Geophagy Is Associated with Growth Faltering in Children in Rural Bangladesh

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Objective To determine the relationship between geophagy (mouthing of dirt, sand, clay, or mud) and growth faltering in young children.

Study design We examined linear growth as height and weight standardized by age and sex, and weight standardized by height, in a cohort of children aged 6-36 months in rural Mirzapur, Bangladesh. We determined geophagy behavior at baseline through caregiver report. Anthropometric measurements were assessed at baseline and at a 1-year follow-up.

Results We found that among children not stunted at baseline, those with caregiver-reported geophagy at baseline grew less over 1 year compared with their peers, with a difference in the change of standardized height for age and sex of –0.31 (95% CI, –0.61 to –0.01).

Conclusion These findings show that caregiver-reported geophagy was associated with growth faltering in a pediatric population in rural Bangladesh. Future studies are needed to learn more about this exposure pathway and its relevance to child growth. *(J Pediatr 2016;178:34-9).*

See editorial, p 7 and related article, p 40

Stunting remains a significant health threat to young children globally despite historic improvement in the health of young children.[1,2] Children who are stunted are at increased risk for mortality in the short term and for other adverse outcomes if they survive.[3-5] In 2014, stunting was estimated to have affected 159 million children aged <5 years, or 24% of children in this age group worldwide.[2] Children who become stunted generally do so by their second birthday.[6] Once stunted, they rarely recover.[7] Children can be at risk for stunting even with adequate nutritional intake, for example, through an inability to absorb nutrients owing to environmental enteropathy,[8] a disorder defined by abnormal intestinal morphology and reduced intestinal barrier function due to repeated exposure to enteric pathogens.[9,10]

Mouthing is considered a normal part of childhood;[11] this behavior generally declines with age, with a maximum between 6 months and 2 years.[12] Mouthing of soil, dirt, or mud, defined as geophagy, can lead to pathogen exposure if there are nearby sources of environmental contamination, such as open defecation or domestic animals.[13,14] In our recent prospective cohort study, geophagy was found to be a risk factor for stunting and environmental enteropathy in a pediatric population in rural Bangladesh.[15]

Although we have observed a prospective association between geophagy and stunting, this analysis included children who were stunted at baseline. It is possible that this association describes a relationship in which children who are stunted are more likely to consume dirt or soil through mouthing, or that stunting tends to occur before geophagy in time. We hypothesize that mouthing of soil is a normal part of child development that declines with age, and that this behavior puts young children who are not stunted at increased risk for growth faltering.

Methods

Informed consent was obtained from a parent or guardian of all study participants. The study procedures were approved by the Research Ethical Review Committee of the International Center for Diarrheal Disease Research, Bangladesh, and

HAZ	Height for age *z*-score
WAZ	Weight for age *z*-score
WHZ	Weight for height *z*-score

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Study participants were identified from the Global Enteric Multicenter Study demographic surveillance system site in the Mirzapur region of Bangladesh, a rural subdistrict located 60 km northwest of the Bangladesh capital of Dhaka.[16] Children aged <36 months were selected from the Global Enteric Multicenter Study demographic surveillance system site using a random number generator between February 2014 and March 2015.[15] Because this study was a pilot investigation, our sample size was based on the number of children who we were able to recruit between February and April 2014. This study was nested within a larger investigation that included evaluation of the association among environmental enteropathy, exposure to enteric pathogens in soil, and geophagy.[15]

A questionnaire was administered to the child's caregiver to obtain information on household demographic characteristics. Caregivers were also asked, "Have you ever observed your child place dirt (soil, mud, clay, dust, sand) in his/her mouth in the past week?" In a previous study, we found a high reliability of caregiver-reported geophagy events in the past week in comparison with observed geophagy events during the 5-hour structured observation period.[4] Assuming that caregiver-reported events in the past week provides a measure of geophagy behavior for a longer time period, our primary analysis focuses on this measure.

