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BREAST-FEEDING, DIARRHOEA AND SANITATION AS COMPONENTS OF INFANT AND CHILD HEALTH: A STUDY OF LARGE SCALE SURVEY DATA FROM GHANA AND NIGERIA

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Summary. Using Demographic and Health Survey datasets from Ghana and Nigeria, this study examined whether the protective effects of breast-feeding are greatest where the poorest sanitation conditions prevail. It was found that mixed-fed infants aged between 0 and 11 months tend to have a higher risk of diarrhoea than fully breast-fed children, while the risk of diarrhoea among weaned infants is twice that of mixed-fed infants. The probit regression models employed in the analysis were used to predict the probability of diarrhoea associated with each breast-feeding pattern for both 'poor' and 'good' sanitation areas. It was found that the risk of diarrhoea among mixed-fed infants in the poor sanitation areas tends to be high while the same risk among fully breast-fed infants tends to be minimal. In essence, the health risks of mixed feeding are real, particularly for infants aged less than 7 months, and are even worse for those weaned before 6 months of age.

Introduction

Diarrhoeal diseases, commonly defined as an increase in the frequency and fluidity of bowel movements relative to the usual pattern of an individual, are major contributors to illness and death among children aged 0 to 4 years in sub-Saharan Africa (Kirkwood, 1989). Although practical, inexpensive methods to reduce diarrhoeal morbidity and mortality are being practised, the results are often disappointing in terms of policy outcomes. Haggerty *et al.* (1994) found that diarrhoeal rates in Zaire are highest in the first year of life and decline with age, thus reflecting the impact on diarrhoeal morbidity of the weaning period. For these children, it would seem obvious that exposure and response to disease are conditioned by socioeconomic and environmental sanitation.

While the focus of research has largely been on environmental risk factors, particularly on the effects of inadequate water supply and sanitation (Esrey & Habicht, 1986; Habicht, DaVanzo & Butz, 1988), the interactions between these risk factors and

breast-feeding behaviour with diarrhoea as the outcome variable have not received so much attention. It is often the case at the household level that a mother may be introduced to a modern health practice, but her decision and ability to use it effectively are powerfully dependent upon a social support system that is ignorant of intervention programmes (PAHO/WHO, 1983). While it is logical that intervention to interrupt diarrhoea transmission should include safe disposal of human faeces and protection of water supplies from contamination, such interventions have almost invariably had no positive effect on diarrhoeal morbidity (Kirkwood, 1989; PAHO/WHO, 1983). Hence this study postulates that the most promising interventions must focus on the household environment and on the immediate risks to which the child is exposed.

This paper studies the interactions between breast-feeding practices, household environmental sanitation and diarrhoea-related diseases in Ghana and Nigeria, employing the recently collected Demographic and Health Survey datasets (Federal Office of Statistics and Macro International Inc., 1992; Ghana Statistical Service and Macro International Inc., 1994). Because cultural antagonism to fully exclusive breast-feeding in the early months of a child's life may seem too great for intervention programmes to breach, it is important that health workers are aware that data from their own communities prove that the health risks of mixed feeding and early weaning are real. After all, most studies quoted in the literature on the epidemiology of diarrhoeal illness are not based on nationally representative samples (Lloyd-Evans *et al*., 1984). Thus the use of large scale survey data, such as Demographic and Health Surveys (DHSs), to confirm what restricted samples may have documented about the epidemiology of diarrhoeal illness is not out of place.

Methods

The data for this study are taken from nationally representative Demographic and Health Surveys (DHSs) conducted in Ghana in 1993 and Nigeria in 1990. Each survey was based on a two-stage stratified design. The survey questionnaire consisted of a Household Schedule and an Individual Questionnaire. The Household Schedule identified women aged 15–49 for detailed interview and also provided descriptive data on household characteristics such as the source of water, type of toilet facility, dwelling characteristics and household possessions, thus providing some measure of the household's living standards.

The Individual Questionnaire included information on the background characteristics of the survey respondent (women aged 15–49) and on various aspects of fertility, mortality, family planning, child nutrition and child health. Such health-related measures as immunization rates, morbidity rates for diarrhoea, respiratory infections and fever were collected for children aged 0–4 years for a reference period, typically 2 weeks or 24 h before the survey. Diarrhoea prevalence or incidence was indicated by three or more watery stools per day at the height of the episode.

