Access to Waterless Hand Sanitizer Improves Student Hand Hygiene Behavior in Primary Schools in Nairobi, Kenya

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Abstract. Handwashing is difficult in settings with limited resources and water access. In primary schools within urban Kibera, Kenya, we investigated the impact of providing waterless hand sanitizer on student hand hygiene behavior. Two schools received a waterless hand sanitizer intervention, two schools received a handwashing with soap intervention, and two schools received no intervention. Hand cleaning behavior after toilet use was monitored for 2 months using structured observation. Hand cleaning after toileting was 82% at sanitizer schools ($N = 2{,}507$ toileting events), 38% at soap schools ($N = 3{,}429$), and 37% at control schools ($N = 2{,}797$). Students at sanitizer schools were 23% less likely to have observed rhinorrhea than control students ($P = 0.02$); reductions in student-reported gastrointestinal and respiratory illness symptoms were not statistically significant. Providing waterless hand sanitizer markedly increased student hand cleaning after toilet use, whereas the soap intervention did not. Waterless hand sanitizer may be a promising option to improve student hand cleansing behavior, particularly in schools with limited water access.

INTRODUCTION

Diarrheal diseases and respiratory infections are major contributors to global child mortality, causing 1.7 million child deaths annually.[1] Transmission of pathogens causing these syndromes is particularly prevalent in schools, where students are in close contact with each other; classrooms in low-income urban settings can be overcrowded because of limited space. Communicable illnesses are a leading cause of missed school days, and absenteeism correlates with low academic achievement.[2,3] It is estimated that hundreds of millions of school days are lost each year globally because of diarrheal illness.[4]

Handwashing education and promotion is a proven strategy to reduce diarrhea and respiratory illness globally.[5] However, hand hygiene programs implemented in schools in various countries have yielded mixed results. Handwashing interventions have been found to reduce illness-related absenteeism in Egypt and China but not in rural Kenya and Israel.[6–9] Hand hygiene compliance directly influences health impacts in such studies and is dependent in part on the availability of water and soap. The United Nations Children Fund (UNICEF) estimates that only 51% of primary schools in 60 low-income countries have access to adequate water supplies.[10] One strategy that addresses the challenges of limited water supplies as well as the time and effort requirements for hand hygiene is the use of waterless alcohol-based hand sanitizer.

In high-income countries, promotion and/or provision of hand sanitizer have been found to both improve hand hygiene compliance and reduce incidence of infectious diseases in a variety of settings, including healthcare facilities, households, and schools.[5,11–13] Hand sanitizer interventions conducted in elementary schools in the United States have reduced illness-related absenteeism by 14–51%.[3,14–17] Home-based hand sanitizer interventions have also been found to reduce respiratory and gastrointestinal illness transmission among households with children enrolled in daycare.[18,19] Alcohol-based hand sanitizers have limited efficacy against some enteric pathogens, such as the spore-forming bacteria *Clostridium difficile* and Norwalk virus.[20,21] However, because of its broad effectiveness, proven improved disinfection capabilities over plain soap, and ease of use, the World Health Organization (WHO) now recommends alcohol-based hand sanitizer as the preferred hand cleaning method for most clinical situations in healthcare facilities around the world.[22]

There is evidence that alcohol-based sanitizers perform as well as handwashing with soap and water in settings where hands are highly contaminated with fecal bacteria and show visible dirt[23,24]; however, limited research has been conducted on the behavioral and health impacts of hand sanitizer use in low-income settings. A randomized controlled trial in Colombia found that access to waterless hand sanitizer in daycare centers reduced the risk of both gastrointestinal and respiratory illnesses among enrolled children.[25] In Bangladesh, a hand sanitizer intervention among households in a low-income urban area was well-accepted but did not improve frequency of hand cleaning behavior compared with a soap and water intervention.[26] These studies suggest that additional work should be done to assess the circumstances under which access to sanitizer can improve hand hygiene behavior and health.

The primary objectives of this study were to pilot implementation of a waterless hand sanitizer intervention in primary schools in Kenya and evaluate the impact of the intervention on student hand cleaning behavior. We compared waterless hand sanitizer promotion with both standard practice (no intervention) and promotion of handwashing with soap. Key outcomes of interest included student hand cleaning rates after toilet use and before eating lunch. A secondary objective of the study was to evaluate the impact of the intervention on self-reported symptoms of diarrheal and respiratory illness among students. In addition, we assessed student and teacher perceptions of waterless hand sanitizer as an alternative to handwashing with soap and water.

