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Exclusive Breastfeeding Reduces Acute Respiratory Infection and Diarrhea Deaths Among Infants in Dhaka Slums

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ABSTRACT. *Objectives.* To describe breastfeeding practices and investigate the influence of exclusive breastfeeding in early infancy on the risk of infant deaths, especially those attributable to respiratory infections (ARI) and diarrhea.

Methods. A prospective observational study was conducted on a birth cohort of 1677 infants who were born in slum areas of Dhaka in Bangladesh and followed from birth to 12 months of age. After enrollment at birth, the infants were visited 5 more times by 12 months of age. Verbal autopsy, based on a structured questionnaire, was used to assign a cause to the 180 reported deaths. Proportional hazards regression models were used to estimate the effect of breastfeeding practices, introduced as a time-varying variable, after accounting for other variables, including birth weight. Overall neonatal, postneonatal and infant mortality, and mortality attributable to ARI and diarrhea were measured.

Results. The proportion of infants who were breastfed exclusively was only 6% at enrollment, increasing to 53% at 1 month and then gradually declining to 5% at 6 months of age. Predominant breastfeeding declined from 66% at enrollment to 4% at 12 months of age. Very few infants were not breastfed, whereas the proportion of partially breastfed infants increased with age. Breastfeeding practices did not differ between low and normal birth weight infants at any age. The overall infant mortality rate was 114 deaths per 1000 live births. Compared with exclusive breastfeeding in the first few months of life, partial or no breastfeeding was associated with a 2.23-fold higher risk of infant deaths resulting from all causes and 2.40- and 3.94-fold higher risk of deaths attributable to ARI and diarrhea, respectively.

Conclusion. The important role of appropriate breastfeeding practices in the survival of infants is clear from this analysis. The reduction of ARI deaths underscores the broad-based beneficial effect of exclusive breastfeeding in prevention of infectious diseases beyond its role in reducing exposure to contaminated food, which may have contributed to the strong protection against diarrhea deaths. *Pediatrics* 2001;108(4). URL: <http://www.pediatrics.org/cgi/content/full/108/4/e67>; *infant mortality, birth weight, breastfeeding, diarrhea, ARI, Bangladesh.*

ABBREVIATIONS. ARI, acute respiratory infection; CI, confidence interval.

There is ample evidence of a positive influence of breastfeeding, especially exclusive breastfeeding, on the survival of the child¹⁻⁵ but less information regarding effects on cause-specific mortality, such as that attributable to acute respiratory infections (ARI) and diarrhea. Yoon et al⁶ reported a higher risk of diarrhea mortality associated with not breastfeeding, whereas the risk for death attributable to ARI, although higher, was not statistically significant. A similar pattern also has been reported from other studies.^{4,7} In a recent meta-analysis of data from 6 developing countries, breastfeeding provided a greater degree of protection against diarrhea deaths than against deaths attributable to ARI in the first 6 months of life, whereas the level of protection was similar for infants who were 6 to 11 months of age.⁸ An important limitation of many of these studies is that they did not use the currently recommended classification of breastfeeding, ie, exclusive, predominant (almost exclusive), and partial,⁹ thus not permitting the protection afforded by each to be assessed.

It also is possible that the positive effect of breastfeeding on survival found in other studies may have been overestimated as a result of confounding. For example, infants with lower birth weight may be less likely to breastfeed or may breastfeed for shorter durations.¹⁰ Because birth weight is a very important determinant of infant survival in both developed and developing countries,¹¹⁻¹⁵ failure to adjust for it or other such factors could explain the observed positive effect of breastfeeding on child survival. The objectives of the current study were to explore the relationships between birth weight and breastfeeding and to assess the effect of exclusive breastfeeding in early infancy on the risk of infant death, especially that attributable to ARI and diarrhea.

METHODS

Study Population and Sample

From November 1993 to June 1995, singleton births to a sample cohort of women who were residents of slum areas in 5 subdistricts of Dhaka City, Bangladesh, were enrolled. Each infant's weight was measured with SECA beam scales (Hamburg, Germany) accurate to 10 g, and information was collected on feeding practices, illnesses since birth, and the mother's perception of the size of the newborn infant. Information on household and parental

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characteristics and the mother's fertility experience had been collected before birth.

