Household vs. neighborhood latrine use: Child health effects in urban Bangladesh

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ABSTRACT

I examine the effect of improved sanitation on child health in urban Bangladesh to assess the relative importance of adult latrine usage versus safe disposal of children's feces. Using longitudinal household survey data, I calculate the change in weight-for-height in 194 children as a function of changes in latrine usage in the surrounding community. Fixed-effects regression techniques control for nonrandom program placement and selection bias. Results suggest that increases in improved latrine use among neighboring households with young children (proxying the safe disposal of children's feces) is associated with significant increases in weight-for-height. There is no effect for increases in latrine usage among neighboring households with no young children (proxying adult latrine usage). I conclude that sanitation infrastructure is an important route to improving children's health in urban slum settings, but such installations must encourage the safe disposal of children's feces in order to realize the greatest health gains.

INTRODUCTION

Inadequate sanitation remains a leading cause of diarrheal disease and mortality among children in developing countries, particularly in urban slums. The Global Burden of Disease Study indicates that 15 percent of all deaths in children under five in low- and middle-income countries are directly attributable to diarrheal disease. Eighty-eight percent of the diarrheal disease burden is caused by unsafe sanitation, water and hygiene (Lopez, Mathers, Ezzati, Jamison, & Murray, 2006). In 2001, more than one million children in South Asia and Sub-Saharan Africa died of conditions related to unsafe water and sanitation. The Millennium Project Task Force on Water and Sanitation has called the lack of sanitation and water in Africa and South Asia a “silent humanitarian crisis” (Bartram, Lewis, Lenton, & Wright, 2005, p. 810). Reducing diarrheal deaths among young children clearly requires effective, targeted sanitation improvements.

In this study I evaluate how improved sanitation affects child nutritional status by limiting exposure to diarrheal pathogens and thereby reducing diarrheal disease burden. Diarrhea is a common and pernicious health problem for children in developing countries. Acute diarrheal causes life-threatening dehydration, while chronic diarrhea can compromise growth and development by preventing the absorption of nutrients and can also increase susceptibility to future illness. Diarrhea is caused primarily by infectious pathogens (including viruses, bacteria, protozoa, and parasites) that are excreted in the feces of infected humans. This infected fecal matter can then be transported to the digestive tract of other uninfected humans via the hands, water, food, or insects (Curtis, Cairncross, & Yonli, 2000).

The framework for determinants of child health (Smith & Haddad, 2000; UNICEF, 1990) suggests at least two important routes for transmission of diarrhea-related pathogens to young children: the behaviors of the child and caregivers, and the health environment. Child care practices and hygiene behaviors can either facilitate or interrupt fecal-oral transmission routes. Several specific hygiene behaviors are hypothesized to be relevant for diarrheal disease risk. Washing hands after defecation with soap, dirt, or ash produces less contamination than washing with water only, although rinsing with contaminated water can recontaminate hands (Hoque, 2003). A comprehensive review of handwashing interventions suggests a reduction in diarrhea risk of 42-47 percent associated with washing hands with soap, although the reviewers express concerns that poor methodology and publication bias may skew this estimate upwards (Curtis & Cairncross, 2003).

While hygiene behaviors are important for diarrheal pathogen transmission, the availability of sanitation infrastructure is also critical. Adequate sanitation prevents fecal matter from contaminating water supplies and the surroundings in which people live, work, play, and travel each day. Several studies demonstrate a strong association between improved latrines and reductions in diarrheal disease (Meddings, Ronald, Marion, Pinera, & Oppliger, 2004; Moraes, Cancio, Cairncross, & Huttly, 2003; von Schirnding, Yach, Blignault, & Mathews, 1991; Young & Briscoe, 1988). In their extensive review of diarrheal disease intervention, Zwane and Kremer (2007) note several problems with this literature, however. First, these studies rarely disentangle the effects of sanitation improvements from water supply improvements. Second, the studies suffer from persistent methodological problems stemming from cross-sectional analysis and the lack of proper comparison group. Sanitation improvements are often assessed in case-control studies comparing children who present at hospitals or clinics, introducing several potential sources of bias (Daniels, Cousens, Makoae, & Feachem, 1990; Ekanem, Akitoye, & Adedeji, 1991).