METHODS

This study was conducted within the densely populated urban community of Kibera in Nairobi, Kenya. Data were

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collected in two villages (Soweto and Gatwikira), where the International Emerging Infections Program (IEIP), a collaboration between the Kenya Medical Research Institute (KEMRI) and the Centers for Disease Control and Prevention—Kenya (CDC—Kenya), has been conducting population-based infectious disease surveillance since 2005. Households in this area also exhibit high rates of pneumonia and diarrheal disease.[27–29] All primary schools within the surveillance area were visited to obtain information on their student population as well as current water supply, sanitation, and hygiene services. Schools with more than 100 students were considered eligible for the study to ensure balance of school populations across treatment arms. We excluded schools that shared latrines with community members, because it would not have been feasible to prevent public use of installed hand cleaning stations. Eight schools meeting these eligibility criteria were identified within the surveillance area. One school among the eight was excluded because it had substantially superior water supply services (a borewell equipped with a water purification and bottling facility on the school premises).

Consent was sought from the administrators and teachers at the remaining seven schools; one school administrator declined to allow his school to participate, leaving six participating schools. Two schools were randomly assigned to receive a handwashing with soap intervention, two schools were randomly assigned to receive an alcohol-based hand sanitizer intervention, and two schools were randomly assigned to receive no intervention (controls). Treatment status was assigned before obtaining consent from parents; the consenting process informed parents of the assignment. Written consent was sought from at least one parent or guardian of each student in the enrolled schools. Students who did not turn in a signed consent did not participate in individual interviews, although their hand cleansing behavior may have been recorded during structured observations; individual students were not identified during observations.

Interventions. Hygiene interventions consisted of an initial teacher training session followed by the installation of soap or sanitizer wall dispensers at the four intervention schools. Each of these schools received two dispensers (containing either liquid soap or hand sanitizer replenished throughout the study), one of which was installed next to the toilets and one of which was installed near the eating area. Wall dispensers were mounted on wooden supports that could be padlocked for security purposes, and they were removed each night for safekeeping by teachers or school administrators. Schools provided with soap (soap intervention schools) also received a plastic 60-L water tank with a spigot mounted on a metal stand (Polytanks, Nairobi, Kenya). Handwashing soap and soap dispensers were purchased locally in Nairobi (Primark Trading Company, Nairobi, Kenya), and the sanitizer product and sanitizer dispensers were imported from a US company (Purell sanitizer; GoJo Industries Inc., Akron, OH). Soap dispensers were manually operated by pulling a lever; the sanitizer dispensers automatically dispensed product when hands were placed underneath the motion sensor. Each intervention school was visited daily by field staff (enumerators) to replenish soap and sanitizer throughout the study period.

The teacher training session included a participatory discussion with teachers on germ theory and hand hygiene, demonstration and practice of correct handwashing or sanitizing method, and distribution of a culturally appropriate student hand hygiene promotion kit. The kit was designed by UNICEF for promoting handwashing with soap in Kenyan schools. The kit included posters, stickers, a classroom activity book, and a DVD presentation on handwashing along with a promotional song. Control schools did not receive training sessions or hygiene kits.

Data Collection. Baseline (before intervention) and endline surveys were conducted with teachers and students at each school. Students enrolled in pre-unit (typically age 5 years) through level P5 (typically age 10 years) were interviewed. Each enumerator was given a list of students by grade level in random order, and students were invited for interview starting at the top of the list. All teachers at each school were invited for interviews. Respondents were questioned about frequency and timing of hand cleaning behavior, when and why their most recent school absence occurred, and their perceptions of soap and sanitizer (during the follow-up survey only).