Infants were visited at home at approximately 1, 3, 6, 9, and 12 months of age, and structured questionnaires were used to collect information on infant feeding and morbidity. For each infant who died during the study period, information for assigning a cause of death was collected through a verbal autopsy questionnaire. This instrument was administered to the infant's caregiver (usually the mother) at the next follow-up visit. The verbal autopsy questionnaire was based on questionnaires used elsewhere in Bangladesh^{16,17} and was pretested before use.

Dependent Variables

Overall mortality and mortality attributable to ARI and diarrhea were chosen as the dependent variables in this analysis. To assign cause of death, we used an algorithm that consisted of 4 steps. In step 1, all deaths in the first 3 days of life (0–2 days) were classified as "early neonatal" because the verbal autopsy instrument was inadequate for assigning causes in these very young infants. In step 2, deaths that were attributable to obvious injuries were classified as attributable to "injury." In step 3, "neonatal tetanus" was assigned the cause of death for deaths between 3 and 13 days that manifested convulsions before death, and either the infant cried normally after birth and stopped crying in the final illness or the infant suckled normally after birth and stopped suckling in the final illness. In step 4, deaths were assigned as either "ARI" or "diarrhea" or both as cause of death if they met the definitions below. Finally, in step 5, deaths that did not meet these definitions were classified according to criteria for possible causes of death (as described in Baqui et al¹⁸) and are grouped under "other" causes.

For an ARI death, 2 conditions had to be met: 1) there was either cough in the 2 weeks before death, starting at least 3 days before death and lasting until the day before death, or difficulty breathing in the 2 weeks before death, starting at least 1 day before death and lasting until the day of death; and 2) at least 3 of the following symptoms were present before death: cough (as defined above), difficulty breathing, noise during breathing, nasal flaring, blue lips/skin, chest in-drawing, rapid breathing, not feeding well or not able to drink, abnormally sleepy or difficult to wake. For a diarrhea death, there must have been frequent loose or liquid stools starting 1 to 13 days before death and lasting until death, with peak stool frequency of 3 or more and with at least 2 of the following symptoms present: weakness, thirst, dry mouth, loose skin, depressed fontanelle, sunken eyes, and no or little urine; or only frequent loose or liquid stools reported in the 2 weeks before death starting 14 or more days before death and lasting until death.

Explanatory Variables

Explanatory variables used in this analysis included 2 key variables of interest—birth weight and breastfeeding status—and measured confounding variables. Birth weight was estimated from weights at enrollment measured as late as 13 days after birth (median: 2 days). Postnatal change in body weight was investigated in a subsample of 99 newborns with daily repeat weights for 14 days after birth.¹⁹ This analysis revealed very little change in body weight in the first 72 hours. Thus, enrollment weight measured within 72 hours of birth was used as birth weight, which was the case in approximately 75% of the infants. In the remaining infants, who were enrolled 3 to 13 days after birth, birth weight was estimated from enrollment weights using a regression model developed from the subsample (birth weight = $2566.0 - 58.5 \times \text{age} + 35.1 \times \text{age}^2 - 4.1 \times \text{age}^3 + 4.2 \times [\text{age} - 3]^3$, where age is in days and $\text{age} - 3 = 0$ if $\text{age} \leq 3$ days). Birth weight was used both as a continuous and a categorical (<2500 g or ≥ 2500 g) variable.

Birth weight was not known for 23 newborns who had died before enrollment. Mothers were asked whether the size of their infant was larger than usual, usual, smaller than usual, or very small. These categories correlated well with measured birth weight. For each of the 4 subjective size categories, the mean birth weight and standard deviation were estimated. Birth weights then were imputed for the 23 newborns who had already died before enrollment and who thus had missing weights, ie, their birth weights were randomly generated from distributions of birth weights based on the mean and half the standard deviation that

corresponded to the same subjective size among infants who were enrolled alive.