In the current study on the effects of latrine improvements on child health in an urban slum in South Asia, I investigate a neglected issue in the literature on sanitation improvements: how do parents dispose of children's feces, and does this behavior change at all when new sanitation infrastructure is installed? The safe disposal of children's feces has been identified as critical for children's health, but little is known about actual practices (F. Ahmed, Clemens, Rao, & Banik, 2004; Gil, Lanata, Kleinau, & Penny, 2004). In general parents are reluctant to let children younger than four or five years use latrines on their own. At the same time, potties and diapers are not widely used in most of the developing world, and particularly not in South Asia. In rural settings, young children are often allowed to defecate in the yard or land surrounding the household. In urban areas that lack sanitation infrastructure, however, parents may have few options for disposing of children's feces and so may leave them in common alleyways or drainage ditches. This increases the likelihood that other children may encounter the fecal material during play and be exposed to diarrheal pathogens.

A review of fifteen studies that either asked about or observed specific disposal behaviors for children's feces found a higher risk of diarrheal disease associated with "risky" disposal (open defecation, no removal of feces from household are) and lower risk of diarrhreal disease associated with "safe" disposal (Gil et al., 2004). A detailed qualitative study in a dense informal settlement in Lima, Peru revealed several determinants of disposal behavior, including age of the child, effort required by the disposal method, and availability of resources for safe disposal of feces (e.g., toilets or latrines for shaking out diaper or emptying latrines) (Yeager, Huttly, Bartolini, Rojas, & Lanata, 1999). The Peru study is one of a very few studies of children's diarrheal disease risk that include direct and detailed observation. In the present study, I address the challenge of analyzing disposal behavior in the absence of such observations.

SANITATION AND CHILD HEALTH IN SOUTH ASIAN SQUATTER SETTLEMENTS

The growth of urban slums has been one of the defining characteristics of the past decades in the developing world. Approximately one billion people live in urban slums, and the slum population is growing by 2.2 percent per year (UN-HABITAT, 2006). Urban slums are characterized by crowding, high density, extreme poverty, lack of land or property tenure, lack of services and infrastructure, and a predominantly informal economy. Because many slum dwellers are recent migrants from rural areas, many of them live without the social networks and kinship ties that can provide emotional, physical and financial support in times of crisis. Sanitation in urban slums is a particular problem. More than one-quarter of the urban population worldwide has inadequate sanitation; the number is much higher for slum dwellers. Inadequate sanitation compels slum residents to use hanging latrines, unhygienic pit latrines, or nearby open spaces, creating significant disease hazards.

The nutritional status of children in urban slums is often worse that that of rural poor children or better-off urban children. While poor children in rural areas, particularly in South Asia, show very high rates of stunting, wasting is usually less severe. However, wasting rates in urban slums are very high, even in the presence of high rates of stunting (BNSP, 2002). While stunting and wasting rates have declined in rural Bangladesh, the prevalence of wasting among urban poor children in three Bangladesh cities has not declined as much as the prevalence of stunting. Seasonal fluctuations in wasting are strong, with the prevalence of wasting highest from the onset of dry season in March up to the beginning of the main harvest in October (Bloem, Moench-Pfanner, Graciano, Stalkamp, & de Pee, 2004).

Diarrheal disease is very common among slum-dwelling children in South Asia, with two-week prevalence estimates ranging from 14 percent for children under five in Karachi, Pakistan (D'Souza, 1997) to 28 percent for infants under one year in Dhaka (Rahman & Shahidullah, 2001). Because of the established link from sanitation to diarrhea to health, there have been many slum upgradation and sanitation initiatives. Bangladesh in particular has made a commitment to improving sanitation. Responding to a decentralized and NGO-driven "100% Sanitation" movement (Allan, 2003), in 2005 the Government of Bangladesh outlined a National Sanitation Strategy to achieve this 100% coverage by 2010. This is an aggressive goal given that only 33% of the population had access to a hygienic latrine in 2003. (Nurul Alam, 2007).

The current study is set in Dinajpur, city of 250,000 residents located in the northwest of Bangladesh, about 400 kilometers from the capital of Dhaka and near the border of West Bengal, India. In 2002 the city's annual growth rate was estimated at six percent. In 2002, CARE – Bangladesh partnered with the International Food Policy Research Institute to implement the SHAHAR community development program. This program was designed to strengthen the food and livelihood security of high-risk urban slum populations in Bangladesh. The main components of the program were sanitation infrastructure; health, hygiene and nutrition education; income-generating activities; and community mobilization. The program was implemented in Dinajpur after successful implementation in Jessore and Tongi, two other cities in northwestern Bangladesh (Das Gupta, 2003). Specific activities since 2002 have included filling ditches, installing hygienic latrines, and developing local Community Resources Management Committees ("Planned habitat changes lifestyle of slum dwellers," 2004).

These gaps in the literature on sanitation discussed above and the goals of the SHAHAR project prompt three research questions. First, do improved latrines affect children's nutritional status? If so, it is possible to identify the mechanisms through which latrine improvements offer health benefits? Specifically, 1) are household or neighborhood effects more important, and 2) is it possible to disaggregate the health effects of new latrines into changes in adult latrine usage and changes in disposal of children's feces?

