

Food Hygiene and Fecal Contamination on the Household Compound are Associated with Increased Pediatric Diarrhea in Urban Bangladesh (CHoBI7 Program)

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Abstract. In this prospective cohort study, we explored individual- and household-level risk factors associated with diarrheal diseases among 251 children younger than 5 years in slum areas of urban Dhaka, Bangladesh. During the 3-month study period, diarrhea surveillance was conducted monthly, and spot checks of the household compound were performed at baseline to assess the presence of feces (animal or human) in the household compound and in cooking and food storage areas, and to assess whether cooked food was covered and refrigerated. We also collected caregiver reports on child mouthing behaviors. Children living in households with feces within 10 steps of cooking and food storage areas (odds ratio [OR], 8.43; 95% CI, 1.01–70.18), those with visible feces found on the ground of the household compound (OR, 4.05; 95% CI, 1.24–13.22), and those in households found to keep cooked food uncovered and without refrigeration (OR, 6.16; 95% CI, 1.11–34.25) during spot checks had a significantly greater odds of diarrhea. There was no significant association between pediatric diarrhea and caregiver-reported child mouthing behaviors or presence of animals in the cooking area. These study findings demonstrate that presence of visible feces in the household compound and near cooking and food storage areas, and poor household food hygiene practices, were significant risk factors for diarrheal disease among young children in Dhaka, Bangladesh. Health communication programs are needed to target these exposure pathways to fecal pathogens.

INTRODUCTION

Diarrheal disease is a leading cause of death in children globally.^{1,2} Nearly 500,000 children are estimated to die of diarrheal diseases annually worldwide.³ In low- and middle-income countries (LMICs), young children experience three episodes of diarrhea on average every year, contributing to malnutrition, impaired growth, and adverse cognitive outcomes.^{2,4} Furthermore, environmental enteropathy (EE)—a condition that is thought to occur from chronic enteric infections from unsanitary environmental conditions, resulting in abnormal intestinal morphology, reduced intestinal barrier function, and increased intestinal inflammation—is a significant contributor to poor child health and growth outcomes in LMICs.^{5–12}

Fecal pathogens can be transmitted through contaminated soil, water, hands, food, surfaces, and objects.^{13,14} In many LMICs, young children are often exposed to animal and human feces and contaminated soil while crawling and playing both inside and outdoors.^{15–17} Young children often put surfaces and objects from their environment in their mouth; this is a normal part of their development.¹⁸ Several studies have demonstrated that geophagy—the consumption of soil, dirt, or mud—and child mouthing of feces, fomites, and contaminated hands, have been associated with EE, diarrhea, and growth faltering in young children.^{16,19–23}

The presence of feces on the household compound and improper waste disposal has been associated with childhood diarrhea.^{24–28} Zoonoses can also cause diarrheal diseases among young children,²⁹ with domestic animals such as birds

spreading fecal pathogens in the household environment.^{30–32} Fecal contamination from animal contact and feces is being increasingly recognized as an important risk factor for enteric infections among young children.^{33,34} In addition, unsafe disposal of child feces can lead to fecal contamination in the household compound and diarrheal disease in young children.³⁵ Most recently, our cohort studies^{16,19,21} in Bangladesh and the Democratic Republic of the Congo found child mouthing of contaminated fomites and feces was associated with diarrheal disease among young children in both rural and urban settings.

Unimproved drinking water and sanitation facilities are well-established risk factors for diarrheal disease.³⁶ Lack of handwashing with soap and challenges in the handling and treatment of drinking water are also associated with childhood diarrheal episodes.^{37,38} Food has long been identified as a critical transmission route for fecal pathogens, with studies^{39–41} reporting food being contaminated with fecal microbes from both humans and animals through poor food hygiene practices. Uncovered food can be contaminated by flies, for example, if flies land on feces then uncovered food.⁴² Fecal pathogens can also grow in food if it is not refrigerated or reheated properly.^{43,44} In addition, cooking and eating utensils may be contaminated by feces in the household environment, increasing the risk of contamination of cooked food.^{15,45}

The Cholera-Hospital-Based-Intervention-for-7-Days (CHoBI7) program, developed by our research group in Bangladesh, is a handwashing-with-soap and drinking-water-treatment intervention for household members of diarrhea patients.⁴⁶ These household members are at a much greater risk of developing diarrheal diseases (> 100 times for cholera) than the general population during the 7-day period after the patient with diarrhea is admitted at a health facility for care.^{47–49} A randomized controlled trial of the initial CHoBI7 program,⁵⁰ which targeted the household contacts of cholera patients, resulted in a significant reduction in both symptomatic cholera infections among

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intervention contacts as well as increased odds of handwashing with soap and improved water quality (relative to *E.coli*) in intervention households that was sustained 12 months post-intervention. CHoBI7 was subsequently expanded to target household members of diarrhea patients of all etiologies, with the inclusion of a mobile health (mHealth) component to accompany the health facility-initiated program and to remove the need for home visits for intervention delivery.^{46,51} The randomized controlled trial of the CHoBI7 mHealth program^{52,53} found that the intervention was effective in significantly reducing the burden of diarrhea and stunting among young children. Most recently, we broadened the scope of the CHoBI7 mHealth program to target child mouthing of contaminated fomites, food hygiene, and child feces disposal.⁵⁴ This program was named the CHoBI7 Baby WASH mHealth program because it targets water, sanitation, and hygiene (WASH) behaviors specific to young children.

