Final report: Impact evaluation of community-led total sanitation (CLTS) in rural Mali

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This report presents data from a cluster randomized controlled trial (registration at clinicaltrials.gov NCT01900912). The study protocol was approved by Institutional Review Boards at Facultad de Ciencias Economicas of Universidad Nacional de La Plata and Stanford University.

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Executive Summary

Globally 2.5 billion people lack access to an improved sanitation facility; in Mali, only 15% of rural households use improved sanitation (JMP 2014). Community-led total sanitation (CLTS) uses participatory approaches to facilitate sustained behavior change to eliminate open defecation by mobilizing communities in order to achieve that goal. Although CLTS has been implemented in over 50 countries, there is a lack of rigorous and objective data on its impacts on sanitation and hygiene behavior, and on health outcomes such as diarrhea and child growth.

This report covers the main findings of the impact evaluation conducted of a community-led total sanitation (CLTS) campaign implemented by the government of Mali (*Direction Nationale de l'Assainissement*) with the support of UNICEF. We conducted a cluster-randomized controlled trial among 121 villages randomly selected from the district of Koulikoro in order to evaluate health and non-health program impacts. Baseline data was collected during April-June 2011, the CLTS intervention program was implemented between September-June 2012, and follow-up data was collected in April-June 2013. A total of 4532 households were enrolled at baseline and 4299 were visited at follow up; 89% of baseline households (N=4031) were successfully matched to a household at follow up. The primary outcomes presented in this report are reported for those households present at both baseline and follow up.

The CLTS campaign was highly successful in increasing access to private latrines, improving the quality of latrines, and reducing self-reported open defecation. Access to a private latrine almost doubled among households in CLTS villages (coverage increased to 65% in CLTS villages compared to 35% in control villages). Self-reported open defecation rates fell by 70% among adult women and men, by 46% among older children (age 5-10), and by 50% among children under five. Children too young to use latrines were also more likely to use a child potty in CLTS villages. The program also increased perceived privacy and safety during defecation among women.

Observations by field staff support respondent-reported reductions in open defecation, use of cleaner latrines, and improved hygiene in CLTS villages. Latrines in the CLTS households were 3 times more likely to have soap present (prevalence ratio [PR]: 3.17, 95% CI: 2.18-4.61) and 5 times more likely to have water present (PR: 5.3, 95% CI: 3.49-8.05). Latrines at CLTS households were more than twice as likely to have a cover over the hole of the pit (PR: 2.78, 95% CI: 2.24-3.44), and 31% less likely to have flies observed inside the latrine (PR: 0.79, 95% CI: 0.68-0.93). CLTS households were also half as likely to have piles of human feces observed in the courtyard (PR: 0.54, 95% CI: 0.37-0.79).

Statistically significant impacts on child diarrheal or respiratory illness were not observed among children under five years of age when analyzing follow-up data only. It should be noted that even though randomization occurred after baseline data collection was complete and socio-economic characteristics were balanced across groups, most symptoms of diarrheal and respiratory illness were more prevalent in CLTS villages at baseline.

There is evidence that the CLTS program has a positive and significant impact on growth outcomes among children less than five years of age. When accounting for baseline height measurements, children under five years old in CLTS villages were taller (+0.18 height-for-age Z-score, CI: 0.03, 0.32) and 14% less likely to be stunted (RR: 0.86, CI: 0.74, 1.0). Improvements in child weight (+0.09 weight-for-age Z-score, CI: -0.04, 0.22) and a reduction in the proportion of children underweight (RR: 0.88, CI: 0.71, 1.08) were also observed but were not statistically significant. The program also appeared to reduce the prevalence of severe stunting by 22% (CI: 0.60 – 1.02) and the risk of being severely underweight by 35% (CI: 0.46 – 0.93).

We measured self-reported all-cause and cause-specific under-five child mortality among the study population as a secondary outcome. Each household was asked to report the age and gender of any household member that had died in the past 12 months and the cause of death. There was no significant difference in all-cause mortality between control and treatment arms (Poisson regression, robust standard errors at the village level). We found a 53% reduction in diarrheal-related under-five mortality in CLTS villages (RR: 0.47, Robust Std. Err. 0.18, 95% CI: 0.23-0.98; N=23 child diarrheal deaths in control, N=11 child diarrheal deaths in CLTS).

In addition, we designed a series of experimental games to measure the role of cooperation in the success of CLTS. We conducted these games over all 121 communities included in the study sample and at both baseline and follow-up. About one half of households in each community were randomly invited to participate to the games. All games were incentivized using valued items (rather than cash). We find a positive and statistically significant impact of the CLTS program on game contributions, indicating that pro-social behavior increased in these communities.

This study provides evidence that a pure behavioral intervention with no monetary subsidies substantially increased access to sanitation facilities in rural Mali. Latrines were also cleaner and better stocked with handwashing supplies in treatment villages, indicating improved hygiene behavior. Our findings suggest CLTS improved child growth and reduced the prevalence of stunting among children. However, the program did not have a significant impact on self-reported diarrheal illness, thus the program may have impacted child growth and mortality through pathways other than preventing diarrhea, such as reducing the subclinical condition of environmental enteropathy *via* decreased exposure to environmental fecal contamination.

1. Study Design and Research Objectives

This evaluation focuses on the effectiveness of a community-led total sanitation (CLTS) program implemented by the government of Mali in small rural communities with poor sanitation coverage. CLTS is an approach that aims at improving sanitation through community mobilization. CLTS does not provide subsidies or hardware, an approach sometimes associated with low take-up (i.e., low latrine usage). Latrine construction for individual households is an important intermediary target, but the ultimate goal of CLTS is to create whole communities that are free of open defecation.

The program result chain is simple. Community members convene to a public meeting, and a number of activities are conducted to raise awareness on the risks associated with open defecation and to develop a plan to build latrines. CLTS facilitators register villagers' stated commitments and conduct follow-up visits for a period from 1 to 3 months. The village is then inspected to determine if all households own a private latrine and to observe any evidence of open defecation. If the village passes the inspection, the CLTS program offers a party to celebrate the end of open defecation. Certification as an open-defecation free village is the main output of the program. This research assesses additional primary outcomes of the program, including access to private latrines, hygiene and water quality, and child health. Secondary outcomes include education, labor, social attitudes, and the capacity for collective action.