METHODS

Sample

The data for this study come from the SHAHAR Dinajpur Survey fielded in 2002-2003 by CARE-Bangladesh and the International Food Policy Research Institute (IFPRI) as part of a community development program in Dinajpur, a city of 250,000 residents in northwest Bangladesh. This SHAHAR program was designed to strengthen the food and livelihood security of high-risk urban slum populations through sanitation infrastructure; health, hygiene and nutrition education; income-generating activities; and community mobilization ("Planned habitat changes lifestyle of slum dwellers," 2004).

The survey was a monitoring and evaluation tool designed to provide baseline and follow-up data on project communities and participants (Das Gupta, 2003). The sampling frame included all 59 *bastis* (slums) in Dinajpur. *Bastis* were assigned a vulnerability score based on observed levels of poverty, social cohesion, community size, and environmental hazards. Fourteen *bastis* were chosen for program intervention based on high vulnerability scores. From a complete census of these fourteen *bastis*, a random sample of 614 households was selected for interviewing. The sample size was chosen to permit statistically significant analysis of child stunting. Because *basti*s were selected for high vulnerability scores, the sample is representative of the poorest slum communities in the city.

From the initial sample of 614 households, enumerators successfully contacted and interviewed 583 households (95 percent) for the baseline survey in August 2002. A second round was fielded in March 2003, and 567 households were successfully interviewed (92 percent of the original sample, 97 percent of the 2002 interviews). The second round of data is not used in the analysis. The final survey round took place in August 2003, with 554 households (90 percent of the original sample, 95 percent of the 2002 interviews) successfully interviewed.

The survey sample includes 200 children ages 0-35 months at the time of the first survey in August 2003, 158 of whom have complete data for both survey rounds. An additional 36 children contribute data for one round only, and six children without complete anthropometry or maternal or household data are omitted from the analysis. The analytic sample therefore includes 352 observations of 194 children (178 observations in 2002 and 174 observations in 2003). Attrition analysis indicates that dropping out of the sample by 2003 is not associated with the health status of the child in 2002 nor with any maternal or household characteristics. There are no significant differences by *basti* in the probability of attrition from the sample by 2003.

Measures

The focal dependent variable is child weight-for-height, which captures short-term changes in food intake and disease status and responds mmediately to changes in the environment, care behaviors, or household food security. A decline in weight-for-height can be caused by a severe bout of illness (particularly diarrheal disease), a short-term reduction in food intake, or both.

Weight-for-height is calculated by dividing the child's weight in kilograms by height (or length, for children under 24 months old) in centimeters as measured by enumerators during the survey. I standardized the weight-for-height into z-scores using the CDC 2000 Growth Charts are the reference population (Kuczmarski, Ogden, & Guo, 2002). The weight-for-height z-score (WHZ) indicates the number of standard deviations away from the median of the reference population. A child with a weight-for-height z-score of less than -2.0 is defined as wasted. Unlike height-for-age, which captures long-term and accumulated effects of dietary intake and disease status, weight-for-height instead captures more recent, short-term nutritional or disease insults. Wasting can be caused by a severe bout of illness, (particularly diarrheal disease), a short-term reduction in food intake, or a combination of both (e.g., when a caregiver restricts a child's food intake during illness).

The focal independent variable is the use of improved latrines. In the 2002 survey round, the female head of household was given four choices to report the household's latrine usage: open space or field, a hanging or "katcha" latrine, a pit latrine (unsealed), or a water-sealed latrine. By 2003, two additional choices were provided due to the construction of new latrines by the SHAHAR project: community toilets, and unsealed but hygienic latrines. Based on discussions with the IFPRI staff and other sources on latrine improvements in South Asia (R. Ahmed, 2005; WHO/UNICEF, 2004), I categorized each latrine type into "improved" (water-sealed, unsealed but hygienic, and community) or "unimproved" (unsealed/unhygienic, hanging/katcha latrine, and open space or field.). Figure 1 summarizes the change in the proportion of households using improved latrines in 2002 and 2003 by *basti* community. Use of improved latrines increased substantially, from 35 percent in 2002 to 61 percent in 2003. There is considerable heterogeneity by neighborhood, however, with increases ranging from 13 to 57 percentage points. Large increases in improved latrine use can be attributed primarily to the installation of community toilets.

I construct several measures of improved latrine use. The first is the female head of household's report of the type of latrine used by the household. The second is the number of available latrines per household as reported by a community informant in a related community survey. The third measure is the proportion of all households in the *basti* using improved latrines. This is a non-self mean. To address the issue of the disposal of child vs. adult feces, I calculated two additional proportions of latrine use at the community level: one for households with one or more children under four years old, and one for households with no children under four. Again, these are non-self means. All five measures of latrine use are calculated for both 2002 and 2003.

