Unsafe Child Feces Disposal is Associated with Environmental Enteropathy and Impaired Growth

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Objective To investigate the relationship between unsafe child feces disposal, environmental enteropathy, and impaired growth, we conducted a prospective cohort study of 216 young children in rural Bangladesh.

Study design Using a prospective cohort study design in rural Bangladesh, unsafe child feces disposal, using the Joint Monitoring Program definition, was assessed using 5-hour structured observation by trained study personnel as well as caregiver reports. Anthropometric measurements were collected at baseline and at a 9-month follow-up. Stool was analyzed for fecal markers of environmental enteropathy: alpha-1-antitrypsin, myeloperoxidase, neopterin (combined to form an environmental enteropathy disease activity score), and calprotectin.

Findings Among 216 households with young children, 84% had an unsafe child feces disposal event during structured observation and 75% had caregiver reported events. There was no significant difference in observed unsafe child feces disposal events for households with or without an improved sanitation option (82% vs 85%, $P = .72$) or by child's age ($P = .96$). Children in households where caregivers reported unsafe child feces disposal had significantly higher environmental enteropathy scores (0.82-point difference, 95% CI 0.11-1.53), and significantly greater odds of being wasted (weight-for-height z score <−2 SDs) (9% vs 0%, $P = .024$). In addition, children in households with observed unsafe feces disposal had significantly reduced change in weight-for-age z-score (−0.34 [95% CI −0.68, −0.01] and weight-for-height z score (−0.52 [95% CI −0.98, −0.06]).

Conclusion Unsafe child feces disposal was significantly associated with environmental enteropathy and impaired growth in a pediatric population in rural Bangladesh. Interventions are needed to reduce this high-risk behavior to protect the health of susceptible pediatric populations. *(J Pediatr 2016;176:43-9)*.

Undernutrition is estimated to be the underlying cause of death for more than one-half of young children globally and is associated with an increased risk of cognitive delays, susceptibility to infections, and lower economic productivity.[1-4] There is a growing body of literature demonstrating an association between environmental enteropathy and undernutrition in susceptible pediatric populations.[5-9] Environmental enteropathy is defined by abnormal intestinal morphology, reduced intestinal barrier function, and increased intestinal inflammation resulting in malabsorption of nutrients and growth faltering in children.[10-18] This disorder is thought to occur from unsanitary environmental conditions, leading to repeated exposures to enteric pathogens.[12-18]

Sanitation interventions implemented in the water, sanitation, and hygiene field typically focus on construction of improved sanitation options targeted at ambulatory populations.[19-21] There is little attention given to open defecation events by young children, despite this practice being common among children in many low-income countries.[22-24] Unsafe disposal of child feces through practices such as disposal in open areas increases exposures to fecal pathogens in susceptible pediatric populations by allowing direct contact with human feces and contaminated soil during play behavior and through vectors such as flies spreading fecal pathogens to food.[25,26] Child feces not being disposed of in a latrine has been associated with an increased risk of diarrhea in young children.[22,27-31] In a meta-analysis of studies on unsafe child feces disposal, this practice was associated with a 23% increased risk of diarrheal diseases.[32]

Furthermore, the health impacts of unsafe feces disposal can extend beyond diarrheal disease. A study in rural Bangladesh found that unsafe child feces disposal was associated with an increased risk of soil-transmitted helminth infections in children younger than 2 years of age.[33] Most recently a cohort study conducted in Mirzapur, Bangladesh, found that young children mouthing soil during play in households with visible feces on their compound had an increased risk of environmental enteropathy and stunting.[6]

CFU	Colony-forming units
HAZ	Height-for-age z scores
icddr,b	International Centre for Diarrhoeal Disease Research, Bangladesh
WAZ	Weight-for-age z scores
WHZ	Weight-for-height z scores

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Our objective in conducting this prospective cohort study was to assess child feces disposal practices in rural Bangladesh and to determine the relationship between this behavior, exposure to enteric pathogens in soil, environmental enteropathy, and growth in a pediatric population. We hypothesized that unsafe disposal of child feces was associated with impaired growth in children through increased exposure to enteric pathogens leading to environmental enteropathy.