The biological rationale for this result chain is that contamination of hands, food, and water by fecal elements, either through human waste, human contact, or flies, leads to infection with gastro-intestinal pathogens. Diarrhea can cause malnutrition, both by dehydrating individuals and by evacuating nutrients before they can be absorbed by the body. Environmental enteropathy may also be caused by exposure to fecal contamination and pathogens; this condition occurs when inflammation of the small intestine reduces capacity to absorb nutrients (Humphrey 2009). Parasites, such as soil transmitted helminthes, can also be transmitted when human waste is not safely contained in the environment (Bethony et al. 2006). Nutritional energy is diverted from growth to fight parasitic and other infections. Reduction in exposure to fecal contamination through improved sanitation and water infrastructure has been shown to lower child mortality (Watson 2006; Cutler and Miller 2005; Gamper-Rabindran, Khan, and Timmins 2008). There is also some evidence that sanitation interventions can improve child growth outcomes (Spears, Ghosh, and Cumming 2013), but rigorous causal evidence is lacking (Dangour et al. 2013).

Non-health impacts have also been posited to result from reduction in sanitation-related disease. Fewer infections in school-age children may lead to a decrease in illness-related absenteeism. Time allocation of older children and mothers may be altered; as time spent caring for sick members is freed up. Labor supply and school participation may increase as a result. Finally, CLTS is hypothesized to work through community mobilization. Community members may change beliefs about their capacity to act, making them rely less on external factors, and more on their community. In particular, they may become better at solving social dilemmas, whenever collective action is required.

We conducted a cluster-randomized controlled trial in rural Mali in order to evaluate health and non-health program impacts. We collected baseline data in 121 villages in April-June 2011. The CLTS intervention program was then implemented between September and June 2012 by the government and UNICEF. We again collected follow-up data in April-June 2013, approximately 1 year after the end of program operation. Study communities were randomly selected from a census of 402 villages in the Koulikoro district of Mali. To be included in the study population, the community had to be relatively small (between 30-70 households), have low latrine coverage (less than 60% of households with access to a private latrine), and could not have been previously enrolled in a CLTS program. An algorithm was used to ensure a buffer of 10 km between each study village to prevent contamination between treatment and control villages.

The main research questions addressed by this evaluation are as follows:

Primary outcomes:

1. What is the impact of CLTS on hygiene and sanitation practices, access to private latrines and open defecation rates?
2. How does CLTS affect the quality of hygiene and sanitation conditions: availability of latrines and hand washing stations, latrine cleanliness, satisfaction, privacy, security, sanitation and hygiene behaviors, and drinking water microbial quality?
3. What is the impact of CLTS on under-five child health, specifically on child diarrhea and child growth?
4. Does CLTS affect diarrhea-related mortality?

Secondary outcomes:

5. How does CLTS affect educational and labor outcomes, social attitudes, and the capacity for collective action?

In the next section, we present the study site and sample. In section 3, we discuss program implementation. In section 4, we present our main evaluation findings on sanitation, hygiene and children's health. Findings on other outcomes are discussed in the appendix.

2. Enrollment

A complete census was completed of each village by the field team. Census and baseline household survey data collection occurred between April and July in 2011. Households with at least one child under ten years of age were invited for an interview at baseline. At follow up, all households that were visited at baseline were targeted for interview..

At follow up a total of 5206 households were interviewed (Table 1). Among these, 4031 households could be matched with observations from baseline with confidence and 1175 households were new. The new households could fall into one of three categories: 1) a household that migrated into the study community since baseline, potentially due to the violence in other areas of the country[1]; 2) a household in which new children were born since baseline; or 3) a household that was present at baseline, but was not able to be matched up with a baseline observation because the head of household changed or the household merged with another household in the village. Table 1 presents the number of "new" households that reported they were not interviewed at baseline (N=897). Households that could be followed from baseline through follow-up make up the study population for the primary analyses presented in this report. There were a total of 6413 children under five and 2700 children under two at follow up (among those households enrolled at baseline).

Table 1 Number of households enrolled in baseline and follow up survey

	All	Control	CLTS
Total households			
Baseline	4532	2166	2366
Follow up	5206	2536	2660
Matched	4031	1911	2120
New	897	486	411
Total children <5 years with health data			
Baseline	6862	3354	3508
Follow up	7603	3710	3893
Total children <5 with anthropometric measurements			
Baseline	6420	3153	3267
Follow up	7328	3564	3764
Matched	2449	1158	1291

Randomization occurred after baseline data collection was complete.

Table 2 shows baseline characteristics of control and treatment groups. The majority of socioeconomic characteristics were balanced between groups at baseline, with the exception of the control group having a slightly higher proportion of households owning a mobile phone. Access to sanitation and an improved water source were also balanced across groups, as was soap and water observed in the latrine and water treatment practices. The percent of latrines observed to have flies or feces visible on the floor were significantly higher in CLTS villages. Anthropometric status among children was also well balanced.

[1] The percent of households indicating migration due to conflict is 0.98%.

Table 2 Baseline characteristics of treatment and control groups

	Control			CLTS			
Household characteristics	**N**	**Mean / %**	**SD**	**N**	**Mean / %**	**SD**	**p-value**
Number of HH members	2166	7.7	4.2	2365	7.6	3.7	0.655
Mean age of children under five (mo)	3472	25.6	17.0	3702	25.2	17.0	0.319
Child is currently breastfed	3326	40%		3475	42%		0.083
Asset index	2166	0.46	0.13	2363	0.46	0.13	0.908
% in poorest quartile	2166	32%		2363	32%		0.970
Owns mobile phone (%)	2165	44%		2363	37%		0.049
HH head has ≥1 year of school	1974	19%		2178	19%		0.931
HH head can read and write	2035	32%		2221	31%		0.825
Access to private latrine (%)	2167	35%		2365	33%		0.873
Soap observed at latrine (%)	1434	3%		1508	3%		0.721
Water observed at latrine (%)	1436	4%		1508	6%		0.222
Flies observed in latrine (%)	1437	57%		1507	69%		0.009
Feces observed on latrine floor (%)	1436	4%		1506	10%		0.001
Cover over the latrine (%)	1437	51%		1510	55%		0.423
Uses improved water source (%)	2102	41%		2270	45%		0.639
Main water source <5 min walk	2156	70%		2357	71%		0.896
Treated water in past 7 days (%)	2106	45%		2272	45%		0.958
Liters per capita per day (LPCD)	2102	45	37	2269	43	44	0.542
household stored water quality (log MPN *E. coli*/100ml)	425	2.2	1.0	419	2.1	1.0	0.117
source water quality (log MPN *E. coli*/100ml)	190	2.4	1.3	205	2.2	1.4	0.148

3. CLTS implementation

CLTS-Mali is run by the *Direction Nationale de l'Assainissement* (National Sanitation Directorate, Ministry of Environment) with the support of several partners, notably UNICEF. It heavily relies on community mobilization as a way to foster collective action and achieve a cleaner environment. Community mobilization works through three stages. First, CLTS facilitators gather the community with the objective of triggering commitments to adopt good sanitation practices. Second, CLTS staff closely monitor the realization of these commitments (building or repairing latrines, stopping open defecation). Finally, after a standardized verification process, upon successful completion of the program, villagers are invited to a party to celebrate their achievement, in the presence of officials, the media and members of neighboring communities.