Information was also obtained regarding breast-feeding patterns for all the respondent's children born in the 5 years preceding the survey. For each child the mother was asked if the child was ever breast-fed, and if so, for how long and the type of other foods and food supplements given to the child. The questionnaire structure

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assumed that only the last born child could still be breast-feeding at the time of the survey (Macro International Inc., 1993). To minimize recall lapses on the part of the respondents, the analysis was limited to the last born child aged less than 24 months before the survey.

It is important to note that although the DHS questionnaire inquired about the child's food intake during the 24 h preceding the survey, the mother was not asked whether these foods and liquids were given regularly. Hence, an individual child could not be classified with complete certainty as 'exclusively' breast-fed. If a child sometimes received ritual foods like honey and sugar water, that child was classified in the study as 'exclusively' or fully breast-fed and the rest classified into the category of 'mixed-fed' infants. The main points defining the feeding types here are that mixed feeding includes breast milk plus other food supplements such as other types of milk, juice and solids while fully breast-fed infants include those receiving only mother's milk plus vitamin drops and medicine. The weaned children are simply those not suckling on the breast.

In order to study the impact of breast-feeding and sanitation variables, the analysis is presented in three parts. In part one, simple descriptive statistics and cross-tabulations were employed to highlight breast-feeding patterns and their interactions with sanitation variables. Parts two and three employed multivariate and stratification techniques to analyse the effects of the various risk factors. The stratification illustrates the differences in interaction terms for diarrhoea morbidity, while the multivariate analysis provides a concise summation of the main and interactive effects.

Model specification

The data employed contain cases in which the mother may choose not to breast-feed or not to feed the child any formula. For this reason, in the empirical implementation of the model, the mother's feeding choice was analysed as a selection of feeding patterns from a set of two unordered patterns: full breast-feeding and mixed feeding. The estimation of a reduced form equation requires that all the right-hand-side variables be exogenous (Holford, 1980). At any point in time, the mother's feeding choice probably depends on the current health of the child. By using a reduced form specification, the use of endogenous variables measuring the child's health status (other than diarrhoea incidence) was precluded but exogenous variables that are determinants of health status were included. The probit model estimated here may be expressed as follows:

$$\log[\text{Prob}(D_{it}=1)/\text{Prob}(D_{it}=0)]=\beta_0+\beta_1 F_{it}+\beta_2 X_{it}+\epsilon_i,$$

where the dependent variable is the log odds that the individual child i at time t (=the 2 weeks immediately before the survey) suffered a bout of diarrhoea relative to the absence of diarrhoea. β_0 is the intercept representing the log odds of diarrhoea for children for whom the values of all covariates equal zero; β_1 is the vector of coefficients of the breast-feeding pattern vector F (breast milk and milk substitutes); and β_2 is the vector of coefficients of the vector of the other covariates, X (age, education, water and toilet facilities). The error term ϵ_i represents the unobserved attributes of the child, mother, household and community which affect the ith child's status, for example the

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child's genetic endowment and the parents' weight and height, which were not measured, and unobserved household and community factors (Rosenzweigh & Schultz, 1983; Ashford & Sowden, 1970). The maximum likelihood estimation method under the HPROBIT procedure in the Stata Statistical Software (StataCorp, 1997) was used in the estimation. In the above form, the method of estimation is the standard probit estimator with a correction to the coefficient standard errors by Huber's method to account for the error structure due to the sample design effect (Huber, 1967).

Results

Although infant breast-feeding appears to be universal in the study samples, very few mothers followed the recommended practice of exclusive breast-feeding for the first 3 months after birth. The data show that few infants were exclusively breast-fed for the first 3 months of age. By 3 months, 97% of all breast-feeding infants were given some liquids like juice in addition to ordinary water, 17·2% were given solids and 41·7% had been given baby formula. In effect, the ideal feeding practices recommended by the World Health Organization (1991) were not rigidly adhered to in the samples.

Although access to water sources may not be a problem, the quality of water may be questionable. Only 13·6% of the Ghanaian sample had an in-house water connection, and 15·4% of the Nigerian sample. Nearly 50% of households in Ghana used water from streams compared with 29% in Nigeria. More households depended on a public tap in Ghana than in Nigeria (20% compared with nearly 13% of households in Nigeria). Sewage disposal by flushing existed in 12% of Ghanaian and 15% of Nigerian households. Between 22 and 24% of all households in the samples had no direct access to a toilet facility. A total of 60% of households in Nigeria and 51% in Ghana used pit latrines. These figures imply that diarrhoeal prevalence is indeed uninhibited.

