International Journal of Epidemiology

Vol. 23, No. 4
Printed in Great Britain

Family Latrines and Paediatric Shigellosis in Rural Bangladesh: Benefit or Risk?

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Ahmed F (International Centre for Diarrhoeal Disease Research, Bangladesh, Dhaka, Bangladesh), Clemens J D, Rao M R and Banik AK. Family latrines and paediatric shigellosis in rural Bangladesh: Benefit or risk? *International Journal of Epidemiology* 1994; 23: 856–862.

Background. The potential benefits of installing excreta disposal facilities on the burden of paediatric diarrhoea in less-developed settings remain controversial. We conducted a longitudinal study to evaluate whether family latrines are associated with interruption of the transmission of shigellosis to younger children in rural Bangladesh.

Methods. We prospectively studied 1529 children under 5 years of age exposed to index cases of *Shigella* dysentery. In all 219 children with culture-proven shigellosis detected during 1 month of follow-up were compared with 1310 control children who did not develop shigellosis or *Shigella*-negative dysentery.

Results. Overall, the presence of a family latrine appeared to be associated with a higher, not a lower, risk of paediatric shigellosis (adjusted odds ratio (OR_a) = 1.37, 95% confidence interval (CI): 0.99–1.89). While use of a pit or sanitary latrine revealed no evidence of a protective association (OR_a = 0.96, 95% CI: 0.43–2.15), use of a hanging latrine in which faeces were discharged directly onto the ground or into a body of water was associated with a notable increase of risk (OR_a = 1.42, 95% CI: 1.02–1.98, $P < 0.05$).

Conclusions. While cautioning that installation of sanitary latrines may not be sufficient to reduce the burden of paediatric shigellosis in less-developed settings, these data suggest that eliminating unsanitary latrines constitutes a potentially important intervention in its own right in these settings.

Improvement of facilities for disposal of excreta was one of the major aims of the International Water Supply and Sanitation Decade (1981–1990).[1] Doubts have been raised, however, concerning the validity of findings of studies that have assessed the impact of excreta disposal facilities on paediatric diarrhoea.[2] Moreover, because the impact of such facilities on diarrhoea may vary according to the pathogen involved,[1] aetiology-specific studies are desirable. Because morbidity and mortality due to shigellosis is particularly high in less-developed countries, assessments of the impact of latrines on the transmission of *Shigella* are of great importance.[3,4] In this paper, we describe the results of a large-scale, community-based study of *Shigella*-exposed neighbourhoods in rural Bangladesh, addressing the following questions: (1) Was the presence of a latrine associated with a lower risk of the occurrence of shigellosis among children? (2) Did this association differ according to whether the latrine was sanitary versus unsanitary? (3) Was the association modified by breastfeeding status?

METHODS

Overview

The association between having a latrine and the occurrence of shigellosis was determined in 1529 Bangladeshi children exposed to *Shigella* in their residential neighbourhoods. Each child was prospectively followed by home visits for 1 month, and the presence and type of a family latrine was related to the occurrence of *Shigella* diarrhoea.

Assembly of Index Cases for Initiating Neighbourhood Contact Studies

As described earlier[5,6] index cases of *Shigella* dysentery were assembled from patients presenting to the three diarrhoeal treatment centres serving the Matlab study population of the International Centre for Diarrhoeal Disease Research, Bangladesh. Such cases were potentially eligible to initiate follow-up in their residential neighbourhoods if the onset of diarrhoea was less than 1

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week before initiation of the neighbourhood contact study. As detailed previously,[5] 240 index cases were chosen among the 507 cases that were eligible during the period 1 November 1987 to 30 November 1989.

Assembly of Subjects for the Study

Workers visited the neighbourhood of each index case within 48 hours of presentation to the treatment centre. Informed consent for participation was obtained from a responsible adult for each participating child. All families situated around the courtyard of the residence of the index case and around two adjacent courtyards constituted the neighbourhood for study. In all 1934 children aged 0–59 months from 240 neighbourhoods were assembled, out of which 1756 (91%), from 1218 families, were present at baseline.