Program implementation rolls out as follows:

1. Pre-triggering visit: CLTS-trained staff convene with village leaders to request a date to meet with the community
2. Triggering visit: A key moment for mobilizing the community is triggering; it consists in a series of activities that aim to raise awareness on the risks associated with open defecation and lead community members to commit to ending OD.[2] Details on commitments are written down in a registry and the whole session

[2] The whole session is usually facilitated by 3 or 4 CLTS-trained staff. They start by inviting community members to express their views on sanitation in their village. They request participants to take a tour of the village in order to map the open defecation areas and pick a sample to show how contamination to food and water occurs. Other activities include prompting villagers to estimate the quantity of feces produced per year, assess out-of-pocket health expenditures, observe flies landing on fresh feces and food, make the community observe and declare that lack of sanitation induces ingestion of feces, then prepare a time bounded action plan to end open defecation.

usually lasts for 3-5 hours and is videotaped. A timeframe for building/repairing latrines is set by the participants with the assistance of CLTS staff.

3. Monitoring: Following triggering, CLTS staff return to the communities to follow-up on commitments. Frequent visits (up to bi-weekly) take place for a period of 1 to 3 months.
4. Inspection and possibly certification: Government officials visit the community to check if each household is equipped with a private latrine (equipped with a bucket of water, and ashes or soap) and if the village is free of open defecation (OD) areas. If these conditions are met, CLTS organizes a ceremony to celebrate the achievement of the community. Villagers, members of neighboring communities, officials and the media are all invited to participate.

During the follow-up survey, we asked respondents in treated villages about their experience with CLTS program implementation (only households that were present at baseline data collection are included in this analysis). Here we summarize the main findings. More than 99% of households in CLTS villages identified their village as a CLTS program beneficiary. A total of 77% of respondents in treatment villages reported attending the triggering event held by the CLTS program. Females were over-represented among participants: 91% reported at least one female household member attended, 77% reported at least one male. Interestingly, 77% report that children participated to triggering.

Not only did most households recall participating in a CLTS triggering session, but they also remembered specific activities. Not surprisingly, the activity most acutely recalled is a demonstration of flies moving from fresh stool to food (87% remembered this activity). It is closely followed by recollection of other activities: mapping of open defecation areas (82%), private commitments to build latrines (82%), the fact that everything was videotaped (81%), the tour of open defecation areas in the village, known as the walk of shame (78%), and estimating amounts of feces produced and related health costs (70%). Two thirds of households (64%) report to have committed during triggering: among these, 92% committed to build latrines and 83% to stop open defecation (OD). When asked if they fulfilled their commitments, 76% report completing the construction of a latrine and 80% report they stopped open defecation (and 16% report that they cut open defecation in half).

Monitoring visits were conducted in the treatment villages at various frequencies. Heterogeneity is expected here as communities may take more or less time to honor their commitments. A total of 76% of households reported that the CLTS program had inspected their household; the mean number of inspections was 3.

Almost all households who reported being inspected identify their village as a certified OD-free village. Most recall that certification took place between March and June in 2012. According to The Ministry of Environment, Open defecation free (ODF) certification was achieved in 59 villages out of the 60 assigned to receive the program.

One might be concerned that other sanitation programs promoting the use of latrines may have been conducted at the same time in treatment and or control villages. We document that, when asked if any organization had come to promote the building of latrines, 94% of households in CLTS villages responded positively, while 10% responded positively in control villages. Notably, the majority (92%) of respondents in control villages identified an organization other than the CLTS program, UNICEF, or the government as the promotional organization. In CLTS villages, 82% of respondents identify CLTS, UNICEF, or the government as the promoter.

Political situation during study implementation

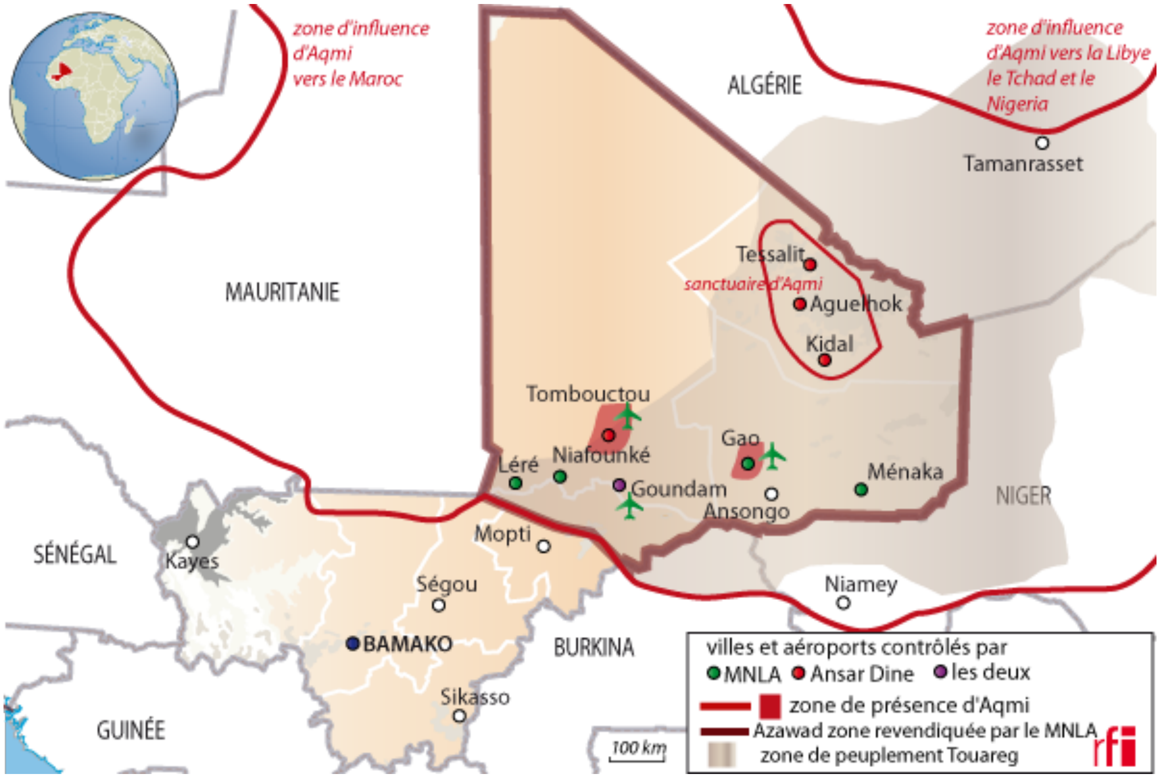
The political situation during the study period was concerning with respect to the field team's safety. The Malian government was overthrown by a military coup in March 2012, about six months prior to the original follow-up period. Due to the conflict, we postponed the collection of follow-up data. The international community severely condemned the coup and some actions were taken to assemble an interim government and call for elections. The situation was institutionally very fragile and soon after, Islamist extremists occupied the Northern region. While the Northern occupants wanted to become independent from the national government, the situation was under control and the disturbances were limited to a very specific geographic zone. This situation lasted for 10 months, but suddenly deteriorated when the rebels seized a nearby city, allowing access to Bamako, the country capital. This prompted a coordinated international response launched in January 2013, commanded by French and Malian troops and supported by most West African countries.