Field staff conducted structured observation of student latrine use at each school from 10:30 AM to 1:30 PM on a rotating schedule of 2–4 days/week per school. Teachers and administrators were not informed of the structured observation schedule ahead of time. Enumerators positioned themselves so that they could observe when students entered the toilets and whether and how students cleaned their hands after exiting the toilet. For each toilet visit, enumerators recorded the sex of the student and whether she or he cleaned her or his hands after using the toilet. If multiple students approached the toilets at one time, the enumerator selected one student arbitrarily to observe and record (students were not aware if they were selected). For each hand hygiene event, enumerators recorded the materials used to clean hands (e.g., sanitizer, water, and soap) and the method used to dry hands. They also timed the duration of hand cleaning (including rubbing, lathering, and rinsing) in seconds using a stopwatch.

Hand cleaning supplies were typically positioned by teachers at both intervention and control schools in a location that students had to walk past to line up to get their free lunch. During the beginning of lunch periods at each school (approximately 30 minutes), enumerators repositioned themselves in the eating area. The proportion of students cleaning their hands before eating lunch was determined by tallying the number of students who approached and used the handwashing or hand sanitizing station (or washed their hands at control schools) and dividing that number by the total number of students eating lunch on the school premises on that day.

Presence of sanitizer, soap, and water was recorded daily by field enumerators at the latrine and eating areas at all schools during unannounced spot checks. To assess how water and soap availability affected hand cleaning behavior, the enumerators also monitored the presence of water and soap during structured observations.

Although the study was not designed to have sufficient power to detect significant impacts on health, students at all study schools were interviewed weekly regarding their health status. Enumerators asked each student which of the following symptoms she or he had experienced in the 24 hours before the interview: loose/watery stool, three or more stools, vomiting, cough, difficulty breathing, sore throat, runny nose (rhinorrhea), and skin rash. In addition, enumerators recorded whether each student had visible rhinorrhea. The WHO case definition of diarrhea (three or more loose/watery stools in 24 hours) was

used as the primary classification of diarrhea.[30] Students were also requested to indicate the consistency of feces produced during their most recent bowel movement on a chart adapted from the Bristol Stool Scale.[31] This visual aid includes seven images of stools that range in consistency from hard spheres to watery liquid. As a second indicator of diarrhea, respondents who indicated that their most recent bowel movement matched Bristol Scale images 6 or 7 (watery stool) were considered to have had diarrhea.

In addition, endline in-depth interviews were conducted with teachers at sanitizer and soap intervention schools to better understand the teachers' experiences with promoting sanitizer or soap. Convenience sampling was used to invite teachers for interviews until three teachers had been interviewed at each school. These interviews were semistructured and included open-ended questions about teachers' personal experiences with sanitizer or soap, positive and negative features of the products, whether and how they felt that access to soap or sanitizer changed their students' behavior, and challenges that students face with respect to practicing good hand hygiene at school. The semistructured interviews were voice-recorded, transcribed, and translated into English.

All structured observation, health, and survey data were collected with personal digital assistants (PDAs) using The Survey System software (Creative Research Systems, Petaluma, CA). The same field staff that conducted the teacher training were also involved in data collection throughout the study. Enumerators rotated daily through schools on an assigned schedule for all types of data collection. Human subjects research approval was obtained from the Stanford Institutional Review Board (Protocol Number 19143) and KEMRI Ethical Review Committee (Protocol Number 1840). Data analysis was conducted with IBM SPSS Statistics 19 (IBM Company, Armonk, NY) and STATA 11 (StataCorp LP, College Station, TX).

Data analysis. The unit of analysis for modeling hand cleaning behavior after toileting was the event (i.e., individual student visit to latrine). The unit of analysis for modeling hand cleaning behavior before eating was the school lunch period (proportion of students that cleaned hands during an observed lunch period), because individual data were not collected. Poisson regression was used to determine prevalence ratios of hand cleaning after toilet use and before lunch among students in intervention schools compared with students in control schools (robust SEs accounted for clustering at the school level).

Multilevel mixed effects Poisson regression models (with random effects for schools and random effects for students nested within schools) were used to generate risk ratios for illness symptoms among students in intervention schools compared with students in control schools, students in sanitizer intervention schools compared with control schools, and students at sanitizer intervention schools compared with students at soap intervention schools. All behavior and health models controlled for week of follow-up; health models additionally controlled for individual age and sex.