Table 1 shows data on the prevalence of diarrhoea in the 2 weeks and the 24 h preceding the survey for children under 2 years of age by selected demographic characteristics. Some 9% of the children in Ghana (and 8·4% in Nigeria) aged 1–35 months had diarrhoea in the 24 h before the survey; 20·3% of all children in Ghana and 17·9% in Nigeria had diarrhoea in the 2 weeks preceding the survey. The prevalence of diarrhoea increased with age, peaked at 12–17 months, and dropped at older ages. There is not much difference in the prevalence of diarrhoea by sex or birth order, but there is a clear association between mother's education and the prevalence of diarrhoea. The more educated the mother, the less likely the child is to experience a diarrhoea episode.

Table 2 presents data on breast-feeding status cross-classified by type of toilet or water facility used by the household for infants aged 0–3 months and 4–6 months respectively.

There is a clear association between maternal use of toilet facilities and breast-feeding practice. If the possession of a flush toilet implies a higher socioeconomic status, then the higher the socioeconomic status of the mother the lower are the child's chances of being fully breast-fed to 3 months. Conversely, the chances of being fully breast-fed are higher for children whose mothers have no access to a toilet facility. In Ghana, for example, five times more mothers with no toilet facility

Table 1. All diarrhoea prevalence by background characteristics

Characteristic	Diarhoea in the preceding 2 weeks	Diarrhoea in the preceding 24 h	*n*
Ghana			
Child's age			
<6 months	14·9	9·3	355
6–11 months	24·9	9·6	354
12–17 months	26·1	13·1	329
18–23 months	21·7	11·8	322
Sex			
Male	20·7	8·9	1034
Female	19·8	9·4	990
Mother's education			
None	24·0	11·9	797
Primary	22·2	9·6	374
Middle	16·9	6·7	735
Higher	10·2	4·2	118
All children	20·3	9·1	2024
Nigeria			
Child's age			
<6 months	11·7	6·6	751
6–11 months	26·3	12·4	813
12–17 months	29·3	14·5	1380
18–23 months	20·7	10·2	1320
Sex			
Male	19·4	10·2	2757
Female	16·4	6·5	2922
Mother's education			
None	20·1	10·2	4117
Primary	14·4	4·9	505
Middle	17·2	7·0	864
Higher	12·7	3·9	193
All children	17·9	8·4	5679

Figures are for children born in the period 1–35 months preceding the survey by the characteristic listed and percentages will not add up to 100.

compared with mothers using a flush toilet (w/c) breast-feed their children fully. In addition, twice as many mothers with a w/c compared with mothers without a toilet facility mix-feed their children; and almost five times more mothers with a w/c compared with mothers without a toilet facility wean their children before 3 months. The pattern is very similar for Nigeria: nearly four times more mothers with no toilet facility compared with mothers with a w/c breast-feed their children fully, while 2·6 times more mothers with a w/c relative to mothers without a toilet facility mix-feed their children.

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Table 2. Feeding patterns of sampled infants, by sanitation factors and age category: Ghana (1993) and Nigeria (1990)

	Breast-feeding status		
Facility	Fully breast-fed	Mixed-fed	Weaned
Ghana			
3 months of age			
Toilet facility			
No facility	35·2	25·9	15·7
Pit	57·6	14·4	10·8
Water closet	7·2	59·7	53·5
All	100·0	100·0	100·0
Drinking water			
In-house	8·5	17·7	43·8
Public tap	16·2	23·5	29·7
Well	15·7	8·9	18·2
Stream/river	59·6	49·9	8·3
All	100·0	100·0	100·0
n	40	171	23
6 months of age			
Toilet facility			
No facility	38·3	15·3	25·9
Pit	55·8	33·5	20·6
Water closet	5·9	51·2	53·5
All	100·0	100·0	100·0
Drinking water			
In-house	9·5	38·4	33·6
Public tap	16·2	31·9	31·2
Well	19·4	16·8	24·7
Stream/river	54·9	12·9	10·5
All	100·0	100·0	100·0
n	61	259	35
Nigeria			
3 months of age			
Toilet facility			
No facility	30·0	23·1	13·4
Pit	62·2	17·8	9·8
Flush (w/c)	7·8	59·1	64·0
All	100·0	100·0	100·0
Drinking water			
In-house	5·8	47·0	32·9
Public tap	49·4	6·2	36·5
Well	11·5	10·1	20·0
Stream/river	33·3	36·7	10·6
All	100·0	100·0	100·0
n	167	304	68