The North was recovered from the rebels in approximately a month. The situation has since been relatively calm (with isolated incidents in the Kidal zone) and a new democratic government was elected in October 2013. As of today, peace has been reestablished, but the situation is still fragile. The Northern region still remains a hostile territory with guerrilla terrorists still in the area.

With respect to the CLTS project under evaluation, the *Direction Nationale de l'Assainissement*, with support from UNICEF, continued with the implementation of CLTS as planned originally. As can be observed in Figure 1, the region where CLTS was being implemented (Koulikoro, with capital Bamako) did experience the conflict by registering a higher than usual internal migration from people coming from the Northern zones and by having security issues in the Northern region.

We would like to note that the calendar for ODF certification was altered due to the higher security requirements for the program staff traveling to rural areas.

Figure 1 Map displaying the regions in Mali affected by the conflict



Source: RFI, Radio France International

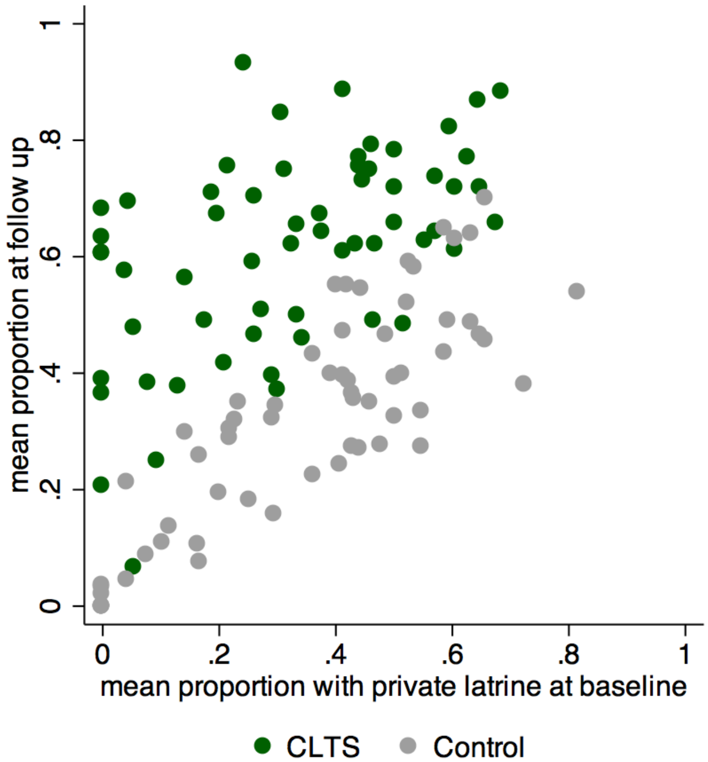
Fortunately, there were no major disruptions with the implementation of the program other than a slower process for final ODF certification, and a delay in data collection for the follow up survey. Originally the follow up survey was scheduled for November 2012, but it was postponed until the research team felt it was safe to resume data collection activities. The timing of the follow-up (April-June 2013) ended up being ideal in terms of matching the same season as the baseline survey, exactly two years post-baseline data collection.

4. Main findings

Sanitation

Access to a private latrine was 65% in CLTS villages at follow up, compared to 35% in the control group at follow up. Access to a private latrine almost doubled as a result of the program (an increase of 87%). Village-level latrine access ranged from 7%-93% in treatment villages and from 0%-70% in control villages.

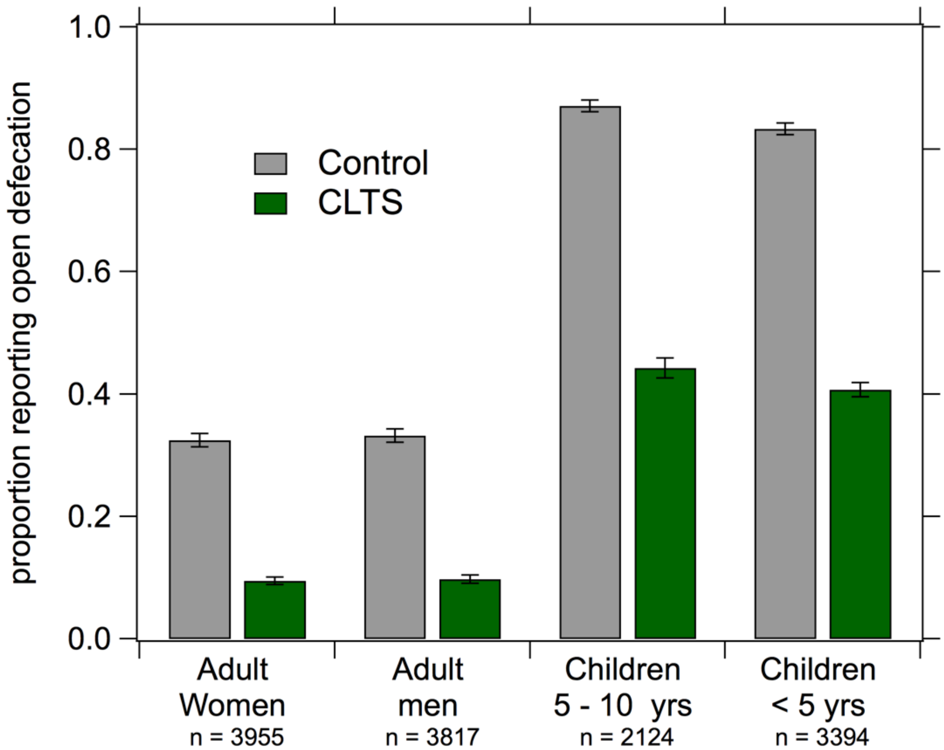
Figure 2 Mean level of access to a private latrine by treatment group at follow up versus baseline levels of access