Our current prospective cohort study, nested within the pilot study of the CHoBI7 Baby WASH mHealth program, seeks to investigate the individual- and household-level risk factors for diarrheal disease among children younger than 5 years residing in slum areas of Dhaka, Bangladesh. We hypothesized that the presence of feces in the household environment, poor food hygiene practices, and child mouthing of contaminated fomites would be associated with pediatric diarrhea in this setting.

METHODS

Study design. This prospective cohort study was nested within the pilot of the CHoBI7 Baby WASH program. The study was conducted from July 2018 to March 2020 and recruited patients with diarrhea presenting with three or more loose stools over a 24-hour period from two hospitals in urban Dhaka, Bangladesh: Mugda General Hospital (a government hospital), and the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b; a private hospital). The eligibility criteria for patients with diarrhea were the following: 1) have three or more loose stools during the past 24 hours, 2) plan to reside in Dhaka for the next 3 months, 3) have no basin for running water in the home (generally, residents in slum areas of Dhaka), 4) have a child younger than 5 years living in the household, and 5) have at least one working mobile phone in the household (to receive intervention content). After the recruitment of patients with diarrhea, their household members were also enrolled in the study. The methodology and content of the CHoBI7 Baby WASH program is published elsewhere.⁵⁴

Diarrhea patients and their household members were followed for 3 months. Informed written consent was obtained from a parent or legal guardian for all study participants. At baseline, caregivers of children younger than 5 years were administered a questionnaire on sociodemographic characteristics, including household literacy, latrine type, roof type, wall type, and refrigerator ownership. Diarrhea surveillance data was collected monthly based on caregiver-reported diarrhea (three or more loose stools over a 24-hour period) in the past 2 weeks for children younger than 5 years during the 3-month study period. At baseline and each monthly visit, caregivers were also administered questionnaires on hygiene behaviors to determine food hygiene and child mouthing behaviors. Child mouthing of dirt was defined as

a child putting dirt, soil, mud, clay, dust, or sand into their mouth in the past week.

Spot checks of the household compound were performed at baseline. For spot checks, animals or feces presence was defined as being within 10 steps of the respective location (e.g., cooking and food storage area). Field research assistants also conducted spot checks of the household compound at baseline to observe the presence of feces (animal or human), refrigeration of cooked food, and covering status of cooked food in cooking and food storage areas.

Statistical analysis. To investigate the association between prevalence of diarrhea in children younger than 5 years and individual- and household-level risk factors, logistic regression models were performed using generalized estimating equations to account for clustering at the household level, with risk factors from surveillance visits being the predictors and diarrhea from the following surveillance visit as the outcome.⁵⁵ All logistic regression models were adjusted for study arm, number of sleeping rooms, roof type, wall type, participant age, and refrigerator ownership. STATA version 13.0 (Stata Corp LP, College Station, TX) was used for analyses. These covariates were selected based on demographic factors associated previously with diarrheal diseases.

RESULTS

Two hundred fifty-one children younger than 5 years were included in this prospective cohort study. The average baseline age was 18 months (SD, 13 months; range, 1–59 months) (Table 1). At baseline, 48% of children (121 of 251) were female and the average number of individuals living in a household was five (SD, 2 individuals; range, 2–12 individuals). Ninety-five percent of children (239 of 251) resided in households with at least one household member who could read and write, and 80% of children (201 of 251) had a caregiver that reported being able to read and write. Ninety-seven percent of children (244 of 251) resided in a household with a concrete floor, 77% (193 of 251) with concrete walls, and 37% (94 of 251) with a concrete roof. Seventy-six percent of children (192 of 251) resided in households with one room for sleeping, and 2% of children (4 of 251) lived in households that used an unimproved latrine. Forty-eight percent of children (120 of 251) resided in a household that owned a refrigerator.