There are three control variables included in the analysis that may also determine children's short-term nutritional status: the food security status of the household, the mother's handwashing behavior, and whether the child is breastfed. A household is considered food secure if the female respondent reports that no adult females skipped meals in the past seven days due to lack of food. The handwashing measure is dichotomized from a list of self-reported maternal handwashing behaviors including the use of soap, ash, dirt, water only, and other. Following other studies of child care practices using this dataset, I code use of soap or ash 1 and all other choices 0 (R. Ahmed, 2005; Garrett & Naher, 2004). Current breastfeeding status, reported by the mother, is a dichotomous measure.

I do not include the household's usual source of water in this analysis. One hundred percent of the households in the SHAHAR sample reported using tubewell water, a safe source in this setting. This universal access to safe water allows the analysis to focus specifically on sanitation as a determinant of child health.

Analytic Approach

The analysis compares the health effects of adults' use of improved latrines to the safe disposal of children's feces (e.g., through a caregiver's use of the latrines for disposal of fecal matter from diapers, potties, etc.). At the level of the household, I am not able to make this comparison, as the female head of household reports only the overall latrine usage for the entire household. However, I can exploit the fact that the full Dinajpur sample includes households with and without young children. The latrine usage of households in the surrounding area that have no children under four years old proxies adult behavior. Latrine usage among households with at least one child under four proxies the safe disposal of children's feces.

Because the study evaluates the effects of a change from unimproved to improved latrines on children's health, there are obvious concerns about nonrandom program placement and selection bias in the adoption of new hygienic latrines. If communities that received new latrines were worse off than communities that did not receive latrines, then children in receiving communities may already exhibit worse nutritional status than children in communities without new latrines. This placement rule would underestimate the effect of latrines on nutritional status. Conversely, if communities received new latrines as a result of bargaining power, social capital, or community efficacy, these communities might also be able to command resources in support of child health, biasing effects of the new latrines upward. At the level of the household, families that chose to use new latrines once available might also be the same households that were motivated to protect children's health; or, households most concerned about child health because of limited resources (e.g., food, a healthy environment) might be the most motivated to use new latrines.

To control for both nonrandom program placement of latrines in communities and selection bias in the use of available latrines, I employ an individual fixed-effects model. The fixed-effects model estimates the change in a child's WHZ as a function of change in latrine usage, time, and other control variables. Formally, the equation for this model is:

$$WHZ_{it} = \alpha + \beta 1 LAT_{it} + \beta 2 X_{it} + \gamma Z_i + \delta TIME_t + \varepsilon_i + \mu_{it}, TIME = 0,1$$

The outcome of interest is child weight-for-height, standardized to a z-score (WHZ), measured for child *i* in time *t*. LAT captures the household's experience of latrine usage in one of the four measures described above. X is a vector of time-varying observed characteristics of the households that I expect to affect weight-for-height, including food security, handwashing, and breastfeeding. Z is a vector of time-invariant observed characteristics of the child and household (note no time subscript) including gender, household occupation, and parental education. Parameters to be estimated include α, $\beta 1$ $\beta 2$, γ, and δ. TIME is a dummy variable that equals zero when t=0 and one when t=1. Therefore, δ estimates the secular change in WHZ from period 0 to period 1. The error terms ε_i and μ_{it} capture time-invariant and time-varying error (including unobserved heterogeneity), respectively. To estimate the equation with the panel data, I subtract the equation for time t=1 from the equation for time t= 0 and rearrange terms, leaving:

$$\Delta WHZ_{it} = \Delta \beta 1 LAT_i + \Delta \beta 2 X_i + \delta TIME + \mu_i$$

Fixed-effects formulations are useful in program evaluations because they can control not only for selection bias into programs but also for nonrandom program placement at the community level (Frankenberg & Thomas, 2001; Gertler & Molyneaux, 1994). The fixed effects approach is computationally equivalent to adding a dummy variable for each child in the analysis, and guarantees that any observed or unobserved characteristics of children, households or communities that may have determined the placement and use of latrines and that did not change from 2002 to 2003 will not bias the estimates of the coefficients of the covariates (Wooldridge, 2003).

Using this fixed-effects approach, I estimate a series of seven models of the change in child WHZ from 2002 to 2003. I first test the five measures of latrine usage described above singly: the household's use of an improved latrine, the availability of latrines in the community, the proportion of households in the community using improved latrines, the proportion of households using improved latrines among households with children under four, and then among households without children under four. The sixth model explicitly tests for different effects of latrine usage among households with and without young children by including them both in the same model. Finally, I test an interaction between level of improved latrine usage in the community and household latrine usage to see if the community effects depend on household behavior.