Acquisition of Baseline Data

On day 1, a reliable adult member was questioned about selected sociodemographic characteristics of the family, including ownership and use of a latrine. The design of the latrine was observed by field workers, with queries being made regarding the underground structure. Mothers (or caretakers, if mothers were absent) were asked about diarrhoea in their children occurring in the previous week, as well as about antibiotic use and the feeding practices of each child. Heights of children were measured to the nearest 1 mm. Height-for-age was assessed in relation to National Center for Health Statistics reference data.[7] A rectal swab was also collected from each participating child and immediately placed in buffered glycerol saline transport medium.[8] Plating was done on MacConkey and *Salmonella-Shigella* media within a few hours of swab collection, and evaluated for *Shigella* using standard techniques.[9]

Surveillance for Post-Baseline Diarrhoea

After baseline, study children were visited on alternate days for 10 days to obtain interval diarrhoeal histories. After day 10, three additional visits were made, commencing from day 17, during which 7-day diarrhoeal recall histories were obtained. To improve the 7-day recall, mothers were encouraged to record diarrhoea on calendars designed for use by illiterate adults. Rectal swabs were collected if diarrhoea, as defined below, was reported in the interval since the previous visit. Field workers were instructed to empirically treat all dysenteric illnesses with nalidixic acid.[10]

Definitions

Several definitions were formulated before analysis of the data. A diarrhoeal day was defined as a 24-hour period with ≥ 3 non-bloody loose or liquid motions, or with ≥ 1 bloody loose or liquid motions. The onset of an episode of diarrhoea was the first day with diarrhoea before which there were at least 3 consecutive diarrhoea-free days. The end of the episode occurred with the onset of ≥ 3 consecutive diarrhoea-free days, the day of termination of the episode being the last diarrhoeal day preceding the diarrhoea-free days.[11] Persistent diarrhoea was defined as an episode that lasted ≥ 14 days while episodes of shorter duration were termed acute.[11] Shigellosis denoted isolation of *Shigella* from a faecal specimen anytime from 3 days before the onset of a diarrhoeal episode to 3 days after the end of the episode. Dysentery denoted diarrhoeal episodes described as bloody. If a child had episodes of both shigellosis and culture-negative dysentery, the child was classified as having shigellosis.

A family was considered to have a latrine if it owned and used a latrine. In the rare event that a family had more than one latrine, the one primarily used by the family was classified. A hanging latrine referred to a platform resting on pillars, with walls made of brick, tin, bamboo, or jute stick, and from which faeces fell directly onto the land surface, embankment, or water. A pit latrine consisted of a concrete slab with a squat-type pan placed over an underground pit. A latrine with a septic tank was denoted as a sanitary latrine. A child was classified as breastfed if breast milk constituted any portion of the child's diet, as ascertained on the day before the onset of illness for children having diarrhoea beginning at or before baseline, and at baseline for other children.

Statistical Analysis

Before analysis of the data, we decided to exclude 227 children detected during follow-up as having culture-negative dysentery, since we were interested in the impact of latrines upon transmission of *Shigella* and since we could not exclude *Shigella* as an aetiological pathogen in these culture-negative episodes, due to the known insensitivity of culture techniques for *Shigella*.[12] After these exclusions, a study population of 1529 children remained. For the examination of associations between exposure variables and acute versus persistent *Shigella* diarrhoea, only episodes of shigellosis having onsets before day 19 of follow-up were included to ensure that all episodes had an equal opportunity of being detected as becoming persistent, regardless of the day of onset (follow-up extended only to day 31).