Observed presence of soap and water (spot checks) at schools was modeled with logistic regression to understand availability over time (independent variables included study day and school fixed effects). Self-reported student attendance at the conclusion of the study between groups was analyzed by logistic regression with robust SEs to account for clustering at the school level. One-way analysis of variance (ANOVA; with Bonferroni multiple comparison tests) was used to determine significant differences in observed hand cleaning duration between treatment groups. In-depth interviews were analyzed by grouping the responses to each prompt, highlighting the concepts mentioned by multiple respondents, summarizing the themes that emerged, and finally, identifying illustrative quotes representative of the dominant themes.

RESULTS

Based on school registrar data, a total of 1,364 students was enrolled in the six participating schools (sanitizer = 435 students, soap = 460 students, and control = 469 students). Signed parental consent was obtained for 82% of the students. All study schools included grade levels pre-unit through P5 (ages 5–10 years); one school also included a nursery class (ages 2–4 year), and four schools also included grades P6–P8 (ages 10–13 years). The number of teachers at each school ranged from 5 to 21. Most schools purchased water from piped public taps off site, although one control and one soap school had a municipal water connection on the school premises that provided intermittent supply. At baseline, none of the schools was observed to have soap present for handwashing at latrine or eating areas.

After interventions were delivered, a total of 253 unannounced daily spot checks was conducted at schools. In control schools, soap was almost never available at latrines (2%) and eating areas (0%); water was available approximately one-third of the time at latrines and eating areas (Table 1). At soap intervention schools, water was available for 54% of latrine checks and 68% of eating area checks, whereas soap was available for over 90% of all checks. Water and soap were overall less available at sanitizer intervention schools than soap intervention schools (Table 1). Analysis of spot check data over time across all the schools showed that the odds of finding soap (odds ratio [OR] = 0.95, SE = 0.01) or water (OR = 0.80, SE = 0.05) present at eating areas as well as the odds of finding soap at latrines (OR = 0.94, SE = 0.02) were significantly negatively associated with the number of study days that had passed ($P < 0.05$), whereas the odds of finding water present at latrines was not associated with study duration (OR = 0.99, SE = 0.02, $P = 0.4$). Structured observation data from school latrines indicate that water was not available during 39% and 29% of toilet use observations at soap intervention and control schools, respectively. Water for handwashing was available during 68% of lunch sessions observed at sanitizer schools, 81% of sessions at soap schools, and 79% of sessions at control schools.

Hand cleaning behavior. A total of 8,733 student toilet use events was observed throughout the study (post-intervention delivery). Of these events, hand cleaning in any way (i.e., with water alone, water and soap, or sanitizer) occurred at 82%

TABLE 1
Soap and water availability at school latrines and eating areas as observed by field staff during unannounced spot checks

	Water available at latrines (%)	Soap available at latrines (%)	Water available at eating area (%)*	Soap available at eating area (%)*
Sanitizer (N = 93)†	2	3	25	5
Soap (N = 93)†	54	91	68	93
Control (N = 67)	34	2	34	0

*Random spot checks usually occurred when the eating area was not being used.
†At intervention schools, soap and sanitizer were recorded as not available when the dispensers had been temporarily removed from the eating or latrine areas.

Proportion of events after toilet use and before lunch in which hand cleaning occurred at hand sanitizer (sanitizer), handwashing (soap), and control schools.

	After toilet use			Before lunch		
	N	Any type of hand cleaning	Cleaning with product	N	Any type of hand cleaning	Cleaning with product
Sanitizer	2,507	0.82*	0.82*	39	0.90	0.61*
Soap	3,429	0.38	0.37*	43	0.82	0.70*
Control	2,797	0.37	0.02	43	0.69	0.01

Product refers to hand soap or hand sanitizer. Analysis presented per toileting event observed and per lunch session observed.
*Significantly different from control arm ($P < 0.05$).

FIGURE 2. Proportion of toilet use events during which a student was observed to clean hands with soap or sanitizer by school intervention status.

of 2,507 toileting events in sanitizer intervention schools, 38% of 3,429 events in soap intervention schools, and 37% of 2,797 events in control schools (Table 2). Students at sanitizer intervention schools were over twofold more likely to clean their hands after visiting the toilet than students at control schools (prevalence ratio = 2.2, 95% confidence interval [95% CI] = 1.2–4.3), whereas students at soap intervention schools were not significantly more likely to clean their hands compared with students in control schools (prevalence ratio = 1.0, 95% CI = 0.3–3.8). Hand cleaning at soap intervention and control schools was dependent on water access, which varied by school as well as by day. When water was available, the rate of students performing any type of hand cleaning increased to 62% of toilet use events at soap intervention schools and 53% of toilet use events at control schools. The rate of hand cleaning after toilet use at soap intervention and control schools was much more variable over time than the rate at sanitizer intervention schools (Figure 1).