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Table 2. *Continued*

6 months of age			
Toilet facility			
No facility	28·0	30·3	15·6
Pit	60·7	16·3	20·4
Flush (w/c)	11·3	53·4	64·0
All	100·0	100·0	100·0
Drinking water			
In-house	11·6	17·0	38·0
Public tap	11·7	13·6	24·2
Well	41·7	37·0	17·5
Stream/river	35·0	32·4	20·3
All	100·0	100·0	100·0
n	189	467	95

In terms of the type of water used, socioeconomic status again appears to play a part in the pattern of breast-feeding. At age 3 months, seven times fewer mothers in Ghana with an in-house water connection relative to mothers who draw water from rivers practise full breast-feeding. On the other hand, five times more mothers with in-house water relative to mothers using river water wean their children before 3 months. The corresponding ratios for Nigeria are 5·7 and 3·0 times respectively.

Six months into breast-feeding, the pattern appears to persist, although with reductions in the ratios. Compared with flush toilet users, 6·5 times more mothers without a toilet facility are still fully breast-feeding their children in Ghana; three times more mothers with a w/c relative to mothers without a facility are mix-feeding their children, while two times more mothers with a w/c relative to mothers with no toilet facility wean their children by 6 months. In Nigeria, although the pattern is generally similar, the gap between the type of breast-feeding and access to a facility narrows.

Overall, Table 2 suggests that maternal use of toilet and water facilities is inversely related to the type of breast-feeding practised: full breast-feeding tends to go with poor sanitation facilities, while mixed feeding is practised more where sanitation is better.

The incidence of diarrhoea can be compared for either a 24-h or a 2-week recall period. In the latter case, either an incidence ('Did the diarrhoea start in the last 2 weeks?') or a prevalence ('Did your child have diarrhoea in the last 2 weeks?') rate can be obtained. In practice, this difference in wording should make very little difference to the rates obtained and therefore one can treat all DHS data as prevalence rates. Table 3 highlights the relationship between diarrhoea prevalence and age at weaning. It shows that the proportion of children who experienced diarrhoea in the 2 weeks prior to the survey rose from 5·5% at age 3 months to 10·2% by age 6 months for infants who were mixed-fed in Ghana. For any particular 3-month period between ages 1–3 and 4–6 months, the diarrhoea prevalence for mixed-fed infants was higher than that of fully breast-fed infants (the ratios being 1·9 in the first 3-month period and 2·1 in the second 3-month period). There therefore appears to be a clear relationship between feeding practice and diarrhoea prevalence. At 3 months, the prevalence of diarrhoea in mixed-fed infants is nearly twice that of fully breast-fed infants. Between 3 and 6

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Table 3. Diarrhoea prevalence in the 2 weeks preceding the survey by age and feeding practice and level of sanitation: Ghana (1993) and Nigeria (1990)

Category	Percentage prevalence among infants aged:			
	3 months	6 months	9 months	12 months
Ghana				
Breast-feeding type				
Mixed-fed*	5·5	10·2	11·8	13·9
Fully breast-fed	2·9 (1·9)	4·8 (2·1)	—	—
Water connection				
In-house	3·2	5·1	8·9	11·0
No in-house	5·7 (1·8)	6·3 (1·2)	12·4	17·0
Toilet facility				
Flush	6·6	4·8	9·0	10·1
No facility	6·0 (1·1)	7·2 (1·5)	13·5	21·8
Nigeria				
Breast-feeding type				
Mixed-fed*	8·4	12·3	28·7	24·3
Fully breast-fed	7·1 (1·2)	9·2 (1·3)	—	—
Water connection				
In-house	5·7	11·2	14·0	19·5
No in-house	7·9 (1·4)	20·3 (1·8)	27·8	33·7
Toilet facility				
Flush	7·2	9·1	11·0	15·7
No facility	9·5 (1·3)	10·2 (1·1)	15·2	21·5

*Mixed-fed infants recieved nutritive foods and/or liquids in addition to breast milk. Fully breast-fed infants were breast-fed in addition to receiving non-nutritive liquids.
Figures in parentheses are obtained by taking the ratio of the larger prevalent rate to the smaller rate.

months of age, there is a substantial increase in diarrhoea prevalence among the fully breast-fed children (the size of the increase being in the ratio 1·7); there is also a rise in diarrhoea prevalence among the mixed-fed infants over the same age range (the increase being in the ratio 1·9).