At the baseline spot checks, 10% of children (24 of 229) resided in households that had visible feces (animal or human) present within 10 steps of cooking and food storage areas, and 29% (72 of 251) had visible feces present on the ground of the household compound (at any location) at baseline. Fifty-seven percent of children (127 of 221) resided in households that had uncovered cooked food items kept without refrigeration. Forty-one percent of children (102 of 251) had caregiver reports of mouthing dirt in the past week at baseline. Seventeen percent of children (43 of 251) had caregiver reports of touching or handling human or animal feces in the past week, and 6% of children (15 of 251) had reports of mouthing human or animal feces in the past week. Eighty-three percent of children (208 of 251) had caregiver reports of touching objects such as toys and bottles, and 70% of children (170 of 251) had reports of mouthing objects such as toys and bottles in the past week.

TABLE 1
Baseline demographic characteristics among households ($N = 211$) with children < 5 years ($N = 251$) in Dhaka, Bangladesh

Characteristic	Value
Baseline age, months; mean \pm SD (min-max)	18 \pm 13 (0.06-59)
Individuals living in household, n ; mean \pm SD (min-max)	5 \pm 2 (2-12)
Literacy of caregiver, n (%)	201 (80)
Unimproved latrine, n (%)	4 (2)
Electricity, n (%)	249 (99)
TV ownership, n (%)	167 (67)
Radio ownership, n (%)	152 (61)
Refrigerator ownership, n (%)	120 (48)
Concrete roof, n (%)	94 (37)
Concrete floor, n (%)	244 (97)
Concrete wall, n (%)	193 (77)

max = maximum; min = minimum.

Children younger than 5 years who lived in households with feces present within 10 steps of cooking and food storage areas had an eight-times greater odds of diarrhea at the subsequent household visit (odds ratio [OR], 8.43; 95% CI, 1.01-70.18) (Table 2). Children with visible feces present on the ground of their household compound area had four-times greater odds of diarrhea at the subsequent household visit (OR, 4.05; 95% CI, 1.24-13.22) (Table 2). Children living in households with uncovered cooked food in cooking and food storage areas had six-times greater odds of diarrhea at the subsequent household visit (OR, 6.16; 95% CI, 1.11-34.25) (Table 2). No other significant associations were found.

DISCUSSION

In this prospective cohort study, we examined potential risk factors for diarrheal disease among children younger than 5 years in urban Dhaka, Bangladesh. We found that the presence of feces within 10 steps of cooking and food storage areas, presence of visible feces on the ground of the household compound, and uncovered cooked food items stored without refrigeration were significant risk factors for

diarrheal disease among young children. These findings demonstrate the need for WASH interventions targeting improved hygiene practices to reduce fecal contamination in the household environment and the need for food hygiene behaviors to improve child health.

The presence of feces near household cooking and food storage areas was associated with subsequent diarrhea in young children. The presence of feces near cooking and food storage areas presents a logical pathway for ingestion of diarrhea-causing pathogens by young children. Previous studies in Bangladesh and similar settings^{41,49,56} have demonstrated that food is often contaminated with fecal microbes in settings with high fecal contamination (e.g., slum areas). Furthermore, cooking utensils and dishes are commonly set on the ground near cooking and food storage areas in our setting; therefore, having feces present on the ground increases the chances of these fomites becoming contaminated. Previous studies have found utensils and dishes to have fecal contamination in settings with poor WASH conditions.^{15,40} The presence of feces near cooking and food storage areas also likely increases the risk of hand contamination when food is prepared.^{57,58}

In our study, the presence of feces on the ground of the household compound was associated with diarrhea in young children. This finding is consistent with that of our previous study in urban Bangladesh¹⁷ and from a study in rural Ethiopia,²⁶ which found that presence of feces around the household compound was associated with greater odds of diarrhea. A previous study in Mozambique⁵⁹ also found that the presence of feces or soiled diapers on the household compound was associated with greater protozoan infections. In rural Kenya, frequent observation of fresh rodent excreta on the household compound was found to be a significant risk factor for diarrhea.⁶⁰ Animal feces can contribute to fecal contamination in the domestic environment, including contamination of stored water and soil.⁶¹ The association observed in our study is likely because feces in the household compound contaminated cooked food and drinking water.^{17,23}

Uncovered cooked food stored without refrigeration was associated significantly with subsequent diarrhea in young

TABLE 2
Associations between household- and individual-level risk factors and diarrhea prevalence at the subsequent clinical surveillance visit for children younger than 5 years in urban Bangladesh

Risk factors	n	%	Surveillance visits, n	3-Month diarrhea prevalence OR (95% CI)	P value
Presence of animals within 10 steps of cooking and food storage areas	47	24	198	2.88 (0.82-10.17)	0.100
Presence of visible feces within 10 steps of cooking and food storage areas	19	10	198	8.43 (1.01-70.18)	0.049*
Presence of visible feces on the ground of the household compound	62	29	215	4.05 (1.24-13.22)	0.021*
Uncovered cooked food items kept without refrigeration	116	58	199	6.16 (1.11-34.25)	0.038*
Children with caregiver reports of mouthing dirt in the past week	87	40	215	0.68 (0.18-2.55)	0.567
Children with caregiver reports of touching/handling feces in the past week	33	15	215	1.62 (0.52-4.97)	0.402
Children with caregiver reports of mouthing feces in the past week	11	5	215	0.55 (0.06-5.11)	0.595
Children with caregiver reports of mouthing objects with visible dirt in the past week	153	71	215	0.34 (0.11-1.09)	0.070

OR = odds ratio.