Although the rate of hand cleaning after toilet use was not significantly different between soap intervention schools and control schools, the use of soap when cleaning hands was significantly higher at soap intervention schools than control schools throughout the study (Figure 2 and Table 2). Among all toileting events, the rate of hand cleaning with product (soap or sanitizer) was 82% at sanitizer schools (prevalence ratio = 38.5, 95% CI = 18.1–81.5), 37% at soap intervention schools (prevalence ratio = 17.2, 95% CI = 4.4–67.5), and 2% at control schools (Table 2). At sanitizer intervention schools, students used sanitizer whenever they cleaned their hands. Notably, at soap intervention schools, when both soap and

water were observed to be present, the rate of hand cleaning with soap was 61% ($N = 2,058$). Students using sanitizer took significantly less time ($P < 0.001$) for cleaning hands (mean = 21 seconds, SD = 9 seconds, $N = 1,575$) than students at soap intervention schools using soap and water (mean = 48 seconds, SD = 33 seconds, $N = 857$). In addition, students at soap intervention schools were observed to clean hands for significantly longer periods of time ($P < 0.001$) than students at control schools (mean = 27 seconds, SD = 20 seconds, $N = 830$).

Field enumerators observed student hand cleaning behavior during 125 different lunch sessions (sanitizer intervention $N = 39$, soap intervention $N = 43$, and control $N = 43$). Overall, rates of hand cleaning before lunch were observed to be higher than rates after toilet use (Figure 3 and Table 2). The mean proportion of students cleaning hands in any way before lunch was not significantly different between schools, with the mean proportion of students as follows: 0.90 at sanitizer schools (prevalence ratio = 1.3, 95% CI = 0.8–2.2), 0.82 at soap intervention schools (prevalence ratio = 1.2, 95% CI = 0.7–2.0), and 0.69 at controls schools (Figure 3 and Table 2). However, the proportion of students cleaning hands with soap or sanitizer (as opposed to water alone) was significantly higher at both soap and sanitizer schools compared with control
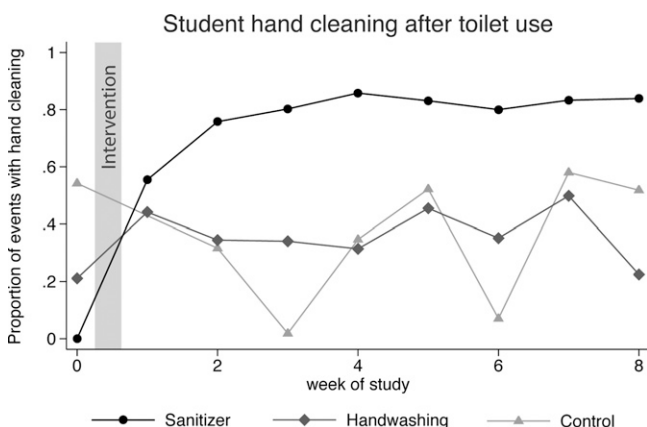

FIGURE 1. Proportion of toilet use events during which a student was observed to clean hands in any way (water only, soap and water, or sanitizer) by school intervention status.
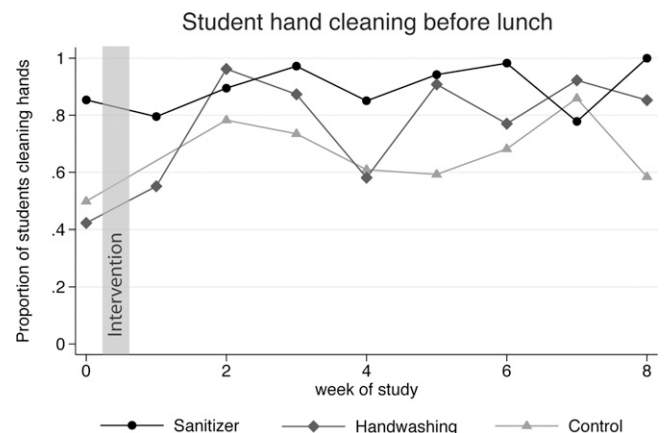