In Nigeria, the difference in the prevalence of diarrhoea between mixed-fed and fully breast-fed infants is smaller at age 3 months than at age 6 months (the relative increase being in the ratio 1·2 versus 1·3, respectively). Unlike Ghana, the Nigeria data do not produce the sharp rise from age 3 to 6 months. However, diarrhoea prevalence at 9 months for mixed-fed infants increased to more than three times the rate at 3 months. The pattern is similar for in-house and non-in-house water use prevalence rates, and also for flush toilet and no toilet facility prevalence rates.

The mean prevalence rates of diarrhoea in infants aged 3 to 6 months are presented in Table 4 for both fully breast-fed and mixed-fed infants, stratified by four sanitation categories. Good quality water was represented by in-house piped water, and private excreta disposal was represented by the availability of a water closet (or flush) system.

Table 4. Prevalence of diarrhoea in the 2 weeks before the survey for infants aged 3–6 months, by feeding practice and level of sanitation: Ghana (1993) and Nigeria (1990)

	Percentage prevalence among infants	
Category	Fully breast-fed	Mixed-fed
Ghana		
In-house water		
Yes	12·4	15·8
No	18·0	22·8
Private excreta disposal		
Yes	5·4	14·1
No	17·7	21·3
Nigeria		
In-house water		
Yes	12·5	17·5
No	24·5	29·9
Private excreta disposal		
Yes	29·6	38·1
No	39·3	48·0

See notes under Table 3 for the definitions of the measures of breast-feeding.

The tabulations show that for each feeding category, infants living under 'poor' sanitation conditions experienced higher levels of diarrhoea.

Multivariate results

The results of three multivariable analysis models are presented in Table 5 for Ghana and Nigeria. Model 1 is the main effects (or simple) model where only the breast-feeding variables are included. Model 2 includes the sanitation and background variables while Model 3 includes the interaction terms from statistically significant sanitation and full breast-feeding variables. Since the probit model has a normal tail, interpreting the coefficients requires thinking in the z metric. For example, the interpretation of the coefficient of the breast-feeding variable for Model 1 in Table 5 is that each one-unit increase in breast-feeding leads to a decrease in the probit index for diarrhoea morbidity of 0·231 standard deviations in Ghana.

Main effects

Results of the multivariable models indicate that both breast-feeding type and environmental sanitation are important determinants of diarrhoeal disease during the first 6 months of a child's life. In essence, the protective effect of full breast-feeding relative to mixed feeding is made clear by the statistical significance of the coefficient

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Table 5. Probit models of diarrhoea for infants aged 3–6 months: Ghana (1993) and Nigeria (1990)

	Ghana			Nigeria		
Variable	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Breast-feeding						
Fully breast-fed	−0·603**	−0·574*	−0·460*	−0·456***	−0·413***	−0·411***
	(0·231)	(0·273)	(0·190)	(0·013)	(0·019)	(0·017)
Mixed-fed	−0·542*	−0·318		−0·220*	−0·210	
	(0·291)	(0·295)		(0·108)	(0·110)	
Age weaned	0·273*			0·320		
(>4 mth = 0)	(0·098)			(0·231)		
Type of water (stream)						
Private tap		−0·036*	0·007**		−0·120*	0·082**
		(0·016)	(0·002)		(0·114)	(0·009)
Rain water		−0·381	0·242*		0·542**	0·239*
		(0·239)	(0·098)		(0·134)	(0·102)
Toilet facility (pit = 0)						
No facility		−0·245	0·149**		0·046	0·222**
		(0·112)	(0·009)		(0·037)	(0·015)
Flush toilet		−0·604**	−0·019**		−0·451***	−0·021**
		(0·280)	(0·008)		(0·179)	(0·006)
Mother's education						
(none = 0)						
Primary		−0·021			−0·213	
Secondary		−0·564***			−0·402***	
		(0·106)			(0·098)	
Higher		−0·073			−0·741**	
		(0·068)			(0·230)	
Refrigerator (no = 0)		−0·022			−0·017	
		(0·093)			(0·095)	
Sex of child (boy = 0)		−0·209			−0·198	
		(0·198)			(0·176)	
Age of child		0·109***			0·036*	
(in months)		(0·009)			(0·012)	
Age squared		0·003***			0·001	
		(0·001)			(0·001)	
Intercept	−0·978	−0·705	−0·590	−0·529	−0·509	−0·483
Log-likelihood	−1029	−1001	−997	−1773	−1750	−1590
Number of cases	2024	2009	989			

***$p<0·01$, **$p<0·05$; *$p<0·10$.

β. Mixed feeding has a somewhat smaller but statistically significant effect ($\beta = -0·220$, $p<0·1$ compared with $\beta = -0·456$, $p<0·01$ for full breast-feeding relative to all other categories in Nigeria; and $\beta = -0·542$, $p<0·10$ versus $\beta = -0·603$, $p<0·05$ in Ghana). The level of significance for both fully breast-fed and mixed-fed variables in the

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Nigerian data is much stronger than in the case of Ghana ($p<0{\cdot}01$ for Model 1 and $p<0{\cdot}05$ for Model 2 but only marginally significant for Models 1 and 2 in Ghana).

