17–19). Third, compared with women in different trials, the women in this observational study had the opportunity to start the supplement early in pregnancy, which increased their total dose.

Recently, the effect of the BINP on childhood underweight has been questioned (30). The authors based their conclusions on an ecologic analysis of prevalence of underweight in intervention and nonintervention areas. Such a crude design does not provide a satisfactory basis for judging the effectiveness of the program. Our data on individual supplementation and BW indicated a substantial effect on BW, although it varied with maternal nutritional status and season.

The results also need to be discussed in the context of BINP performance, as reported by the World Bank (31). The report suggests that the program might have been more successful if it had restricted its attention to the most malnourished women, improved targeting to reduce type II error, and tried harder to discourage leakage and substitution. Although we were unable to answer questions related to leakage (ie, whether the supplements intended for the study subjects were shared with others) and substitution (whether the supplement replaced usual dietary intake), our results suggest that targeting based on a BMI < 18.5 results in a detectable positive effect of supplementation on BW when the biological plausibility of such an effect is likely. However, contrary to the report, we showed that a positive effect is possible in relatively well-nourished women who are marginally malnourished in the local context but who may be considered severely malnourished in the global context; in most malnourished women, no such effects occur. Our results support the seasonal effects presented in the BINP report.

Our study provides evidence for relatively large effects at the beginning of the year—an improvement in BW of ≈183 g after an average of 83 d of supplementation. The usual period of relative food insecurity in Bangladesh is from mid-August to mid-November, ie, 2–5 mo before births in January and February (32–34). Flooding usually occurs in August–September, but during the study year flooding was excessive and of a longer duration. The relatively large effect of supplementation may have been related to the excessive flooding during the months before the study onset and to the pronounced food insecurity that followed.

The association between days of supplementation and BW varied by maternal postpartum weight group. This finding may

have different explanations. Prenatal food supplements consumed by underweight women are partitioned to both the mother and fetus. Winkvist et al (22) have suggested that both mother and fetus may benefit from a supplement. Maternal prepregnancy weight and the dose of the supplement determine the size and partitioning of the effect that preferably should be evaluated over an entire pregnancy cycle (21, 22, 35). Our study lacked information on maternal weight change and was limited to the period from pregnancy to childbirth. The differential effect on BW by lower and higher maternal postpartum weight groups may fit with the principles suggested by Winkvist et al (22). Ideally, we should have had used prepregnancy or early pregnancy weights in the analysis. However, we used maternal postpartum weight as a dichotomous stratification variable with an arbitrary division into 2 groups. Any misclassification into lower and higher maternal weight groups that may have happened through differential pregnancy net weight gains probably had no major influence on the results.

Eligibility for prenatal food supplementation in Bangladesh is limited to women with a BMI < 18.5. This arbitrary criterion should be reexamined because women with a BMI approaching 18.5 in this study had a clear positive effect of food supplementation.

To conclude, we have shown an association between prenatal food supplementation and BW that varied with maternal weight and season. The relatively large effect observed occurred mainly after a period of food insecurity in the study area. These findings may be important in determining which population groups should be targeted for prenatal food supplementation programs. It is possible that malnutrition will cease to be a major public health problem because improvements in BW have positive effects across generations, ie, female newborns with higher BWs will become well-nourished women who later give birth to infants with higher BWs. There is a need to understand the effect of prenatal food supplementation on perinatal mortality because evidence of the direct effect of prenatal food supplementation on mortality is still limited in the context that the relation between size at birth and infant mortality is primarily due to the close relation between birth weight and gestational age at birth.