All models control for two other determinants of child WHZ that may have also changed as a result of the SHAHAR program: household food security and mother's handwashing behavior. To control for age-related declines in WHZ in this population, I also include the child's breastfeeding status, a dummy variable for the 2003 survey round, and the interaction of 2003 survey round and the child's age in months in 2002.

RESULTS

Descriptive statistics by year of survey for the full sample of 352 observations are presented in Table 1. Note that the sample ages twelve months from 2002 to 2003. Several variables reflect this aging process in predictable ways: mean WHZ declines slightly from -1.37 to -1.56 and breastfeeding prevalence declines. There is a steep increase in the use of improved latrines (from 33 to 59 percent). Effective handwashing and household food security also increase, most likely as a result of the SHAHAR program interventions.

The fixed-effects models shown in Table 2 assess the effect of changes in latrine availability and use on child WHZ. Model 1 tests the effects of a change from unimproved to improved latrine use at the household level. This measure has no significant effect on the change in child WHZ—the household's toileting behavior does not matter for child health. Results for Model 2, in which latrine usage is measured by available latrines per households in the *basti*, are similar to Model 1. Recall that these models cannot distinguish between the disposal of children's feces vs. adult use of improved latrine. The latrine measure simply captures the change of some or all household members from using an unimproved latrine type to an improved type.

In the third column, the measure of latrine usage is the (non-self) percentage of all sampled households in the child's community (*basti*) that use improved latrines. Each percentage point increase is associated with an increase in WHZ of .015 standard deviations. For example, a child living in a community where the percentage of households using improved latrines increased from 35 to 60 percent over the course of the survey year (typical for neighborhoods in this sample) would experience an increase in WHZ of 25 percentage points * .015 = .375 standard deviations, net of the age-related secular decline and changes in food security, breastfeeding, and handwashing. For a two-year-old girl who is 80 centimeters tall and weighs nine kilograms, this translates to a weight gain of 280 grams that is directly attributable to the change in latrine use in households in the surrounding neighborhood. This effect is larger than the weight gain attributed to an increase in household food security (.320 standard deviations in WHZ).

I next focus specifically on the effect of improved latrine usage just among households in the community with children under four. Thirty-seven percent of all surveyed households in both years have at least one child under four years old. Results from this model are shown in Table 3, Model 4. The neighborhood effect is strong and significant, and of comparable magnitude to the latrine usage coefficient in Model 3. In Model 5 I replace the variable capturing latrine usage among households with young children with the variable representing latrine usage among households without young children. There is no significant relationship.

In Model 6 I confirm this finding by including both community-level variables. A test of the equivalence in the coefficients (not shown) is rejected. Clearly the neighborhood-level effect of latrine is driven by the behavior of households with young children. Taken together, Models 4, 5 and 6 present the key finding of the study: latrine usage among households with young children is a strong predictor of child WHZ; at the same time, latrine usage among households without young children makes no significant difference. This suggests that the availability of new latrines has changed how and where children defecate, and has thereby reduced the exposure of other children to contaminated fecal matter.

Model 7 includes the household's own latrine usage as well as the interaction between household use and the percentage of households with children under four who use hygienic latrines. Neither coefficient is significant, indicating that the nutritional gains from the improved latrines are independent of the household's own latrine use. It is also interesting to note that the coefficient for mother's handwashing behavior, which is not significant in Models 1 and 2, becomes marginally significant in models that measure use of improved latrine at the community level (Models 3-7), with an effect of comparable size to the food security measure and the change in latrine use at the community level.

Additional analyses were undertaken to test the robustness of results to alternative explanations and to test underlying assumptions of the analytic approach. First, I attempted to confirm that observed improvements in children's weight-for-height z-scores were directly related to decreases in diarrheal disease prevalence by adding a measure of diarrheal disease (mother reporting that the child had diarrheal episode in 15 days prior to interview) to Model 4 from Table 3 (results not shown). The coefficient on the diarrheal disease measure is negative but not significant and does not attenuate the effect of latrine usage on child weight-for-height. I attribute this finding to the somewhat crude measure of diarrheal disease.