The usage of private latrines as the main defecation location also increased in CLTS villages. When a household had access to a private latrine, it was almost always the prime defecation location. In both CLTS and control villages, 98% of adult men and 98% of adult women reported the latrine as their main defecation location. In CLTS villages, children over the age of 5 years were significantly more likely to use a private latrine when it was available; 89% of girls and boys used the latrine in CLTS villages compared to 57% (boys) - 62% (girls) in control villages. Although younger children do not directly use latrines (because of safety reasons), they were significantly more likely to use a child potty as their main defecation location in CLTS villages (51%) than in control villages (15%). There is also an 18 p.p. drop in the percent of households that share their latrine in CLTS villages. In CLTS villages shared latrines are used by a mean of 2.7 households, compared to a mean of 3.1 households in control villages.

In addition to increased use of private latrines, self-reported open defecation rates fell by 70% among adult women and men, by 46% among older children (age 5-10), and by 50% among children under five (figure 3).

Figure 3 Proportion of households reporting open defecation as main defecation location for specified demographic by treatment status at follow up.



Latrines (both existing and built as a result of the program) were primarily pit latrines without a concrete slab (79%); only 19% of latrines have a concrete slab. Latrines were newer by 1.6 years on average in treated communities (mean is 5.4 years old in control communities compared to 3.8 years old in treatment communities). A total of 70% of latrines in CLTS villages were located within 10 meters of the household, compared to 54% in control villages.

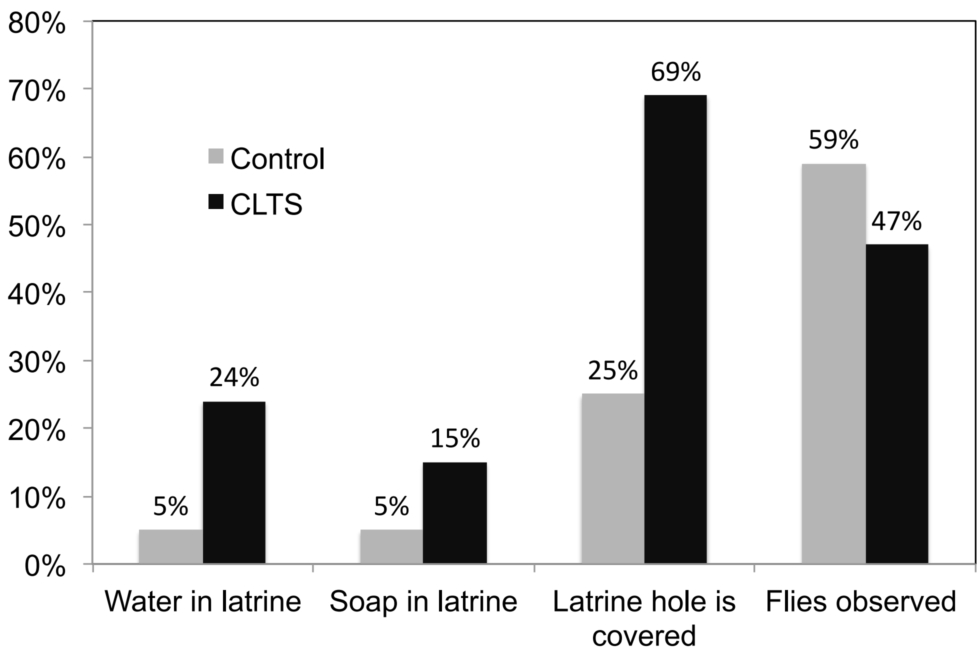
The CLTS program improved the quality of sanitation facilities. Households ranked their primary defecation location as better in terms of cleanliness, functionality, privacy, and comfort in CLTS communities (Table 3). For example, households in CLTS villages ranked the cleanliness of their latrines as good 65% of the time *versus* only 38% of the time in control villages.

Table 3 Rating of primary defecation location by treatment group (%)

	Cleanliness		**Functionality**		**Privacy**		**Comfort**	
	Control	CLTS	Control	CLTS	Control	CLTS	Control	CLTS
Good	38	65	51	69	52	71	41	62
Fair	42	28	34	24	28	19	39	29
Poor	20	7	15	6	19	10	20	9

Latrines in the CLTS households were 3 times more likely to have soap present (PR: 3.17, 95% CI: 2.18-4.61) and 5 times more likely to have water present (PR: 5.3, 95% CI: 3.49-8.05) (Figure 4). Latrines at CLTS households were more than twice as likely to have a cover over the hole of the pit (PR: 2.78, 95% CI: 2.24-3.44), and 31% less likely to have flies observed inside the latrine (PR: 0.79, 95% CI: 0.68-0.93). CLTS households were about half as likely to have piles of human feces observed in the courtyard (PR: 0.54, 95% CI: 0.37-0.79). Animal feces were 11% less likely to be observed in the courtyards of CLTS households (PR: 0.89, 95% CI: 0.84-0.87).

Figure 4 Latrine cleanliness by treatment group at follow-up



Overall satisfaction with sanitation was higher in CLTS communities and there was evidence that the program improved the defecation experience for women. Households in CLTS villages were more likely to report being satisfied (70%) with their overall sanitation situation then households in control villages (50%). Women in CLTS villages were significantly more likely to feel as though they had privacy when defecating (PR: 1.14, 95% CI: 1.02-1.27) and to feel safe defecating at night (PR: 1.12, 95% CI: 1.03-1.22). People view their village as cleaner in CLTS villages; respondents in CLTS villages were more likely to classify their village as "very clean" compared to control villages (31% vs. 14%). Households in treated communities were more likely to find it shameful to practice OD, (86% *versus* 72%) and more likely to have the view that most people in their village use latrines. Indeed, half (49%) of respondents in control villages agreed with the statement "the majority of people in my community do not use latrines for defecation," while only 14% of respondents in CLTS villages agreed with the statement.