The effects of no toilet facility and no in-house water connection indicate that there is a strong link between poor environmental conditions and the risk of diarrhoeal disease. The consumption of untreated water can increase the risk of diarrhoea independent of feeding mode. It is important to note, however, that other measures of household sanitation, such as adequate food storage practices proxied by the availability of refrigeration, did not associate significantly with diarrhoea ($\beta=-0{\cdot}017$, $p>0{\cdot}10$ for households in Nigeria with this facility relative to those who do not have it). For Nigeria as a whole, the availability of a refrigerator has very little effect on diarrhoea prevalence, as indicated by the non-significance of the p value, perhaps because most baby food is stored in food flasks. The availability of a refrigerator in Ghana, however, appears to play a part in diarrhoea prevention, since the value of the coefficient in Model 2 is marginally significant ($p=0{\cdot}12$).

To assess the risk associated with the sanitation variables, the coefficients from the main effects model were used to predict the probability of diarrhoea for each feeding mode at three levels of water quality: in-house, public tap and other sources. The resulting predicted values give the probabilities that an infant with a given characteristic will experience an episode of diarrhoea over a 14-day period, and therefore represents the average effect for children in the 0–6 months age segment. Full breast-feeding produces the lowest risk of diarrhoea. The predicted probability of a child having diarrhoea in this category is 0·09 compared with 0·17 for public tap and 0·43 for other sources. In other words, supplementing fully breast-fed infants with public tap water nearly doubles the risk of diarrhoea while non-piped sources like river water raise the risk by nearly five times. In effect, because mixed-fed infants consume greater quantities of water and other liquids, they face much greater risk when these liquids are contaminated.

The child's age also turns out to be a strong predictor of diarrhoea for the two samples in Model 2. Diarrhoea increases with age up to about 18 months in Nigeria and to about 17 months in Ghana and thereafter decreases to normal levels (because quadratic ax^2+bx+c turns over at $x=-b/2a$, which for the age and age^2 coefficients is about 18 months for Nigeria and 17 months for Ghana). Further examination of the age components shows that age *per se* is a poorer predictor of diarrhoea than age at which breast-feeding stopped. Children weaned before age 4 months tend to have a greater risk of diarrhoea than those still being breast-fed. Again the logic is that infant foods can become contaminated more easily under poor hygienic conditions, so keeping the child on the breast is protective against disease.

Interactions

Using the same argument as in the case of water quality, one can argue that not giving infants breast milk substitutes and semi-solid foods too early in life (before age 4 months) is most effective at decreasing diarrhoea prevalence under poor sanitary conditions. Model 3 (Table 5) was designed to assess whether the protective effects of full breast-feeding vary with the levels of sanitation (proxied by rain water, flush toilet, private tap and no toilet facility). This was done by interacting the sanitation variables with the main effect model variables. The effect of covariates if there are interactions

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is to raise or lower the risk of diarrhoea when a mother is simultaneously breast-feeding fully and using rain water or flush toilet or using a private tap or has no toilet facility. The null hypothesis here is that there are no significant interactions.

For the two datasets, the hypothesis that modern sanitary facilities would have the most pronounced effect on breast-feeding when supplementary foods are introduced is well supported. Full breast-feeding tends to reduce the risk of diarrhoea while using rain water, and when the mother has no access to a toilet facility. The magnitudes of the coefficients for the interaction variables of rain water and no toilet facility relative to in-house water and flush toilet indicate that full breast-feeding has a strong protective effect for infants living in communities with poor sanitation. This supports the hypothesis that breast-feeding has a stronger protective effect where sanitation is poor.