Research assistants trained in standardized anthropometry measured the child's weight once and height 3 times. Three standard anthropometric scores were recorded: height for age *z*-score (HAZ), weight for age *z*-score (WAZ), and weight for height *z*-score (WHZ), using the World Health Organization child growth standards.[17]

A check of child and caregiver hand cleanliness was conducted according to previously published methods.[18] This indicator was used as a proxy measure of child and caregiver hygiene practices. For the hand cleanliness check, research assistants assessed the respondent's fingernails, finger pads, and palms on both the left hand and right hand for cleanliness and assigned one of the following codes for each part of the hand: visible dirt, unclean appearance, and clean appearance. An intensive training was conducted on how to assess hand cleanliness before the study was conducted. For this analysis, a child or caregiver with "visibly soiled hands" was defined as an individual with a code of visible dirt for all parts of the hand (ie, finger pads, nails, and palms).

Statistical Analyses

We investigated the relationship between baseline geophagy and growth faltering in a rigorous analysis of prospective growth for young children over 1 year, dependent on geophagy at baseline assessment. We also investigated risk factors for geophagy, including child age, sex, visibly soiled caregiver hands, family size, and a caregiver with no formal education. To determine the temporality of geophagy and impaired growth, we stratified children by initial growth status. We examined children who were stunted at baseline, with an HAZ ≥2 SDs below average, separately from those with normal growth at baseline, with an HAZ >2 SDs below average.

We analyzed these standardized anthropometric scores in a longitudinal analysis for children by their baseline geophagy for each strata of baseline stunting using generalized estimating equations.[19] The resulting model is for population average growth over the 1-year follow-up period conditional on baseline geophagy, assuming

$$\mathrm{E}\left(Z_{ij}\middle|\mathrm{Geophagy}_i\right)=\beta_0+\beta_1\mathrm{I}(\mathrm{Geophagy}_i=0)+\beta_2\mathrm{I}(j=1)+\beta_3\mathrm{I}(j=1)\mathrm{I}(\mathrm{Geophagy}_i=1). \quad (1)$$

Here HAZ at baseline for child i at observation $j = 0$ or 1 is represented by Z_{ij}, and geophagy at baseline is represented by $\mathrm{Geophagy}_i$. For children with no geophagy at baseline, growth at followup is described by $\beta_0 + \beta_1$. The change in standardized anthropometry for these children over 1 year (between baseline and the 1-year follow-up time points), accounting for growth relative to peers of the same age and sex, is specified by β_1. For children with geophagy reported at baseline, growth at follow-up is described as $\beta_0 + \beta_1 + \beta_2 + \beta_3$. The change in standardized growth for children with baseline geophagy over the 1-year follow-up is represented as $\beta_1 + \beta_3$. The effect of geophagy on growth is specified by β_3, the interaction between time and baseline geophagy. We used this function for population average growth to determine growth over 1 year for children who were not stunted at baseline. To account for the correlation between standardized anthropometry at baseline and the 1-year follow-up for the same child, we used generalized estimating equations with the child as the cluster.

To determine which children were most at risk for geophagy, we examined child age, caregiver hand cleanliness, family size, and caregiver education. Child age was specified as <24 months vs >24 months,[11,20] and caregiver hand cleanliness was evaluated according to previously published methods[18] as a proxy of child and caregiver hygiene.

Results

A total of 324 children were screened for eligibility. Of these, 99 children (31%) were excluded because they were not available, 1 child (<1%) died, 1 child (<1%) was ill and could not participate, 1 child (<1%) was excluded because the caregiver refused to participate, and 6 children (2%) were unable to complete the baseline visit. The study cohort included 216 children aged <3 years. The median number of individuals living in the household was 5 ± 1.9 (range, 1-12). The median caregiver age was 25 ± 6.2 years (range, 17-52 years). Ten percent of the caregivers (n = 22) had no formal education, 26% (n = 57) had completed primary school, and 64% (n = 137) had completed secondary school or higher. Ninety-five percent of the children (205 of 216) were present at the 1-year follow-up, and 28% (n = 58) of these children had a caregiver report of geophagy in the past week at the baseline assessment. The average age and standard anthropometric measurements of these children by baseline geophagy and stunting are presented in **Table I**. The majority of study children were falling