CLTS villagers are also more likely to report that people get sick with diarrhea (i) by being in contact with other sick individuals (+7.2 p.p. from 54%), (ii) because of lack of personal hygiene (+8.1 p.p. from 79%), and (iii) due to a dirty environment (+9.6 p.p. from 76%). CLTS villagers are also more likely to report that diarrhea prevention involves washing hands and bathing children (+2.4 p.p. from 20%). Few households across both groups mentioned that using latrines help prevent diarrhea.

On average, respondents reported that it took 6 days to build their latrine (SD 5) and 71% reported that the latrine did not cost anything to build. Latrines (and houses) in Mali are primarily constructed from mud brick (a mixture of clay, water, and binding material such as straw), which can be made at no cost. Respondents reported that household members themselves constructed 89% of latrines; 34% of households obtained help from other community members, and 16% hired someone to built the latrine or assist. Interestingly, children were more likely to have participated in building private latrines in CLTS villages than in control villages. In CLTS villages, households were less likely to think latrines are too expensive to build (21% in CLTS villages compared to 35% in control).

Notably we did not find any evidence that the impacts of the intervention on sanitation access declined over time. Figure 5 demonstrates that the proportion of households with access to a private latrine was not associated with months since the village received ODF certification.

Figure 5 Mean level of access to a private latrine at the village level versus mean months since ODF certification.

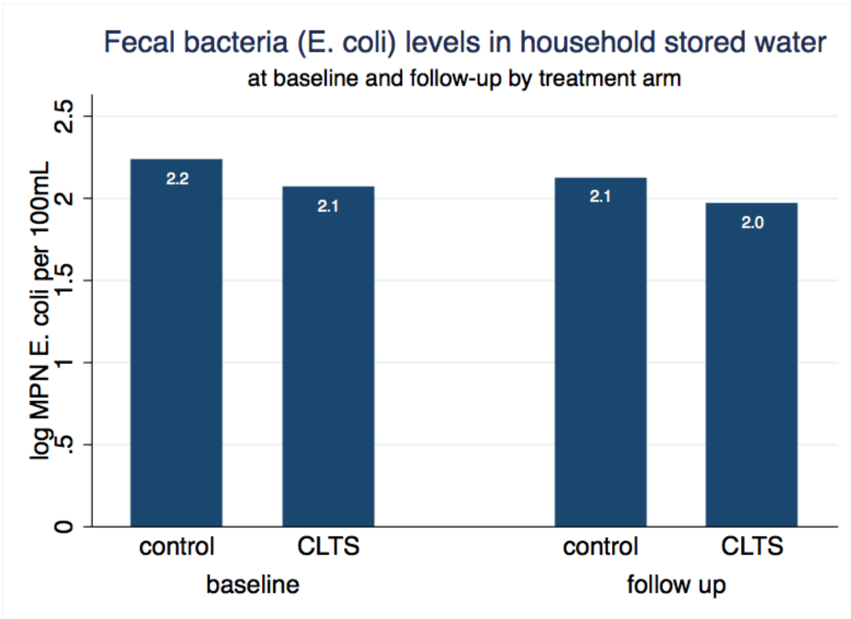
Hand hygiene and water quality

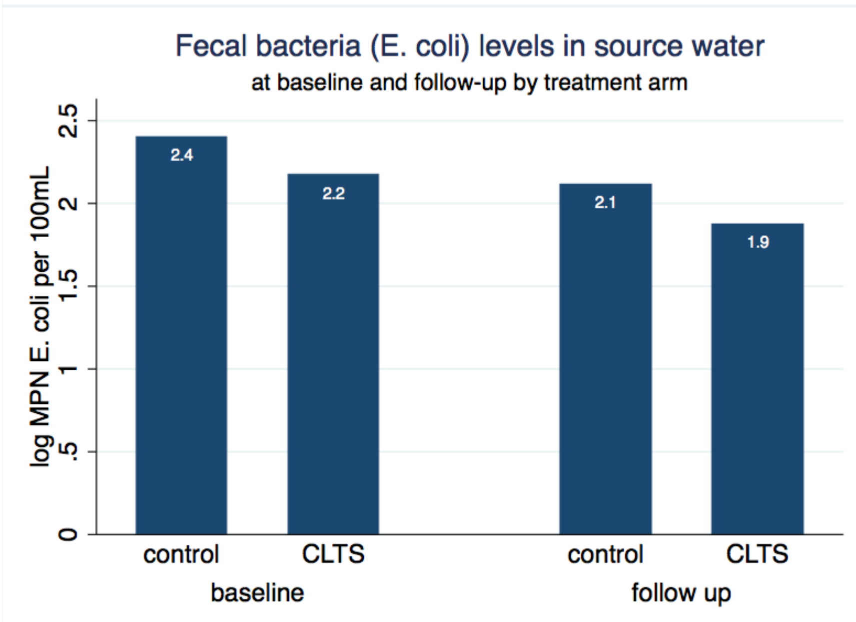
Female respondents in CLTS villages report a higher daily frequency of hand washing with soap (mean 2.3 times per day) compared to respondents from control villages (mean 1.9 times per day, $p<0.001$, linear regression with clustered standard errors). However, there were no significant differences in the presence of visible dirt on respondent hands between groups ($p>0.1$). Respondent hands were observed to have visible dirt 70-85% of the time in both groups. Knowledge of critical times to wash hands with soap improved in CLTS villages. For instance, we found a 15 p.p. increase in the fraction of respondents answering that it is important to wash hands after defecation (unprompted) over 35% in control villages.

Very few respondents mentioned that human waste is what makes water unsafe for drinking. CLTS households were 1.3 times more likely to report treating their drinking water (Poisson regression, 95% CI 1.4-1.8). Among those households treating their water, the predominant method was straining through a cloth (88%). This method was more common in CLTS villages (51.5%) than in control villages (42%). There is also a statistically significant 6 p.p. increase in CLTS villages on using chlorine to treat water. However, on average, chlorine is not commonly used (only 8% of households use chlorine in control villages). CLTS households reported using slightly higher quantities of water (46.8 vs. 45.9 liters per capita per day), but the difference was not statistically significant ($p=0.10$).

Source water and household stored water were sampled at baseline and at follow up. On average, 3 source water samples and 7 household drinking water samples were collected per village, resulting in a total of 796 source water and 1733 stored drinking water samples. Samples were processed by the IDEXX most probable number method to enumerate *E. coli* bacteria per 100mL of water sample. Levels of bacterial contamination were reduced in treatment villages, but the reductions were not statistically significant (Figure 6)

Figure 6 Levels of fecal indicator bacteria in household stored water and source water at baseline and follow up, by treatment status.