Stratification

The analysis was stratified by type of water connection where 'good' and 'poor' are used to refer to in-house water and non-in-house water respectively. Similarly, households were stratified according to the type of toilet facility (no toilet facility = poor; flush system = good). Results of this analysis for Ghana and Nigeria are presented in Table 6. In Nigeria, while breast-feeding is a significant protective factor in both the poor and good sanitation areas, the magnitude of the effect in the poor communities is greater than in the good sanitation areas ($\beta = -0{\cdot}590$, $p < 0{\cdot}01$ for fully breast-fed infants in poor areas compared with $\beta = -0{\cdot}282$, $p < 0{\cdot}05$ in good areas). This was also the case for mixed-fed children in Nigeria. In Ghana, for a child who is fully breast-fed and living in a poor area $\beta = -0{\cdot}665$ ($p < 0{\cdot}01$), whereas $\beta = -0{\cdot}532$ ($p < 0{\cdot}05$) for a child who is fully breast-fed and living in a good area; for mixed-fed children in a poor area, $\beta = -0{\cdot}515$ ($p > 0{\cdot}10$) versus $\beta = -0{\cdot}416$ ($p < 0{\cdot}01$) for mixed-fed children living in a good area. In the poor sanitation areas of Nigeria, the coefficient for fully breast-fed infants ($\beta = -0{\cdot}590$) is twice that for the good sanitation areas ($\beta = -0{\cdot}282$). The coefficients are also highly significant ($p < 0{\cdot}001$ versus $p < 0{\cdot}05$).

The parameters estimated from the stratified models were also used to predict the probability of diarrhoea associated with each breast-feeding pattern for both the poor and good sanitation areas. The poor sanitation areas tend to increase the risk of diarrhoea among mixed-fed infants but have a much lower effect on the fully breast-fed infants (predicted probabilities of positive outcome derived from the estimates equal 0·34 and 0·11 for the poor and good areas respectively for the Nigerian data). In effect, full breast-feeding can mitigate, to a large extent, the risk posed to households by poor sanitation and untreated water facilities.

Discussion

There are two logical conclusions to be made from this study's findings. First, the benefits derived from improving household sanitation would be greater for infants who are less breast-fed or weaned at a very early age, and less for those who are fully breast-fed. The other interpretation is that full breast-feeding has a stronger protective effect when sanitation is poor. It appears that fully breast-fed infants face a much lower

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Table 6. Diarrhoea model stratified by type of toilet facility and water connection for children aged 3–9 months of age: Ghana (1993) and Nigeria (1991)

	Type of sanitation			
	Poor		Good	
Variable	β	SE	β	SE
Nigeria				
Fully breast-fed	−0·590***	0·213	−0·282**	0·198
Mixed-fed	−0·275*	0·140	−0·267*	0·195
No in-house water	0·382**	0·182	0·263*	0·190
No toilet facility	0·248***	0·098	0·198**	0·089
Age given solids	−0·011***	0·002	−0·010***	0·008
Lagged weight (SD)	−0·027**	0·010	−0·012**	0·007
Child's age	−0·042**	0·022	−0·046**	0·029
Age squared	0·001*	0·001	0·014**	0·006
Intercept	−0·793		−0·681***	
No. of cases	3407		3407	
Log-likelihood	−5076·4		−4793·0	
Ghana				
Fully breast-fed	−0·665***	0·279	−0·532***	0·120
Mixed-fed	−0·515	0·572	−0·416***	0·125
No in-house water	0·327***	0·086	0·062*	0·039
No toilet facility	0·142	0·206	0·092*	0·048
Lagged weight (SD)	−0·026	0·031	0·001**	0·001
Child's age	0·076**	0·043	0·034**	0·017
Age squared	−0·028***	0·002	−0·009***	0·002
Intercept	−0·465		−0·531	
No. of observations	1823		1823	
Log-likelihood	−4540·3		−4371.6	

***$p < 0·01$; **$p < 0·05$; *$p < 0·10$.

risk of diarrhoea than mixed-fed children, and the difference in risk is greater for infants who live in poor sanitation areas with no toilets and poor quality water. Full breast-feeding protects them from the contaminating effects of poor and unhygienic water.

Not only is early mixed feeding an unnecessary and inappropriate substitute for colostrum, but it also appears to be an important route for the transmission of bacteria, exposing infants to the risk of early diarrhoea and dehydration – very significant causes of infant mortality. In an environment where homes have stagnant water nearby and houseflies move around without any control, diarrhoea will continue to prevail unless mothers revert to the practice of full breast-feeding in the child's first 4–6 months of life. Full breast-feeding is much more protective against diarrhoea than mixed feeding. Previous research supports this finding for parts of Nigeria (Huttly *et al.*, 1987).