REFERENCES

1. WHO. WHO's contribution to the report for the follow-up to the world summit for children. Geneva, Switzerland: World Health Organization, 2001.
2. UNICEF. State of world's children 2005. New York, NY: UNICEF, 2004.
3. Villar J, Belizan JM. The relative contribution of prematurity and fetal growth retardation to low birth weight in developing and developed societies. Am J Obstet Gynecol 1982;143:793–8.
4. Villar J, de Onis M, Kestler E, Bolanos F, Cerezo R, Bernedes H. The differential neonatal morbidity of the intrauterine growth retardation syndrome. Am J Obstet Gynecol 1990;163:151–7.
5. Villar J, Belizan JM, Spalding J, Klein RE. Postnatal growth of intrauterine growth retarded infants. Early Hum Dev 1982;6:265–71.
6. Villar J, Smeriglio V, Martorell R, Brown CH, Klein RE. Heterogeneous growth and mental development of intrauterine growth-retarded infants during the first 3 years of life. Pediatrics 1984;74:783–91.
7. Grantham-McGregor SM, Fernald LC. Nutritional deficiencies and subsequent effects on mental and behavioral development in children. Southeast Asian J Trop Med Public Health 1997;28(suppl):50–68.
8. Martorell R, Ramakrishnan U, Schroeder DG, Melgar P, Neufeld L. Intrauterine growth retardation, body size, body composition and physical performance in adolescence. Eur J Clin Nutr 1998;52(suppl):S43–52; discussion S52–3.
9. Ashworth A. Effects of intrauterine growth retardation on mortality and morbidity in infants and young children. Eur J Clin Nutr 1998;52(suppl):S34–41; discussion S41–2.
10. Lechtig A, Habicht JP, Delgado H, Klein RE, Yarbrough C, Martorell R. Effect of food supplementation during pregnancy on birthweight. Pediatrics 1975;56:508–20.
11. Prentice AM, Whitehead RG, Watkinson M, Lamb WH, Cole TJ. Prenatal dietary supplementation of African women and birth-weight. Lancet 1983;1:489–92.
12. Prentice AM, Cole TJ, Foord FA, Lamb WH, Whitehead RG. Increased birthweight after prenatal dietary supplementation of rural African women. Am J Clin Nutr 1987;46:912–25.
13. Kardjati S, Kusin JA, De With C. Energy supplementation in the last trimester of pregnancy in East Java: I. Effect on birthweight. Br J Obstet Gynaecol 1988;95:783–94.
14. Ceesay SM, Prentice AM, Cole TJ, et al. Effects on birth weight and perinatal mortality of maternal dietary supplements in rural Gambia: 5 year randomised controlled trial. BMJ 1997;315:786–90.
15. Mardones-Santander F, Rosso P, Stekel A, et al. Effect of a milk-based food supplement on maternal nutritional status and fetal growth in underweight Chilean women. Am J Clin Nutr 1988;47:413–9.
16. Rush D, Stein Z, Susser M. A randomized controlled trial of prenatal nutritional supplementation in New York City. Pediatrics 1980;65:683–97.
17. de Onis M, Villar J, Gulmezoglu M. Nutritional interventions to prevent intrauterine growth retardation: evidence from randomized controlled trials. Eur J Clin Nutr 1998;52(suppl):S83–93.
18. Osrin D, Costello A. Maternal nutrition and fetal growth: practical issues in international health. Semin Neonatol 2000;5:209–19.
19. Merialdi M, Carroli G, Villar J, et al. Nutritional interventions during pregnancy for the prevention or treatment of impaired fetal growth: an overview of randomized controlled trials. J Nutr 2003;133(suppl):1626S–31S.
20. Persson LA. Breaking the cycles of malnutrition: are pregnancy nutrition interventions effective? J Health Popul Nutr 2001;19:158–9.
21. Winkvist A, Rasmussen KM, Habicht JP. A new definition of maternal depletion syndrome. Am J Public Health 1992;82:691–4.
22. Winkvist A, Habicht JP, Rasmussen KM. Linking maternal and infant benefits of a nutritional supplement during pregnancy and lactation. Am J Clin Nutr 1998;68:656–61.
23. Prentice AM, Whitehead RG, Roberts SB, Paul AA. Long-term energy balance in child-bearing Gambian women. Am J Clin Nutr 1981;34:2790–9.
24. Lawoyin TO, Oyediran AB. A prospective study on some factors which influence the delivery of low birth weight babies in a developing country. Afr J Med Med Sci 1992;21:33–9.
25. Kinabo J. Seasonal variation of birth weight distribution in Morogoro, Tanzania. East Afr Med J 1993;70:752–5.
26. Hort KP. Seasonal variation of birthweight in Bangladesh. Ann Trop Paediatr 1987;7:66–71.
27. World Bank. Staff appraisal report: Bangladesh Integrated Nutrition Project. Washington, DC: Population and Human Resources Division, 1995.
28. WHO. Measuring change in nutritional status: guidelines for assessing the nutritional impact of supplementary feeding programmes. Geneva, Switzerland: World Health Organization, 1983.
29. Cleveland W. Robust locally weighted regression and smoothing scatterplots. J Am Statist Assoc 1979;74:829–36.
30. Hossain SM, Duffield A, Taylor A. An evaluation of the impact of a

US$60 million nutrition programme in Bangladesh. Health Policy Plan 2005;20:35–40.

31. World Bank. Project monitoring assessment report: Bangladesh Integrated Nutrition Project. Washington, DC: World Bank, 2005.

32. Tetens I, Hels O, Khan NI, Thilsted SH, Hassan N. Rice-based diets in rural Bangladesh: how do different age and sex groups adapt to seasonal changes in energy intake? Am J Clin Nutr 2003;78:406–13.

33. Huffman SL, Wolff M, Lowell S. Nutrition and fertility in Bang-ladesh: nutritional status of nonpregnant women. Am J Clin Nutr 1985;42:725–38.

34. Brown KH, Black RE, Becker S. Seasonal changes in nutritional status and the prevalence of malnutrition in a longitudinal study of young children in rural Bangladesh. Am J Clin Nutr 1982;36:303–13.

35. Winkvist A, Jalil F, Habicht J-P, Rasmussen KM. Maternal energy depletion is buffered among malnourished women in Punjab, Pakistan. J Nutr 1994;124:2376–85.