Child health

The primary outcomes of this analysis include prevalence of diarrhea using a 2-day recall period, height-for-age Z-scores, weight-for-age Z-scores, stunting, and proportion underweight among children under-five in study households. We also report the impact of the intervention on the prevalence of respiratory illness. We include only those children in households that were enrolled at baseline. Table 4 shows the unadjusted means of health outcomes at baseline and follow up by treatment status. Notably, both gastrointestinal and respiratory illness symptoms were higher at baseline in treatment communities.

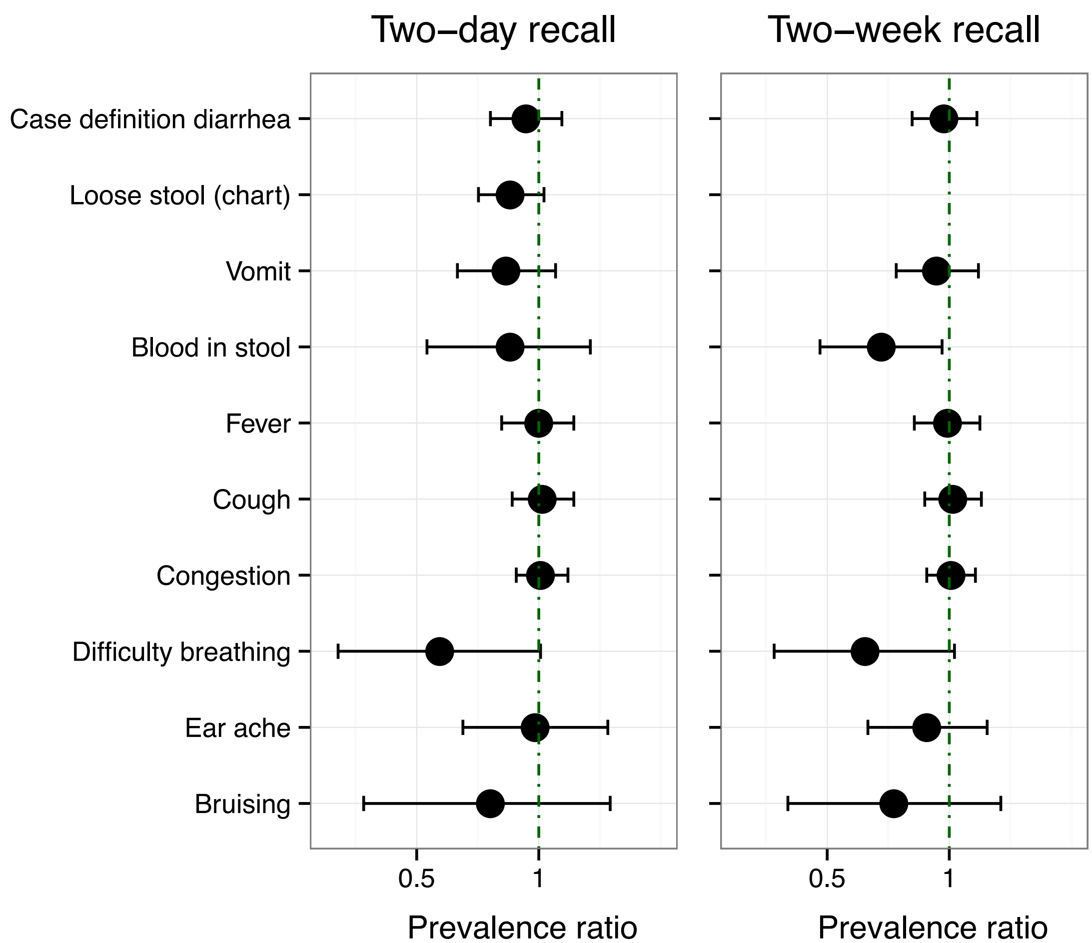
Table 4 Unadjusted mean prevalence of gastrointestinal and respiratory illness symptoms and anthropometric status among children five years and younger at baseline and follow-up, by treatment group. Mean proportions shown for illness symptoms reported by respondent for two-day and two-week recall periods. Mean and standard deviation (SD) shown for anthropometric z-scores at baseline and follow up for children under five years. Mortality estimates show number and % of households reporting a death of a child less than 60 months old in the past 12 months.

	Baseline				Follow up			
	Control		CLTS		Control		CLTS	
Two-day recall	N	mean	N	mean	N	mean	N	mean
Case definition of diarrhea Φ	3354	0.178	3508	0.212	2872	0.241	3140	0.225
Loose stool, by chart β	2721	0.277	2735	0.288	2420	0.165	2646	0.141
Blood in stool	3353	0.021	3507	0.024	2866	0.014	3133	0.012
Vomiting	3362	0.044	3512	0.053	2874	0.045	3148	0.038
Fever	3360	0.171	3513	0.227	2881	0.207	3150	0.206
Congestion	3363	0.200	3509	0.290	2881	0.351	3149	0.358
Cough	3363	0.194	3510	0.274	2882	0.263	3151	0.269
Difficulty breathing	3355	0.025	3506	0.060	2882	0.037	3149	0.021
Ear ache	3355	0.026	3510	0.035	2882	0.025	3149	0.025
Bruising Θ	-	-	-	-	2878	0.023	3148	0.018
Two-week recall	N	mean	N	mean	N	mean	N	mean
Case definition of diarrhea	3349	0.251	3494	0.287	2869	0.320	3130	0.312
Blood in stool	3338	0.037	3495	0.046	2853	0.034	3111	0.023
Vomiting	3350	0.073	3499	0.098	2864	0.081	3135	0.076
Fever	3352	0.264	3506	0.311	2875	0.288	3140	0.285
Congestion	3355	0.280	3503	0.363	2881	0.444	3141	0.449
Cough	3352	0.270	3500	0.348	2877	0.341	3140	0.349
Difficulty breathing	3343	0.040	3494	0.081	2866	0.052	3132	0.032
Mortality	N	mean	N	mean	N	mean	N	mean
All-cause mortality	2165	0.118	2364	0.104	1887	0.081	2097	0.076
Diarrhea-related mortality	2165	0.011	2364	0.011	1887	0.011	2097	0.005

Φ Defined as three or more loose or waterly stools per 24 hour period
β Image selection of 6 or 7 on stool chart, not including exclusive breastfeeding children
Θ Not measured at baseline

We use poisson regression to generate the prevalence ratio of children under five in the intervention group compared to the control group for all acute illness outcomes. All models include robust standard errors to account for clustering. There were no statistically significant impacts of the program on diarrheal or respiratory illness symptoms using a two-day recall period. We also measured all illness symptoms using a two-week recall period; the prevalence of bloody stool was 32% lower in CLTS villages (RR: 0.68, 95% CI: 0.48 – 0.97). Ear ache and bruising serve as negative control variables that would not be expected to be affected by the intervention; notably we do not see an impact on these outcomes, suggesting that reporting bias is likely not an issue. Controlling for child age in months does not change these results (data not shown).