For a more direct test of the association between latrine usage on diarrhea, I also model the odds of having a diarrheal disease episode in the past fifteen days as a function of latrine usage among households in the community with children under five. A fixed-effects specification is difficult here because the model would be estimated on only 48 observations for 24 children: 18 children who report diarrhea in 2002 but not in 2003, and six who report the opposite. Instead, I estimate a logistic regression on the pooled sample of 317 observations, controlling for breastfeeding, handwashing, household food security, age, gender, survey round and the interaction between survey round and latrine usage. I also adjust standard errors for clustering at the community level. Results (not shown) suggest each percentage point increase in improved latrine usage in households with young children is associated with a reduction in the odds of diarrhea of four percent, a significant finding at least in this pooled cross-sectional analysis. This provides at least weak evidence for the hypothesis that changes in latrine usage improve children's nutritional status by reducing diarrheal disease incidence. The interaction of latrine use and survey round is not significant, suggesting that the association of latrine usage with child health is not due to some other aspect of the SHAHAR program intervention.

A second set of additional analyses addressed the limitation of the fixed-effects specification. While they offer substantial benefits in terms of controlling selection bias, the fixed-effects models rely heavily on the assumption that all unobserved characteristics of children, households and *bastis* are fixed between the two survey rounds. Because the latrine intervention was part of a larger community development initiative, it could be the case that other features of the SHAHAR program led to health and nutrition improvements in the sampled children. I examined this possibility in two ways. First, the analyses shown above in Tables 2 and 3 include two household measures that should capture some of the other improvements related to SHAHAR: the household food security status and the mother's handwashing behavior. The inclusion of these measures does not attenuate the effects of community-level latrine usage. In an alternative specification (not shown) I also employed a more general community-level measure: whether the community respondent reported that the community had come together to build something or start a new program in the past year. A change in this variable from 2002 to 2003 might indicate an overall increase in activity, resources, or social efficacy that could improve child health independently of the latrine effect. This variable is not significant in any specification, consistent with the explanation that sanitation improvements were responsible for increased WHZ.

A third set of additional analyses addresses the sensitivity of results to the classification of different latrine types as improved vs. improved. Analyses shown in Tables 2 and 3 were repeated for several other possible classifications of latrines. First, I address the hypothesis that only a reduction in open defecation makes a difference for child health by including only "open defecation" in the "unimproved latrine" category. I also test a similar hypothesis by including only hanging latrines and open defecation in the unimproved category. In both of these scenarios, the community-level measure of hygienic latrine usage is not significant, suggesting that reducing the level of open defecation or hanging latrine usage in the community is not sufficient to improve children's health. These results are consistent with the fact that there is still considerable variation in the hygiene level of the "improved" latrine options these two scenarios. For example, the categorizations in these two scenarios would not capture the health effects of a change from an unsealed pit latrine to another form of hygienic latrine. Unsealed pit latrines often have minimal odor and insect control and may have unstable or unsafe slabs. It is reasonable to imagine that both adult toileting and child feces disposal behavior could change if unsealed pit latrines were replaced by more hygienic options.

Next, I categorize only the hanging and the unsealed pit latrines as unimproved, for the analytic purpose of testing whether the observed health effects are due perhaps to the broader SHAHAR interventions and not to the latrine changes. The largest proportionate changes in latrine usage from 2002 to 2003 were reductions in hanging and unsealed pit latrines. If these results were significant, it could indicate that the broader SHAHAR project components (rather than latrine usage changes) were responsible for changes in children's health. However, these results are not significant. Similarly, I evaluate the complement of this hypothesis, in which only the latrine categories to which most respondents shifted their behavior by 2003 are deemed "improved". I then assume that only community toilets, or the public latrine blocks build as part of the SHAHAR intervention, are improved. Again, none of these scenarios yields significant results.

Finally, I explore two possible but unlikely latrine categorization schemes. First, I add add community toilets to the list of unhygienic latrine types. Some sanitation experts consider all community toilets to be "unimproved" because of their communal nature; however, these sorts of communal sanitation blocks have been successful, particularly in South Asia. Analytically, this scenario assesses the health effects of a shift away from community toilets, a rare occurrence in the current dataset since community toilets were primarily built between 2002 and 2003. The final alternative scenario eliminates the somewhat subtle distinction between an "unsealed pit latrine" and an "unsealed but hygienic pit latrine" by placing them both in the unimproved category. This categorization is not consistent with the SHAHAR survey instrument, which adds "unsealed but hygienic pit latrine" as a new category in 2003, reflecting a specific hygienic latrine type installed as part of the SHAHAR project. Results from these last two scenarios are also not significant.

From this process of elimination, I maintain that the latrine categorization used in the analysis is the correct categorization, due both to its consistency with recognized definitions of improved sanitation, and its ability to test the specific hypothesis I am interested in, namely that the available sanitation options in a neighborhood may change the behavior of adults responsible for the disposal of children's fecal matter.