All analyses were adjusted for participant age, study arm, number of sleeping rooms, roof type, wall type, and refrigerator ownership.

* Significant at $P < 0.05$.

children. This is likely because uncovered food can be contaminated through flies and rodents. Flies usually eat and defecate at the same time, and thus can transmit pathogens not only from their wings and legs, but also from their gut.^{62,63} Consistent with our finding, in South Africa,⁴⁴ not storing food in a refrigerator was associated with diarrhea among young children. In addition, a study conducted in Dhaka, Bangladesh,⁴² found that poor food storage practices such as uncovered food were associated with greater childhood diarrhea.

Our study did not find an association between child mouthing of contaminated fomites and diarrhea. This was unexpected and may be attributed to mouthing of hands being a more important transmission route, which we did not explore in our study. Young children in our study setting frequently play with toys and bottles with visible dirt, and then put their hands into their mouth.^{64,65} Hand contamination is an important transmission route for ingestion of fecal pathogens in young children.⁶⁶ Our recent study in the Democratic Republic of the Congo²³ and a previous study in Bangladesh⁶⁷ investigated the relative importance of various environmental transmission pathways for fecal pathogens on subsequent diarrhea in children younger than 5 years and found hand contamination to be the only transmission route significantly associated with subsequent diarrhea. Future studies should assess hand contamination and capture hand-to-mouth events among young children.

More than 98% of participants had access to improved sanitation, despite living in slum areas of Dhaka, Bangladesh. Although improved sanitation is associated with decreased diarrheal disease incidence in young children,^{68–71} diarrheal disease was still highly prevalent among our study population. This finding suggests that other fecal transmission pathways are important contributors to diarrheal diseases in this setting. Interventions are needed to reduce fecal contamination in the household environment (likely from unsafe child feces disposal and animal feces) and to promote food and hand hygiene behaviors. Potential interventions can include making soap and water for handwashing available in cooking areas, child potties being used and cleaned frequently, disposing of child feces safely in a latrine, keeping animals away from food preparation and storage areas, sweeping up animal feces in the household compound frequently and disposing of them in the latrine, covering cooked food and reheating food before eating, and washing utensils with detergent before use. Formative research is needed to tailor these WASH interventions for our target communities in slum areas of Dhaka, Bangladesh.

Our study has several strengths. First, we conducted spot checks in addition to collecting data on caregiver-reported behaviors, whereas many studies rely solely on caregiver reports to identify risk factors of diarrheal diseases. A second strength is that this is a prospective cohort study that monitored children for 3 months. This allowed us to assess diarrhea at multiple time points instead of a single time point. A third strength is that this research was conducted in an urban slum setting—a setting often more vulnerable to fecal contamination because of high population density and poor WASH infrastructure.^{17,21}

This study also has some limitations. First, caregiver-reported diarrhea in the past 2 weeks was our study outcome and may be prone to reporting bias, compared with 2-day or 7-day recall.⁷² We selected this recall period to

align with the Demographic and Health Surveys (DHS). A shorter window would have reduced diarrhea prevalence and our ability to detect a significant difference between children with and without study risk factors. Given our already-small sample size, we felt it was better to use the 2-week recall period used by the DHS. Future studies should collect data on 2-day, 7-day, and 14-day recall periods for diarrhea. Second, we did not include in our analysis a measure of fecal contamination of food, soil, objects, surfaces, or hands to investigate these pathways as risk factors for diarrhea. This would have provided valuable information on pathogen-specific risk factors for diarrhea and would elucidate further potential transmission pathways for diarrheal diseases for this population. Third, we did not investigate causality in this study; rather, this was an association study. Last, we did not differentiate between human and animal feces during spot checks. Future studies could collect stool samples and perform molecular typing to investigate whether stool samples are zoonotic or human in origin, as has been done in a previous study.⁷³

CONCLUSION

In this prospective cohort study conducted in urban slums in Dhaka, Bangladesh, we found that the presence of feces in cooking and food storage areas, presence of visible feces on the ground of the household compound, and uncovered cooked food stored overnight without refrigeration were associated with subsequent diarrhea among young children. This finding highlights the need for WASH interventions to reduce fecal contamination in the household environment, and the need for improved food hygiene practices to reduce diarrheal disease risk for this susceptible pediatric population.

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