Information on infant feeding practices in the 7 days preceding each visit resulted in the classification of the infant into exclusively breastfed (breast milk and nothing else), predominantly breastfed (breast milk with water, sugar water, honey, or other nonmilk liquid), partially breastfed (breast milk with animal/powdered/condensed milk, cereals, eggs, vegetables, fruits, lentils, or meat/fish), and not breastfed. Variables were created only from information from the months 0, 1, and 3 visits. Because the number of infants who were not breastfed at these visits was small, they were grouped with the partially breastfed in the analysis. These were used as time-varying variables in the proportional hazards regression models to assess the effect of feeding practices in the first few months of life on infant mortality. For 157 (9%) infants, there was missing feeding information at the month 1 and/or 3 visit.

The measured confounding variables included in the analysis were proximate determinants of growth, such as child's age and sex, and parental and household variables that act either through the proximate determinants or by other mechanisms, some of which are not measurable. The parental and household variables (mother's age, education, height, place of birth and parity, previous child death of the mother; father's education; and household religion, monthly income, and economic status indicator) were included in the regression models to account for the factors that were not measurable. Many of these variables are associated with growth or mortality risk in children.^{19,20}

The study was approved by the ethical review committees of International Centre for Diarrhoeal Disease Research, Bangladesh, and the Johns Hopkins School of Public Health. Informed verbal consent was obtained from at least 1 parent/caregiver of the infant. Sick infants were referred to an appropriate facility. Parents were encouraged either to seek early care from a health facility or to obtain assistance from 1 of our 3 field offices to facilitate referral. A study physician was assigned to the Dhaka Shishu (Children's) Hospital to ensure that enrolled infants who were admitted for illness received appropriate care.

Analysis

Total and cause-specific mortality rates by age were calculated for selected sociodemographic, economic, and maternal endowment categories. To account for differential follow-up time, Kaplan-Meier estimates of the survival functions²¹ and person-time calculations were used. Child-years were calculated for neonatal (0–28 days) and postneonatal age groups. Exact times of follow-up for deaths were used in the calculation of child-years; however, infants who out-migrated (14%) did so between scheduled visits with unknown exit times. For the out-migrated infants, the time from birth to the last visit when the infant was present and a time period equal to half the interval between the last scheduled visits was added to get the person-time. The latter was 1.5 months (0.125 years) for out-migration after the month 3 visit, 1 month (0.083 years) for out-migration between the month 1 and 3 visits, and 0.5 month (0.042 years) for out-migration before the month 1 visit. All follow-up was truncated at 12 months (365.25 days).

Mortality rate ratios were estimated comparing mortality rates between different levels of the selected variables, and 95% confidence intervals (CI) were calculated by Miettinen's test-based method.^{22,23} The relationship between birth weight and breastfeeding status was explored using proportions and means. Tests of significance for differences were performed using χ^2 tests for proportions and *t* tests for means.

Cox proportional hazards regression analysis was performed to estimate the effect of the key explanatory variables on total and cause-specific mortality after accounting for the effect of other confounding variables.²⁴ Hazard ratios were estimated as the exponential of the regression coefficients, and 95% CI for the hazard ratios were calculated.²⁵

Models were built in 2 stages. In the first, only the confounding variables were incorporated in 7 different models: for 3 event types (all deaths, ARI deaths, diarrhea deaths) and 3 age periods (neonatal, postneonatal, infancy). Two models for neonatal cause-specific deaths were not constructed as there were only 7 ARI and 4 diarrhea deaths. Deaths attributed to both ARI and diarrhea were included in both ARI and diarrhea models. In the neonatal models, follow-up was truncated at 28 days, whereas in the post-

neonatal models, only those who survived the first 28 days were included and age was adjusted to start at 0 from age 28 days (adjusted postneonatal age = age - 28). Deaths at under 72 hours of age were not included as events to avoid reverse causality because the illness preceding these early deaths could have influenced feeding practices before death. Only variables that were significant at the 0.10 level were retained in the final models. Sets of dummy variables were not separated, eg, both of the dummy variables for household income were retained although only 1 of them met the criteria. Additional variables were dropped from some of the models for lack of events (deaths) in the reference categories of those variables. Because of missing values for some confounding variables, 33 infants were excluded from the final models.