Inter-group comparison of means were statistically compared with the Student's t-test, comparisons of proportions were evaluated with the χ^2 or Fisher's exact test, and medians were assessed with Wilcoxon's rank sum test. To evaluate the association between presence of

latrines and the occurrence of paediatric shigellosis, we compared cases (n = 219), neighbourhood contacts aged <60 months with culture-confirmed shigellosis; with controls (n = 1310), those in the same age group in whom neither shigellosis nor *Shigella*-negative dysentery was detected. The magnitude of the association was expressed as odds ratio to incorporate simultaneous analysis of outcomes detected at baseline or thereafter. To obtain odds ratios adjusted for the simultaneous confounding effect of relevant baseline variables, selected on the basis of either statistical significance or biological importance, multiple logistic regression models were fitted, taking case-control status as the dependent variable (PROC LOGISTIC, Version 6.07, Statistical Analysis Software, Cary, NC).[13] Possible interactions between variables were also evaluated. The 95% confidence intervals (CI) for odds ratios were computed with Woolf's method in simple analyses, and with use of the standard error of coefficients in logistic models. Adjustment for the clustering of responses among families was done by a software program developed by Research Triangle Institute (Shah B V, Folsom R E, Harrell F E, Dillard C N. *RTILOGIT: Procedure for Logistic Regression on Survey Data, January 1987.* Research Triangle Institute, PO Box 12194, Research Triangle Park, NC 27709, USA). All test statistics were interpreted in a two-tailed fashion to estimate *P* values and confidence intervals.

RESULTS

Baseline Comparability

In all 219 cases of microbiologically-confirmed shigellosis were found among 204 families. Bivariate comparisons of cases and controls for several relevant baseline characteristics revealed that older age (median age of 33 versus 27 months, $P < 0.001$), stunting (mean height-for-age z scores of −2.9 versus −2.5, $P < 0.001$), lack of breastfeeding (34% of cases versus 11% of controls among under-3 year olds, $P < 0.001$), Muslim religion (98% of cases versus 95% of controls, $P < 0.05$), family ownership of land (89% of cases versus 82% of controls, $P < 0.05$), and lower age of the index case (median age 4 versus 5 years, $P < 0.01$) were significantly associated with the occurrence of *Shigella* cases (Table 1).

TABLE 1 *Comparison of cases and controls for selected baseline features, Bangladesh, 1987–1989*[a]

Feature	Cases (n = 219)	Controls (n = 1310)
Median age of child (months) (range)	33 (5–59)	27*** (0–59)
Male	108 (49)	670 (51)
Muslim	215 (98)	1246 (95)*
Height-for-age z score[b] (Mean ± SD)	−2.9 ± 1.1	−2.5 ± 1.2***
Breastfed[c]	82 (66)	730 (89)***
Median years of schooling of mother or caretaker (range)	0 (0–12)	0 (0–12)
Median family size (range)	7 (2–20)	6 (2–24)
Median per capita yearly income of family (range)[d]	3007 (833–18 743)	3000 (383–29 000)
Family owns land	194 (89)	1069 (82)*
House with tin or brick walls[e]	72 (33)	384 (29)
Functioning tubewell in courtyard	62 (28)	407 (31)
Residence in index family	15 (7)	70 (5)
Shigella species of index case		
flexneri	106 (48)	675 (52)
dysenteriae 1 (*shiga*)	95 (43)	493 (38)
Other	18 (8)	142 (11)
Median age of index case (years) (range)	4 (0–68)	5** (0–79)
Male index case	141 (64)	887 (68)
Index case is mother[f]	0 (0)	10 (1)
Season of selection[g]		
Pre-monsoon	54 (25)	295 (23)
Monsoon	56 (26)	431 (33)
Post-monsoon	109 (50)	584 (45)

[a] Values represent number (per cent).
*$P < 0.05$; **$P < 0.01$; *** < 0.001, for comparison of cases versus controls.
[b] For 215 cases and 1267 controls with known information.
[c] Under-3 year olds only (124 cases and 819 controls).
[d] Bangladesh taka (1 US dollar = 32 taka). Three controls with unknown income were excluded.
[e] Excluded one control with unknown wall type.
[f] No caretaker was an index case.
[g] Pre-monsoon = March–May; monsoon = June–September; post-monsoon = October–February.