DISCUSSION

This study reveals that increases in the proportion of households in the surrounding *basti* that use an improved latrine are associated with improvements in child weight-for-height, an important measure of short-term nutritional status. Notably, the effect remains strong and significant if the community-level measure covers only households with children under four, but disappears if the community-level measure includes only households with no young children. This novel finding provides strong evidence that children's toileting matters most to realizing health gains from sanitation investments. The use of longitudinal data allows children to act as their own controls, a stumbling point of many other evaluation studies using cross-sectional or case-control methods.

These results confirm previous findings on sanitation improvements and health: first, that it is the safe disposal of children's feces that provides the greatest health benefit (Ezzati, Utzinger, Cairncross, Cohen, & Singer, 2005; Shordt, 2006; Yeager et al., 1999). A second finding confirmed here is that sanitation improvements are likely to make the greatest impact in crowded urban areas where fecal matter can easily contaminate residential areas (Esrey, 1996; Ezzati et al., 2005). This study extends previous research by quantifying the differential impact on health of adult toileting behavior versus the excreta disposal behavior of households with young children.

The Dinajpur case also demonstrates that public, shared sanitation facilities can be acceptable and may lead to substantial improvements in children's health. This contradicts the prevailing opinion in sanitation studies that communal latrines cannot be considered an improved or sanitary option (Cairncross & Valdamis, 2006). Results presented here suggest that the financing of sanitation improvements, whether through public investment or private entrepreneurship, could be an important component of urban slum development (Shordt, 2006). A case study in India demonstrated that latrine installations financed through micro-loans can improve health and household income (UNDP-World Bank South Asia Water and Sanitation Program 1999a). A similar initiative demonstrated that individual slum residents were willing to build their own toilets once sewer lines were built under streets (UNDP-World Bank South Asia Water and Sanitation Program 1999b). Other studies report successful operation of public pay-for-use toilets and sanitation blocks in South Asia urban slums (Srinivas, Narender, & Rajeswara Rao, 2003; Water and Sanitation Program, 1998), though these facilities can present maintenance challenges (Water for Asian Cities Programme -- India, UN-HABITAT, & Pradesh., 2006).

A limitation of the study is the lack of data on how community latrines were allocated to *bastis*, for example whether *bastis* had to compete for a limited number of installations or if latrine blocks were allocated to the most vulnerable communities first. There is also no information on latrine maintenance over time, and the survey permits identification only of short-term changes in nutritional status of children. Though the gains are impressive, it is impossible to know whether these results will persist. The fact that the sampling frame included only the most vulnerable *bastis* in Dinajpur may limit the applicability of the findings to other settings. As discussed above, the available data on diarrheal disease prevalence was not detailed enough to directly evaluate diarrhea as the mechanism linking sanitation improvements to weight gains. Finally, it is possible that observed improvements in weight-for-height are related to unobserved changes in households or neighborhoods, although I have attempted to rule out as many alternative explanations as possible.

The results on the importance of community-level sanitation measures highlight other analyses that could be fruitful here. First, spatial analysis that pinpoints the location of new community toilets and shows which houses within each *basti* changed latrine usage could provide additional insight into the specific mechanisms through which sanitation improvements work. Spatial analyses of cholera and diarrheal risk in Matlab, Bangladesh suggest that this approach can effectively incorporate multiple types of data and can also improve the applicability of results to other areas with different risk profiles (Ali, Emch, Donnay, Yunus, & Sack, 2002; Emch, 1999).

Approximately one billion people live in urban slums, and the slum population is growing by 2.2 percent per year (UN-HABITAT, 2006). While more than one-quarter of the urban population worldwide has inadequate sanitation access, the proportion is much higher for slum dwellers. Millennium Development Goal 10 calls for halving the number of people without access to safe water and basic sanitation by 2015. The United Nations has declared 2008 the International Year of Sanitation in recognition of the importance on MDG 10 and to draw attention to the level of investment needed to meet the goal--up to $30 billion annually (Toubkiss, 2006). Because current funding falls well below that level, the investments that are made must be as effective as possible.

Findings from the present study suggest that latrine improvement projects that do not change the disposal practice for children's feces will not improve children's health. Sanitation upgrades are also ineffective in improving child health when implemented in dispersed households, but more effective when implemented in clusters. A key message from this study is that the environment vs. behavior dichotomy is a false one. In Dinajpur's *basti* setting, a child's "environment," at least in terms of diarrheal pathogen exposure, is largely shaped by the behavior of other children and adults in surrounding households. This implies that behavioral interventions (supported in part by social pressures) may be as important in determining the health environment as the placement of services or investment in infrastructure.

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Table 1. Selected Child, Household, and Community Characteristics:SHAHAR-Dinajpur Survey, Dinajpur, Bangladesh. 2002-2003.