In the second stage, the 2 key explanatory variables of interest were added to the "base" models from stage 1. For events before the month 1 visit, feeding status at enrollment (month 0) contributed to the breastfeeding variables in the model. For events between months 1 and 3 visits, feeding status at the month 1 visit was the source, whereas the breastfeeding status at the month 3 visit was used for all events that occurred later.

We estimated expected declines in infant mortality as a result of improvements in breastfeeding practices. The average of the prevalence of different breastfeeding categories at the month 1 and 3 visits was taken as a proxy measure of breastfeeding practices in the first 4 months of life. Mortality rates for each breastfeeding category then were estimated on the basis of this prevalence estimate, the overall infant mortality rates from the sample, and the hazard ratios from the regression. Assuming that these mortality rates and all other factors remain constant, infant mortality rates then were reestimated for different prevalence levels of breastfeeding practices. Changes in these prevalence levels assumed shifts from both predominant and partial + no breastfeeding to exclusive breastfeeding, and from partial + no to predominant breastfeeding.

All analyses were performed with the SAS System software (version 6.12; SAS Institute, Cary, NC). The procedure PROC PHREG was used for proportional hazards regression models. The Corel Quattro Pro (version 7; Ottawa, Canada) spreadsheet program was used for estimating expected mortality reductions.

RESULTS

General and Baseline Characteristics of the Sample

The mean age of the mothers of the newborns was approximately 25 years; almost three quarters did not have any formal education, and 95% were Muslim. A little more than two thirds of the mothers were born outside Dhaka, and 23% were shorter than 145 cm. For 26% of the mothers, this was their first infant and for another 23% the second, and approximately 31% of the mothers had had a previous child

death. Almost 60% of the fathers did not have any education. The mean monthly household income of the sample was approximately US \$75, and nearly 40% of the households did not have any of the following: television, radio, bicycle, rickshaw, cupboard, table, and watch/clock. Almost half of the newborns (47%) were of low birth weight (<2500 g), and mean estimated birth weight was 2516 g.

Mortality and Cause of Death

A total of 180 deaths were identified in the study cohort by 12 months of age. This translates into a crude rate of 107 infant deaths per 1000 live births. Using the complement of the Kaplan-Meier estimate of the survival function, the overall infant mortality risk was 114 deaths per 1000 live births. This is a better estimate as it takes into account losses to follow-up. Exactly one third of these deaths (60) occurred in neonates (0-28 days), another 99 deaths (55%) were in the 1- to 5-month age range, and only 21 deaths (12%) happened in the latter half of infancy (Table 1). Deaths attributable to early neonatal causes accounted for almost half of the neonatal deaths, 9 were attributable to tetanus (15%), and 6 (10%) could be attributed to ARI. Only 3 of the neonatal deaths were attributable to diarrhea, and 1 was attributable to ARI and diarrhea. During the first part of the postneonatal period (29 days-5 months), ARI was responsible for one quarter of the deaths, whereas diarrhea was the cause of death in 20% of the cases. In 7 cases, both diarrhea and ARI were identified as causes of death. The pattern was similar in the second half of the postneonatal period (6-11 months), with ARI being responsible for a greater proportion of the deaths.

Bivariate Relationships

Except for marginally significant differences at enrollment (0 months), low and normal birth weight infants differ very little with regard to how they were fed throughout infancy (Table 2). Because most newborns were given water, sugar water, honey, or other liquids for a few days after birth, exclusive breastfeeding was much less prevalent at this age (overall:

TABLE 1. Distribution of Deaths in the Sample by Cause and Age at Death

Cause of Death	All Deaths	Age Group	
		Neonatal (0-28 Days)	Postneonatal (29 Days-11 Months)
Early neonatal	27 (15%)	27 (45%)	—
Injury	4 (2%)	1 (2%)	2 (1%)
Neonatal tetanus	9 (5%)	9 (15%)	—
Only ARI	39 (22%)	6 (10%)	33 (25%)
Only diarrhea	26 (14%)	3 (5%)	23 (20%)
Both ARI and diarrhea	10 (6%)	1 (2%)	9 (7%)
Other causes			
Possible ARI	11 (6%)	5 (8%)	6 (5%)
Possible diarrhea	8 (4%)	0 (0%)	8 (7%)
Possible ARI and diarrhea	5 (3%)	0 (0%)	5 (4%)
Possible malnutrition	2 (1%)	0 (0%)	2 (2%)
Possible malnutrition and ARI	5 (3%)	1 (2%)	4 (3%)
Possible malnutrition and diarrhea	1 (1%)	0 (0%)	1 (1%)
Possible malnutrition, ARI, and diarrhea	5 (3%)	0 (0%)	5 (4%)
Not determined	28 (16%)	7 (12%)	21 (18%)
Total	180 (100%)	60 (100%)	120 (100%)

TABLE 2. Percentage Distribution of Enrolled Infants by Age, Current Breastfeeding Practices,* and Birth Weight†

Age (mo)	Birth Weight Category and Breastfeeding Status							
	Normal Birth Weight (≥ 2500 g)				Low Birth Weight (< 2500 g)			
	Exclusive	Predominant	Partial+ None	Total	Exclusive	Predominant	Partial+ None	Total
0 (± 15 d)	7.5	64.4	28.1	100%	4.7	66.2	29.1	100%
1 (± 15 d)	53.7	14.8	31.5	100%	52.4	13.9	33.7	100%
3 (± 15 d)	24.8	15.0	60.2	100%	26.5	12.8	60.7	100%
6 (± 15 d)	4.8	11.6	83.6	100%	4.8	10.0	85.2	100%
9 (± 15 d)	1.3	5.7	93.0	100%	0.2	5.2	94.6	100%
12 (± 15 d)	0.0	4.6	95.4	100%	0.0	3.4	96.6	100%

* Based on breastfeeding practices in the 7 days preceding each visit.

† There were no significant differences between normal birth weight and low birth weight infants at any age (at age 0, $P = .06$).

6%). More than half of the infants were breastfed exclusively at age 1 month, declining to approximately one quarter at 3 months. After 6 months of age, very few infants were breastfed exclusively, but even at 12 months of age, approximately 4% of the infants were still receiving breast milk with no other caloric food (predominant). Because very few infants were not breastfed at any age (maximum: 7% at 12 months of age), their data were combined with those from the partially breastfed infants.

Neonates who were born to more educated, taller, or wealthier mothers were less likely to die. If the infants survived beyond the first month of life, only maternal education and household income plus household economic status were associated with reduced risk of death (Table 3). The associations between all other confounding variables and mortality were statistically nonsignificant. Low birth weight was a strong determinant of neonatal and postneonatal mortality.

We observe a similar trend in the relationship between the percentage of children who died and

breastfeeding practices in 3 different age periods (Table 4). This association is the strongest and the most obvious in the period between the month 1 and 3 visits, when 7% of the infants who were partially or not breastfed at month 1 died in the following 2 months compared with approximately 2% of those who were breastfed exclusively.

Proportional Hazards Regression

Infants who were either partially or not breastfed had a higher risk of postneonatal death than infants who were breastfed exclusively for the first 4 months of life (Table 5). The risk also was slightly greater in partially or not breastfed neonates but was not significant. For infancy, partially or not breastfed infants had 2.23 times the mortality risk of infants who were breastfed exclusively during the first 4 months. The hazard ratio estimates for ARI and diarrhea deaths were 2.40 and 3.94 among partially or not breastfed infants, compared with exclusively breastfed infants. These effects also were seen in the postneonatal period. There were too few ARI or diarrhea

TABLE 3. Effect of Selected Sociodemographic, Economic, and Maternal Endowment Characteristics on Mortality by Age Group ($n = 1677$)