Association between Type of Latrine and the Occurrence of Shigellosis

Table 2 shows the relationship between having a family latrine and the occurrence of shigellosis. Overall, use of a family latrine appeared to be associated with a higher, not a lower, risk of paediatric shigellosis (odds ratio adjusted for covariates [OR_a] = 1.37, 95% CI: 0.99–1.89). Compared to having no latrine, having a hanging latrine was significantly associated with the occurrence of shigellosis ($OR_a = 1.42$, 95% CI: 1.02–1.98, $P < 0.05$), whereas having a pit or sanitary latrine was not ($OR_a = 0.96$, 95% CI: 0.43–2.15). Additional adjustment for the clustering of responses among families yielded adjusted odds ratios of 1.42 (95% CI: 1.02–1.99, $P < 0.05$) and 0.96 (95% CI: 0.44–2.10) for hanging or pit/sanitary latrines, respectively.

TABLE 2 *Overall association between latrine type and episodes of shigellosis: Bangladesh, 1987–1989*

	Cases No. (%)	Controls No. (%)	Crude odds ratio (95% confidence interval)	Adjusted odds ratio[a] (95% confidence interval)
No latrine	131 (60)	905 (69)	1.00[b]	1.00[b]
Latrine	88 (40)	405 (31)	1.50** (1.12–2.02)	1.37 (0.99–1.89)
Hanging latrine	79 (36)	348 (27)	1.57** (1.16–2.13)	1.42* (1.02–1.98)
Pit or sanitary latrine[c]	9 (4)	57 (4)	1.09 (0.53–2.26)	0.96 (0.43–2.15)

[a]Adjusted for age (coded directly, in months), height-for-age (z scores), breastfeeding (0 = no, 1 = yes), mother's education (in years), religion (0 = Hindu, 1 = Muslim), land ownership (0 = no, 1 = yes), tubewell in courtyard (0 = no, 1 = yes), index age (in years), and season (coded as dummy variables) in multiple logistic models fitted to the 215 cases and 1267 controls with complete information. Children aged ≥ 36 months classified as non-breastfed.
[b]Referent group.
[c]Families of nine controls had sanitary latrines, while none of the case families had sanitary latrines.
*$P < 0.05$; **$P < 0.01$, for comparison of cases versus controls.

Modification of the Association by Breastfeeding Status

Because breastfeeding is documented to be a potent protective factor against *Shigella* diarrhoea in Bangladesh,[5] and because excreta disposal improvements have been observed to have a substantially greater impact on infant mortality among non-breastfed than among breastfed infants in other settings,[14] we examined the possibility that breastfeeding was an important modulator of the association between latrines and the risk of *Shigella* diarrhoea. Among non-breastfed children, the association between having a hanging latrine and paediatric shigellosis, compared to having no latrine, was substantial ($OR_a = 1.82$, 95% CI: 1.18–2.80, $P < 0.01$), whereas no association was observed for having a pit or sanitary latrine (Table 3). The elevated risk associated with hanging latrines was primarily attributable to an increase in the occurrence of persistent *Shigella* episodes ($OR_a = 3.10$, 95% CI: 1.55–6.20, $P < 0.01$) rather than to an increase in the occurrence of acute episodes of shigellosis ($OR_a = 1.44$, 95% CI: 0.82–2.52). In contrast, no such associations were seen among breastfed children (OR_a for shigellosis = 0.97, 95% CI: 0.55–1.69; OR_a for persistent shigellosis = 1.18, 95% CI: 0.47–2.97; OR_a for acute shigellosis = 0.94, 95% CI: 0.42–2.12).

Other Modifications of the Association

To further define the association between hanging latrines and *Shigella* in non-breastfed children, several additional subgroup analyses were performed. The association seemed to increase with increasing age of the child, with a peak in the fourth year of life ($OR_a = 3.62$, 95% CI:1.73–7.57, $P < 0.001$), though the association declined in the fifth year ($OR_a = 1.02$, 95% CI:0.49–2.13). The association appeared to be somewhat greater if the mothers had no schooling ($OR_a = 2.17$, 95% CI:1.17–4.02, $P < 0.05$) than if the mothers had some schooling ($OR_a = 1.58$, 95% CI:0.86–2.90). The association also seemed to be more pronounced during the monsoon season ($OR_a = 2.77$, 95% CI: 1.09–7.00, $P < 0.05$) than during the other seasons ($OR_a = 1.50$, 95% CI:0.55–4.08 for the pre-monsoon season; ($OR_a = 1.68$, 95% CI:0.93–3.03 for the post-monsoon season).