The association between diarrhoea and age-complementary variables like lagged weight was found to be weak when age was not included in the estimation equations.

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This is probably because the risk of diarrhoea increases with age as full (or exclusive) breast-feeding is replaced by mixed feeding. It was found that age at supplementation was more significantly related to diarrhoea prevalence than the age of the infant *per se*. (The estimated test statistics show that $X^2_{ML} = 35{\cdot}3$ with $p < 0{\cdot}001$ is more significant than $X^2_{ML} = 6{\cdot}4$ with $p = 0{\cdot}120$ for the age variable *per se*.)

While mixed-fed children have a higher risk of diarrhoea than fully breast-fed infants in the first 3–6 months of life, they are still probably only half as likely to develop diarrhoea in comparison with children weaned very early after birth. This inverse relationship between the extent of breast-feeding and the risk of diarrhoea appears to stem from two factors: (1) reduced protection from maternal antibodies in breast milk and (2) an increase in exposure to food-borne pathogens. The data showed a positive interactive effect between breast-feeding and in-house water connection, which could be explained as follows. There is a high correlation between in-house water connection and maternal socioeconomic status, such as education or labour force participation, each of which, as a result of time constraints, restricts the mother's ability to fully breast-feed her child. In other words, full breast-feeding is most common among poorer women who may not have access to an in-house water connection or a modern toilet facility. Because they breast-feed their children fully under unhygienic conditions, their children tend to enjoy the benefits of full breast-feeding more.

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References

Ashford, J. R. & Sowden, R. D. (1970) Multivariate probit analysis. *Biometrics* **26**, 535–546.

Esrey, S. A. & Habicht, J.-P. (1986) Epidemiologic evidence for health benefits from improved water supply and sanitation in developing countries. *Epidemiol. Rev.* **8**, 117–128.

Federal Office of Statistics (FOS) and Macro International Inc. (MI) (1992) *Nigeria Demographic and Health Survey 1990*. FOS and MI, Calverton, MD.

Ghana Statistical Service (GSS) and Macro International Inc. (MI) (1994) *Ghana Demographic and Health Survey 1993*. GSS and MI, Calverton, MD.

Habicht, J.-P., DaVanzo, J. & Butz, W. P. (1988) Mother's milk and sewage: their interactive effects on infant mortality. *Pediatrics* **18**, 456–461.

Haggerty, P. A., Levine, M. M., Murty, D. K. & Pandit, C. G. (1994) Community-based hygiene education to reduce diarrhoeal disease in rural Zaire: impact of the intervention on diarrhoeal morbidity. *Int. J. Epidemiol.* **23**, 1050–1059.

Holford, T. R. (1980) The analysis of rates and survivorship using loglinear models. *Biometrics* **36**, 299–305.

Huber, P. J. (1967) The behavior of maximum likelihood estimates under non-standard conditions. *Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability*, vol. 1, pp. 221–233.

HUTTLY, S. R. A., BLUM, D., KIRKWOOD, B. R. & EMEH, R. N. (1987) The epidemiology of acute diarrhea in a rural comunity in Imo State, Nigeria. *Trans. R. Soc. trop. Med. Hyg.* **81**, 865–870.

KIRKWOOD, B. R. (1989) Diarrhoea. In: *Disease and Mortality in sub-Saharan Africa*, pp. 134–151. Edited by F. G. Feachem & D. T. Jamison. Oxford University Press, Oxford.

LLOYD-EVANS, N., PICKERING, H. A., GOH, S. G. J. & ROWLAND, M. G. M. (1984) Food and water hygiene and diarrhea in young Gambian children: a limited case-control study. *Trans. R. Soc. trop. Med. Hyg.* **78**, 209–211.

MACRO INTERNATIONAL INC. (1993) *An Assessment of the Quality of Health Data in DHS Surveys*. DHS Methodological Reports, No. 2. Macro International Inc., Calverton, MD.

PAHO/WHO (1983) *Oral Rehydration Therapy: An Annotated Bibliography*. PAHO, Washington, DC.

ROSENZWEIGH, M. R. & SCHULTZ, T. P. (1983) Estimating a household production function: heterogeneity, the demand for health inputs, and their effects on birthweight. *J. Polit. Economy* **91**, 723–746.

STATACORP (1997) *Stata Statistical Software Release 5.0*. Stata Corporation, College Station, TX.

WORLD HEALTH ORGANIZATION (1991) *Indicators for Assessing Breastfeeding Practices*. WHO, Geneva.