Characteristic Category	Age Group and Rate Ratio			
	Neonatal Period		Postneonatal Period	
	RR	95% CI	RR	95% CI
Birth weight				
LBW (< 2500 g)	2.35	1.40–3.96	2.21	1.54–3.17
NBW	1.00		1.00	
Maternal schooling				
Any	0.46	0.22–0.96	0.52	0.32–0.86
None	1.00		1.00	
Monthly income				
US \$60+	0.77	0.44–1.35	0.54	0.35–0.83
US \$40–59	0.46	0.23–0.91	0.71	0.46–1.10
US \$0–39	1.00		1.00	
Household economic status*				
High	0.54	0.29–1.03	0.51	0.33–0.80
Medium	0.61	0.33–1.12	0.59	0.38–0.91
Low	1.00		1.00	
Mother's height				
150.0–168.0 cm	0.77	0.42–1.40	0.72	0.46–1.12
145.0–149.9 cm	0.51	0.26–0.98	0.70	0.45–1.10
126.3–144.9 cm	1.00		1.00	

RR indicates person-time–based rate ratio; LBW, low birth weight; NBW, normal birth weight.

* A relative indicator of household economic status in a population in which almost all households live below poverty level; high, household has television, radio, or bicycle/rickshaw; medium, household has none of the above but has cupboard, table, or watch/clock; low, household has none of the above.

TABLE 4. Relationship of Breastfeeding Practices With Neonatal and Postneonatal Deaths

	<i>n</i>	Deaths	%
Neonatal period*†			
Exclusive breastfeeding	104	2	1.9
Predominant breastfeeding	1094	19	1.7
Partial breastfeeding or not breastfeeding	479	12	2.5
Postneonatal period			
Period from month 1 to month 3 visits‡			
Exclusive breastfeeding	796	14	1.8
Predominant breastfeeding	260	6	2.3
Partial breastfeeding or not breastfeeding	516	36	7.0
Period from month 3 to month 12 visits§			
Exclusive breastfeeding	424	15	3.5
Predominant breastfeeding	232	6	2.6
Partial breastfeeding or not breastfeeding	916	42	4.6

* Excluding deaths <3 days of age.

† Feeding practice at enrollment.

‡ Feeding practice at month 1 visit.

§ Feeding practice at month 3 visit.

deaths in neonates to permit an analysis. Predominantly breastfed infants did not seem to differ from those who were given breast milk exclusively, except for having a higher, though nonsignificant, risk for diarrheal deaths.

Estimating Expected Reductions in Infant Mortality

The percentage reductions in infant mortality rates to be expected as a result of breastfeeding promotion activities at varying levels of effectiveness in a Bangladesh urban slum setting were estimated (Table 6). The current prevalence of different breastfeeding practices in the first 4 months of life is based on a proxy measure (the average of the prevalences at 1 and 3 months of age shown in Table 2). The overall infant mortality rate of 114 per 1000 live births and the hazard ratios associated with breastfeeding categories in the infant models for all deaths (Table 5) contributed to the estimation. Increase in the prevalence of exclusive breastfeeding from current levels to approximately 78% (twice the current level) should result in the reduction of infant mortality by almost one third.

DISCUSSION

This study confirmed the importance of breastfeeding for infant survival. The study also examined the relationship between breastfeeding and cause-specific infant mortality in a community-based setting in a developing country. Approximately 42% of infant deaths in this population could be attributed to 2 causes: diarrhea and ARI. This proportion increases to 61% when possible causes are included. The proportion of infants who died as a result of these 2 causes is comparable to other studies from Bangladesh, which used a similar verbal autopsy instrument.¹⁸

We observed a strong positive effect of exclusive breastfeeding in the first months of life on infant survival. Because breastfeeding was modeled as a time-varying variable, the feeding status at the month 3 visit was included as the risk factor for all deaths after that visit. For deaths before the month 3 visit, the feeding status from the immediately pre-

ceding visit was incorporated in the model. This approach guards against reverse causality because feeding practices often change during serious illness, such as an illness preceding death.