DISCUSSION

Our results indicate that having a family latrine was associated with an elevated, not a reduced, risk of the occurrence of shigellosis among rural Bangladeshi children; that this elevation of risk was attributable both to an apparent lack of protection associated with pit or sanitary latrines and to an elevation of risk associated with hanging latrines; and that children weaned from breastfeeding were particularly vulnerable to the environmental risk of hanging latrines. The results of a previous study, although not reaching statistical significance, also suggest that open latrines increase the risk of *Shigella* infections among family contacts of *Shigella* index cases.[15] Before considering the implications of these findings, several limitations of our study require discussion.

Potential Limitations

Our study reflects the experiences of subjects in close residential proximity to index cases with culture-confirmed *Shigella* dysentery. It is uncertain whether

TABLE 3 *Association between latrine type and episodes of shigellosis, by child's diet: Bangladesh, 1987–1989*

Feature	Cases No. in stratum (% with cited feature)	Controls No. in stratum (% with cited feature)	Crude odds ratio for stratum (95% confidence interval)	Adjusted odd ratio [a] for stratum (95% confidence interval)
Non breastfed				
No latrine	75 (55)	397 (68)	1.00[b]	1.00[b]
Any latrine	62 (45)	183 (32)	1.79**	1.73*
			(1.23–2.62)	(1.13–2.63)
Hanging latrine	56 (41)	156 (27)	1.90***	1.82**
			(1.28–2.81)	(1.18–2.80)
Pit or sanitary latrine	6 (4)	27 (5)	1.18	1.16
			(0.47–2.95)	(0.44–3.06)
Breastfed				
No latrine	56 (68)	508 (70)	1.00[b]	1.00[b]
Any latrine	26 (32)	222 (30)	1.06	0.96
			(0.65–1.74)	(0.55–1.65)
Hanging latrine	23 (28)	192 (26)	1.09	0.97
			(0.65–1.82)	(0.55–1.69)
Pit or sanitary latrine	3 (4)	30 (4)	0.91	0.82
			(0.27–3.07)	(0.17–3.86)

[a] See Table 2.
[b] Referent group.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

observations about these intensely exposed children can be generalized to settings with less intense exposure. The increased occurrence of shigellosis associated with hanging latrines could have been due to a bias if such latrines tended to be used by families that were otherwise more susceptible to shigellosis. However, this seems unlikely since the association was restricted only to non-breastfed children, and since the overall association persisted despite control for several potential confounding variables. Nevertheless, it is still possible that other unmeasured factors could have partially accounted for the findings. Bias could also have arisen if shigellosis had been more intensely detected in children of families having hanging latrines than those of families having no latrines. This possibility seems unlikely for several reasons. Firstly, field workers collected diarrhoeal histories using structured data forms. Secondly, workers were unaware of the study hypothesis. Thirdly, the proportion of potential follow-up days during which diarrhoeal histories were obtained were similar among families in the different latrine categories. Finally, among non-breastfed children, the association between having a hanging latrine and the occurrence of severe episodes of shigellosis with visible blood, which were unlikely to have been missed, remained substantial ($OR_a = 1.75$, 95% CI:0.93–3.32).

The purpose of the study was to evaluate whether family latrines interrupted *Shigella* transmission among *Shigella*-exposed neighbourhoods and therefore it was conceptually appropriate to include all shigellosis cases detected among the contacts. However, the inclusion of families with multiple shigellosis cases could have created interpretational problems due to the potential non-independence of these intra-family episodes. We evaluated this potential problem in two ways. Firstly, we repeated the analysis including only initial cases occurring in any particular family. This analysis was similar to the original analysis. For example, among non-breastfed children, OR_a for hanging latrines versus no latrine = 1.75 (95% CI:1.12–2.72, $P < 0.05$). Secondly, we repeated the analysis using a statistical technique that adjusted estimates of variance for odds ratios to account for intra-family clustering of shigellosis cases. As described earlier, this analysis differed little from the original analysis.