Characteristic	2002 Mean (SD) or Proportion	2003 Mean (SD) or Proportion
Child characteristics		
Age in months	18.22 (9.88)	30.70 (10.16)
WHZ	-1.37 (1.16)	-1.56 (1.08)
Child is breastfed	0.87	0.61
Household characteristics		
Household uses improved latrine[a]	0.33	0.59
Household is food secure[b]	0.68	0.73
Adult female washes hands with soap/ash after defecation	0.83	0.95
Community characteristics		
Available latrines per household	0.27 (0.26)	0.37 (0.17)
Improved latrine usage, all households in *basti*[c]	0.32	0.59
Improved latrine usage, households in *basti* with children < 4 years old[c]	0.31	0.59
Improved latrine usage, households in *basti* with no children < 4 years old[c]	0.34	0.63
Community organized to secure resources or build infrastructure in last year	0.40	0.51
N	178	174

Note. Children were aged 0-35 months at the time of the first survey round in 2002.
[a] Improved latrine categories include water-sealed, unsealed but hygienic, and community latrines. Unimproved latrine categories include unsealed, pit, hanging/katcha, and open space/field.
[b] Food security is measured by a negative response to the questions, "Did any adult women forgo meals in the past 7 days due to lack of food"
[c] These measures are calculated as non-self means, meaning that the child's own household is not included in the calculation.

Table 2. Coefficients for Determinants of Child Weight-for-Height z-score From Individual Fixed-Effects Models, Dinajpur, Bangladesh, 2002-2003.

	Model 1 b [|t|]	Model 2 b [|t|]	Model 3 b [|t|]
Health environment			
Household uses improved latrine	0.105		
	[0.84]		
Available latrines per household in community		0.269	
		[0.87]	
Community mean of improved latrine use			0.015
			[2.09]**
Household food security			
Household is food secure	0.325	0.300	0.320
	[2.26]**	[2.03]**	[2.24]**
Care variables			
Mother washes hands with soap or ash	0.316	0.322	0.381
	[1.55]	[1.59]	[1.88]*
Child is breastfed	-0.141	-0.156	-0.147
	[0.84]	[0.93]	[0.89]
Survey round = 2003	-1.240	-1.272	-1.613
	[5.03]***	[5.08]***	[5.31]***
Survey round = 2003 * child age in months in 2002	0.031	0.032	0.031
	[3.85]***	[3.98]***	[3.91]***
Constant	-1.771	-1.783	-2.26
	[6.27]***	[6.28]***	[6.09]***
Number of observations	352	352	352
Number of children	194	194	194
Model R-squared	0.20	0.20	0.22

Note. Absolute value of t statistics in brackets

* Significant at P ≤ 10%; ** at P ≤ 5%; at P ≤ 1%

Table 3. Coefficients for Determinants of Child Weight-for-Height z-score From Individual Fixed-Effects Models, Dinajpur, Bangladesh, 2002-2003.

	Model 4 b [|t|]	Model 5 b [|t|]	Model 6 b [|t|]	Model 7 b [|t|]
Health environment				
Household uses improved latrine				0.217
				[0.83]
Community mean of improved latrine use				
Households with children < 4	0.011		0.010	0.012
	[2.17]**		[1.86]*	[2.19]**
Households with no children < 4		0.007	0.004	
		[1.27]	[0.63]	
Interaction: Community mean of improved latrine use (households with children < 4) * Household uses improved latrine				-0.002
				[0.41]
Household food security				
Household is food secure	0.322	0.324	0.321	0.309
	[2.26]**	[2.26]**	[2.25]**	[2.14]**
Care variables				
Mother washes hands with soap or ash	0.378	0.352	0.387	0.370
	[1.88]*	[1.73]*	[1.91]*	[1.82]*
Child is breastfed	-0.122	-0.152	-0.128	-0.121
	[0.73]	[0.91]	[0.77]	[0.72]
Survey round = 2003	-1.536	-1.423	-1.605	-1.545
	[5.48]***	[4.95]***	[5.32]***	[5.47]***
Survey round = 2003 * child age in months in 2002	0.031	0.031	0.031	0.030
	[4.00]***	[3.90]***	[3.96]***	[3.84]***
Constant	-2.144	-1.989	-2.233	-2.219
	[6.45]***	[5.85]***	[6.17]***	[6.43]***
Number of observations	352	352	352	352
Number of children	194	194	194	194
R-squared	0.22	0.21	0.23	0.23

Note. Absolute value of t statistics in brackets
* Significant at P ≤ 10%; ** at P ≤ 5%; at P ≤ 1%

Figure 1: Proportion of Households Using Improved Latrines by Community, Dinajpur, Bangladesh, 2002-2003.