Similar to findings from previous studies, the risk ratio estimates associated with partial or not breastfeeding were higher for diarrhea deaths than for ARI deaths, although the CI overlapped. The highest risk group for diarrhea deaths included infants who were either not breastfed or who received, in addition to breast milk, other energy-containing foods at an age when they were not necessary. Contaminated complementary foods are primary sources of gastrointestinal pathogens²⁶ and are the most likely explanation for the observed association. The higher, though nonsignificant, risk of diarrhea deaths among predominantly breastfed infants lends support to this hypothesis because, in addition to breast milk, these infants were, by definition, receiving noncaloric drinks, which were likely to be contaminated. Previous studies also have reported a protective effect of breastfeeding on diarrhea morbidity and mortality.^{6-8,27-29}

There was approximately a 2.5-fold increase in the risk of ARI deaths when infants received energy-containing food in addition to breast milk or were not breastfed in early infancy. Although there is considerable evidence of an increased risk of respiratory infections associated with not breastfeeding from both developed and developing countries,³⁰⁻³² there have been few reports of increased risk of ARI deaths among nonbreastfed infants.⁷ The hazard ratio for all deaths also was increased among infants who were not exclusively or predominantly breastfed. The most likely explanation for the observed effect on ARI and all-cause deaths is the known anti-infective and nutritional properties of breast milk.³³⁻³⁷ This probably also is responsible for part of the effect on diarrhea deaths.

A component of the observed effect of breastfeeding may have been through its effect on infant nutritional status. In an earlier analysis of these data, we found a strong positive relationship between exclusive breastfeeding and infant growth.¹⁸ Additional evidence in support of this hypothesis was found when we incorporated a time-varying infant nutritional status variable in the models (data not shown). In those models, the hazard ratio estimates for the breastfeeding variable, though still significant and in the same direction, was closer to the null in comparison with the estimates in Table 5.

The small sample size and the consequent low power to detect a difference prevents us from reaching a firm conclusion regarding the risk from predominant compared with exclusive breastfeeding. We did see an increased risk of deaths attributable to diarrhea among infants who were predominantly breastfed, but the CI overlapped 1. The literature on the effect of predominant breastfeeding on mortality is very limited. This is attributable mainly to the fact that predominant breastfeeding, ie, the addition of water, sugar water, or other nonmilk drinks, seldom is treated as a separate category. It is either combined with partial breastfeeding or not distinguished from

TABLE 5. Adjusted Hazard (Risk) Ratios and 95% CI for Breastfeeding Status From the Proportional Hazards (Cox) Regression Models, by Age Group and Cause of Death

Breastfeeding Status*	Cause of Death		
	All Deaths	ARI	Diarrhea
Neonatal period			
Predominant	0.86 (0.20–3.68)†	—	—
Partial+none	1.17 (0.26–5.30)	—	—
Postneonatal period			
Predominant	0.96 (0.49–1.89)‡	0.77 (0.21–2.85)§	1.82 (0.49–6.79)
Partial+none	2.30 (1.48–3.59)	2.74 (1.27–5.92)	4.04 (1.50–10.87)
Overall infancy			
Predominant	1.13 (0.65–1.97)¶	0.91 (0.33–2.56)#	2.22 (0.67–7.37)**
Partial+none	2.23 (1.45–3.44)	2.40 (1.14–5.04)	3.94 (1.47–10.57)

All models exclude deaths <3 days of age. Variables in the models: a continuous birth weight variable, time-varying variable for breastfeeding status, and selected confounding variables.

* Reference category: exclusive breastfeeding mode.

Other variables in models: † height and education; ‡ income, education, and parity; § none; || parity; ¶ religion, income, height, education, and parity; # income, height, and education; and ** parity.

TABLE 6. Estimation of Expected Reduction in Infant Mortality After Improvement in Breastfeeding Practices in the Bangladesh Urban Slum Setting

Improvement in Breastfeeding Practice*	Breastfeeding Practice (Prevalence)			Infant Mortality Per 1000 Live Births†	Percentage Reduction in Infant Mortality
	Exclusive	Predominant	Partial+None		
Current‡	39%	14%	47%	114	—
Some	54%	18%	27%	99	13
Medium	65%	16%	19%	90	21
High	70%	18%	12%	84	26
Very high	78%	17%	5%	77	32

* Proxy measure of breastfeeding practices in first 4 months of life.