The exclusion of the 227 neighbourhood children with *Shigella*-negative dysentery, which represented shigellosis cases in which *Shigella* could not be isolated due to the vagaries of antibiotic use and specimen processing,[8,16] as well as other cases of dysentery, could be questioned. However, bias due to their exclusion seems unlikely for the following reasons. Firstly, the differential use of antibiotics was unlikely, since among children with shigellosis or culture-negative dysentery at baseline, the ingestion of antibiotics during the 7 days prior to baseline

did not differ significantly by type of family latrine. Secondly, the procedure for specimen collection and processing was similar for all children and laboratory personnel were unaware of the type of latrine. Although repeating the analysis with the 227 culture-negative dysentery cases included in the case definition reduced the magnitude of the association (among non-breastfed group, OR_a for hanging latrines versus no latrine = 1.23, 95% CI: 0.86–1.76), we believe that this was most probably due to the heterogeneous aetiology of culture-negative dysentery among the under-5 year olds.

Biological Implications

The apparent lack of protection associated with pit or sanitary family latrines could suggest that small numbers of such facilities in a highly contaminated environment are not sufficient to reduce paediatric shigellosis or that unhygienic behavioural practices may have counteracted the potential benefits of such latrines.[1,17] The association between hanging latrines and paediatric shigellosis probably occurred in part because hanging latrines directly deposited faeces into, or near, canals and other bodies of water, contaminating drinking and cooking water from these water sources, and exposing individuals during swimming, bathing, or other water-related activities.[18,19] Although discharge of uncovered contaminated faeces on land by hanging latrines could have promoted transmission via mechanical carriage by flies,[20] or by direct exposure of children playing in these areas, it seems to be an unlikely explanation for our observation because the comparison group comprised families without latrines.

The apparent increase in the magnitude of the association between hanging latrines and shigellosis with age of the child could reflect greater environmental exposure to faecal contamination with increasing mobility. On the other hand, the absence of a demonstrable association in the fifth year of life could be because of the protective effect of acquired immunity resulting from prior infections.[21] The stronger association observed in the rainy season could have been due to monsoon-induced dispersion of faecal material from the grossly contaminated hanging latrines, leading to greater contamination of water sources. The fact that hanging latrines were associated with greater increases in the occurrence of persistent shigellosis than of acute shigellosis is likely related to the small inoculum required to transmit *Shigella*,[4] and the possibility that increasing the inoculum size via environmental contamination has a greater effect on diarrhoeal severity than diarrhoeal incidence.[22]

Practical Implications

The failure to observe a protective effect of pit or sanitary latrines, does not preclude a role in interrupting the transmission of shigellosis, but suggests that these measures must be supplemented by other interventions for the control of shigellosis. Our data indicate that elimination of unsanitary latrines constitutes a clear public health priority. The potential benefits of eradication of unsafe latrines are especially cogent in view of the demonstrable association between unsafe latrines and persistent *Shigella* diarrhoea, a major cause of malnutrition and death among children in less-developed countries.[3,23]

ACKNOWLEDGEMENTS

This research was supported by the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B), and funded by the Diarrhoeal Diseases Control Program of the World Health Organization and the US Agency for International Development (USAID grant # DPE-5928-A-00-6002-00). ICDDR, B is supported by countries and agencies which share its concern for the health problems of developing countries. Current donors include the aid agencies of the Governments of Australia, Bangladesh, Belgium, Canada, Denmark, France, Japan, The Netherlands, Norway, Saudi Arabia, Sweden, Switzerland, the UK, and the US; international organizations including the United Nations Development Programme, the United Nations Children's Fund, and the World Health Organization; and private foundations including the Ford Foundation and the Sasakawa Foundation.

The authors gratefully acknowledge the technical assistance and support of ICDDR,B staff members. Dr Isabelle de Zoysa and Dr David Sack gave helpful advice for the design and analysis of the study. The Demographic Surveillance System project of ICDDR,B provided demographic information.

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(Revised version received December 1993)