Figure 7 Prevalence ratio of gastrointestinal and respiratory illness symptoms in treatment group compared to the control. Error bars show 95% confidence intervals generated by Poisson regression models with robust standard errors (unadjusted). Two-day recall period is shown on left; two-week recall period is shown on right.



To assess the impact of CLTS on child growth outcomes, we assess changes in height-for-age z-scores and weight-for-age z-scores among children that were present both at baseline and follow up. We found a statistically significant improvement of 0.18 HAZ points among children under five in treatment communities. Stunting among children in CLTS villages was 14% lower than control villages. Improvements in WAZ and a reduction in the proportion of children underweight were observed but were not statistically significant. The prevalence of severe stunting was reduced by 22% in CLTS villages and being severely underweight was reduced by 35% compared to control children (Table 5)..

Table 5 Child growth among children under five years of age by treatment status. Models include children under five years of age measured at baseline and at follow up. Height-for-age z-scores and weight-for-age z-scores are modeled with linear regression; stunting and underweight are modeled with Poisson regression to generate prevalence ratios. All models include robust standard errors to account for clustering at the village level.

	Baseline		Follow up		Effect size or Prevalence ratio (PR)			
	Control	CLTS	Control	CLTS	Unadjusted			
Panel children					N		95% CI	p-value
Height-for-age z-score	-1.18 (1.6)	-1.18 (1.6)	-1.77 (1.2)	-1.60 (1.2)	2415	0.18	0.03 - 0.32	0.022
Weight-for-age z-score	-1.27 (1.4)	-1.26 (1.4)	-1.36 (1.0)	-1.27 (1.0)	2452	0.09	-0.04 - 0.22	0.155
Stunted	0.30	0.30	0.41	0.35	2415	0.86	0.74 - 1.00	0.047
Severely stunted	0.12	0.12	0.16	0.12	2415	0.78	0.60 - 1.02	0.067
Underweight	0.28	0.28	0.26	0.22	2452	0.88	0.71 - 1.08	0.226
Severely underweight	0.11	0.10	0.08	0.05	2452	0.65	0.46 - 0.93	0.020

Mortality

We measured self-reported all-cause and cause-specific mortality among the study population at follow-up. Each household was asked to report the age and gender of any household member that had died in the past 12 months and the cause of death. A total of 706 deaths were reported;16% of all households reported at least one death in the past 12 months. The most common cause of death was reported by family members to be malaria (31% of all deaths); diarrhea was reported as the cause of 7% of all deaths. About half of all deaths were children under five (48%). Households in CLTS and control arms were equally likely to report a death of a child under five years of age (RR: 0.98, CI: 0.83-1.15). CLTS households were 53% less likely to report a child death by diarrhea (RR: 0.47, Robust Std. Err. 0.18, 95% CI: 0.23-0.98; N=23 child diarrheal deaths in control, N=11 child diarrheal deaths in CLTS; Table 4).

5. Discussion

This study provides rigorous evidence that a pure behavioral intervention with no monetary subsidies can increase access to sanitation facilities in rural Mali. Access to a private latrine almost doubled among households in CLTS villages (coverage increased to 65% in CLTS villages compared to 35% in control villages). Self-reported open defecation rates fell by 70% among adult women and men, by 46% among older children (age 5-10), and by 50% among children under five. The success of the campaign in promoting latrine construction is similar to other community-led sanitation programs that have been evaluated in India that have increased latrine access by 20-33 p.p. (Pattanayak et al. 2009; Arnold et al. 2010; Patil et al. 2014).

Although the program led to dramatic improvements in sanitation access, quality of latrines, and improved hygiene behaviors (such as keeping soap and water in the latrine), villages did not reach universal access as intended by the program. Although certification was awarded prematurely in some villages, universal access would most likely have been infeasible. The fact that follow-up data was collected a full year after village certifications indicate that the CLTS intervention can be sustainable, but longer-term studies would also shed light on how long improvements in sanitation access persist through time.

Statistically significant impacts on child diarrheal or respiratory illness were not observed among children under five years of age when analyzing follow-up data only. Illness symptoms were higher in CLTS villages at baseline. This is surprising considering that control and CLTS communities were well balanced in terms of socio-economic characteristics, sanitation access, and child anthropometrics. However, randomization occurred after baseline, so field staff were blinded to treatment status at baseline.

The CLTS program appeared to reduce stunting by 14% among children under five. The observed improvement in child height (+0.18 HAZ) is less than the 0.3-0.4 increase in HAZ points found in Madhya Pradesh, India during an evaluation of India's total sanitation campaign (Hammer and Spears 2013). Considering that nutritional supplement interventions typically improve HAZ by 0.3 (Dewey and Mayers 2011), our finding seems biologically plausible. Notably, children aged two to four years in the follow-up survey were less than two years old at baseline, the ideal age range for preventing growth faltering (Victora et al. 2010).

Our study may be the first to evaluate the impact of sanitation on child mortality using an RCT design; we found diarrhea-related under-five child mortality was 57% lower in CLTS villages. One important limitation of our study was that we did not use verbal autopsy to measure cause-specific mortality (the WHO recommended verbal autopsy instrument can take 40-60 minutes to complete). Therefore, some diarrheal deaths may have been misclassified, however we would not expect differential misclassification between groups.

The improvements in child growth were observed despite the fact that the program did not significantly reduce diarrheal illness among children under five. One explanation for this finding is that the CLTS program reduced child exposure to fecal contamination, through reduction in open defecation and/or improvements in hand hygiene behavior. Lower levels of environmental fecal contamination could potentially contribute to less environmental enteropathy among children, a subclinical condition characterized by poor nutrient absorption in the gut and associated with stunting in children (Lunn 2000; Campbell, Elia, and Lunn 2003). Environmental enteropathy has been shown to be associated with a contaminated environment; a study in rural Bangladesh found that children from households with improved sanitation and a cleaner household were less likely to have biomarkers indicative of environmental enteropathy (Lin et al. 2013). Further research is needed to better understand the causal mechanisms underlying the impact of the CLTS program on child growth and whether or not improved sanitation can reduce child environmental enteropathy.

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