Methods

This prospective cohort study of 216 randomly selected children 6-30 months of age was conducted in Mirzapur upazila in the Tangail district of Bangladesh at the site of the Global Enteric Multicenter Study demographic surveillance system. This study was nested within a larger investigation of the association between geophagy (mouthing of soil), environmental enteropathy, and stunting. The sample size was based on the number of study participants who could be recruited from February to April 2014. Study participants 6-30 months of age were selected to target children most susceptible to growth faltering.[34] A 9-month follow-up was conducted in study households between November and December 2014. A stool sample was collected from each child at baseline, and research assistants trained in standardized anthropometry measured the child's weight once and height 3 times. These measurements were used to calculate z scores according to the World Health Organization child growth standards.[35] Two soil samples also were collected in the outdoor courtyard area where the enrolled child was observed playing in a subset of 128 randomly selected households.

Informed consent was obtained from all study participants, and study procedures were approved by the research ethics committees of the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b); an exemption was obtained from the ethical review board at the Johns Hopkins Bloomberg School of Public Health.

A 5-hour structured observation session was conducted by a trained research assistant between 8:00 a.m. and 1:00 p.m. from February to April 2014 in the household of each enrolled child. A structured observation tool was used to collect information on whether the child had a defecation event and how the caregiver disposed of the child's feces. Defecation events were divided into the following categories: open defecation event; child toileting event (if the child used a toilet or latrine); and a child potty event. We had the following categories for child feces disposal: (1) feces disposed of in a toilet or latrine; (2) feces scattered in yard or compound; (3) feces disposed of in an open space adjacent to the household compound; (4) feces buried; (5) feces thrown in a location designated for household waste (eg paper, wrappers); (6) no feces disposal; (7) other; and (8) did not observe. We used the Joint Monitoring Program definition of "safe feces disposal," which was defined as feces disposal in a latrine/toilet or buried. Any other method of feces disposal was defined as "unsafe feces disposal."[36] Using the aforementioned categories, we also asked caregivers how they disposed of their child's feces.

We also observed child hand washing practices after a defecation event during the structured observation period. We defined hand washing behavior in the following categories: (1) no hand washing; (2) hand washing with one hand; (3) hand washing with 2 hands; and (4) could not observe. The cleansing agent used during the child hand washing event was recorded as follows: water only; bar soap and water; and did not observe.

All stool samples collected were transported in cooler boxes to the Enteric Microbiology Laboratory at icddr,b in Dhaka, Bangladesh and stored at −80°C until analysis. Alpha-1-antitrypsin (Biovendor, Asheville, North Carolina), Neopterin (Genway, San Diego, California), and Calprotectin (ALPCO, Salem, New Hampshire) enzyme-linked immunosorbent assay kits were run for sample analysis according to the package insert. Myeloperoxidase enzyme-linked immunosorbent assay kits also were run according to the manufacturer specified instruction, except for a 1:500 dilution used for initial runs (ALPCO). The environmental enteropathy disease activity score was calculated by the use of fecal myeloperoxidase, alpha-1-antitrypsin, and neopterin, according to previously published methods.[10]

Soil samples were stored in cooler boxes and transported to the Enteric Microbiology Laboratory at icddr,b in Dhaka, Bangladesh, where total *Escherichia coli* counts and diarrheagenic *E coli* were detected according to previously published methods.[6,37,38] The complete soil findings were published previously elsewhere.[6] The objective of the current analysis was to stratify the soil findings by child feces disposal practices.

Statistical Analyses

Our primary objective in conducting this study was to determine whether unsafe child feces disposal was significantly associated with elevated markers of environmental enteropathy and impaired growth in young children. Therefore, our primary study outcomes are calprotectin, environmental enteropathy disease activity score, and height-for-age z scores (HAZ), weight-for-age z scores (WAZ), and weight-for-height z scores (WHZ). A z score less than −2 was classified as stunted for HAZ, underweight for WAZ, and wasted for WHZ.[39,40] Our measurements of unsafe child feces disposal were based on the observed behavior during 5-hour structured observation and caregiver reported behavior. To assess the association between unsafe child feces disposal and the selected fecal markers of environmental enteropathy, linear regression models were used with calprotectin and environmental enteropathy disease activity score as the outcomes and our measures of unsafe child feces disposal as predictors.

To assess the association between unsafe child feces disposal and growth, linear regression models were used with the change in HAZ, WAZ, and WHZ as outcomes and logistic regression models with being underweight, stunted, or wasted as outcomes and unsafe child feces disposal as the predictor. For our adjusted models, covariates were selected if their association with the outcome had significance