† Assumes a risk ratio of 2.30 for partial+no breastfeeding and 1.20 for predominant breastfeeding (Table 5).

‡ Average based on Table 2.

exclusive breastfeeding. Studies have shown that intake of water, tea, and other nonmilk drinks in addition to breast milk increases the risk of diarrhea.^{27,29,38,39}

The data presented do not suggest that birth weight is an important influence on the breastfeeding–infant mortality relationship in this population. Contrary to reports from other populations,^{10,40} birth weight did not seem to influence breastfeeding significantly at any age. One possible explanation is that because low birth weight is so common, small infants are accepted as the norm and thus size does not influence feeding decisions. Unlike many other populations, breastfeeding until 12 months is a norm in this poor Bangladeshi community. Furthermore, because most deliveries take place at home, low birth weight infants are not subject to medical interventions that may change their breastfeeding practices.

Unlike most other studies, in which comparisons usually are made between breastfed and nonbreastfed children or the effect of breastfeeding duration is examined, our classification of breastfeeding status corresponds to the World Health Organization's recommended definitions and provides evidence on the benefits of currently recommended breastfeeding practices.⁴¹ A recent meta-analysis provided convincing evidence of the protection provided by any breastfeeding against all infant deaths and deaths attributable to diarrhea and ARI.⁸ This study, conducted in a population in which breastfeeding is

nearly universal, indicates that exclusive breastfeeding in the first few months of life imparts additional protection. These results, therefore, reinforce the scientific basis of the current recommendations for continuing exclusive breastfeeding until 4 to 6 months of age.⁴²

In this study, the risk of neonatal mortality was approximately one third of infant mortality. This is unexpectedly low. It is possible that some early neonatal deaths were missed in the sample because the newborns were not enrolled before death; however, the rates in this study are consistent with findings from surveillance data from another sample of the Dhaka slum population. Neonatal and postneonatal rates of 31 and 68 per 1000 live births, respectively, were reported from that surveillance.⁴³ Breastfeeding data used in this analysis were collected infrequently and did not capture changes between visits. It is reassuring that misclassification of feeding practices for this reason would reduce rather than exaggerate the observed relationships.

Findings from this study indicate that although breastfeeding in this population is nearly universal, interventions to improve infant feeding practices could result in a considerable reduction in infant mortality. It is worthwhile to note that human immunodeficiency virus infection still is extremely uncommon in this population and so does not influence the assessment of the benefits and risks of breastfeeding or efforts to promote exclusive breastfeeding.

However, if findings from South Africa that exclusive, as opposed to mixed, breastfeeding protects the infant from human immunodeficiency virus transmission are confirmed, there will be another important reason to promote exclusive breastfeeding.⁴⁴

Promotion of exclusive breastfeeding in the first 4 to 6 months of life and reduction in the current practices of giving potentially contaminated drinks or foods are likely to be beneficial for infant survival in this population, with reductions expected in both diarrhea and ARI deaths, as well as in all deaths. The limited number of infants who were breastfed exclusively to 6 months of age as currently recommended precluded an assessment of protection in the fifth and sixth month of life, so the full benefits may be even greater if these recommendations were followed. Although somewhat simplistic, the estimates in Table 6 provide a measure of the expected benefits in infant survival as a result of breastfeeding promotion activities. They are consistent with earlier estimates of potential reductions in diarrhea mortality after increased breastfeeding.⁵ Thus, estimates indicate that infant mortality could be reduced by almost one third if the prevalence of exclusive breastfeeding in the first 4 months of life could be raised to nearly 80%, with smaller gains with intermediate improvements in breastfeeding practices. Recent studies in Bangladesh showed that such improvements in breastfeeding practices can be achieved through community-based interventions.⁴⁵

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S.A., R.B., G.A., and A.B. conceptualized and designed the study. S.A. and G.A. were responsible for the implementation of field work. S.A., R.B., L.C., and S.B. designed the analysis. S.A. drafted the manuscript, which then was revised by all investigators.

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