FIGURE 3. Proportion of students observed to clean hands in any way (water only, water and soap, or sanitizer) before lunch by school intervention status.
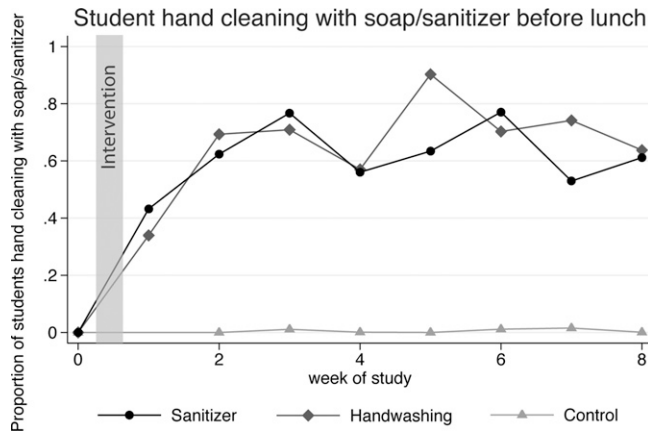
FIGURE 4. Proportion of students observed to clean hands with soap or sanitizer before lunch by intervention status.

schools throughout the entire study (Figure 4). The mean proportion of students cleaning hands with product before lunch was 0.61 at sanitizer schools (prevalence ratio = 126.8, 95% CI = 31.9–503.8), 0.70 at soap intervention schools (prevalence ratio = 143.0, 95% CI = 38.9–525.6), and 0.01 at control schools (Table 2).

Health. A total of 4,667 health interviews was conducted with students during 8 weeks after the intervention. During the study, the mean prevalence of students reporting symptoms consistent with the case definition of diarrhea was 8.8% in sanitizer intervention schools, 9.5% in soap intervention schools, and 11.3% in control schools. The mean prevalence of students identifying their most recent stool as loose/watery feces (image 6 or 7) on the Bristol Stool Chart was 20.1% in sanitizer intervention schools, 23.7% in soap intervention schools, and 23.0% in control schools. Throughout the follow-up period, a mean of 34.1% reported cough in the past 24 hours at sanitizer intervention schools compared with 40.0% in soap intervention schools and 39.6% in control schools. Enumerators recorded visible rhinorrhea for 28.2% of interviewed students at sanitizer intervention schools, 27.6% of students at soap intervention schools, and 36.1% of students at control schools.

Compared with a control school student, a student at a sanitizer intervention school was less likely to report three or more loose/watery stools in the past 24 hours or any loose/watery stool in the past 24 hours; identify image 6 or 7 on the stool chart; report vomiting, cough, difficulty breathing, or skin rash; or have observed rhinorrhea. Among these findings,

the only statistically significant difference was that students in sanitizer schools were 23% less likely to be observed with rhinorrhea than students in control schools ($P = 0.02$). Compared with soap intervention schools, students in sanitizer intervention schools were 20% less likely to report loose/watery stool ($P = 0.01$) (Table 3). Compared with students at control schools, students at soap intervention schools were less likely to report three or more loose/watery stools in the past 24 hours, report vomiting or difficulty breathing, or have observed rhinorrhea. The only statistically significant difference was that students at soap intervention schools were 23% less likely to be observed with rhinorrhea than students in control schools ($P = 0.01$) (Table 3).

The within-school intraclass correlation coefficients (ICCs) of health outcomes ranged from < 0.01 to 0.01, indicating low correlation of health outcomes measured within schools compared with between schools. In contrast, the within-student ICCs of repeated health measurements were much higher (range = 0.09–0.38), suggesting that children were reporting chronic illness or repeat episodes of acute illness. When school-associated random effects are removed from the model, the modeling results are similar to those results of the main model. However, when student-associated random effects are removed, the observed reductions among sanitizer intervention students are statistically significant for any loose stool (risk ratio [RR] = 0.86, $P = 0.04$), cough (RR = 0.88, $P = 0.03$), and diarrhea (RR = 0.76, $P = 0.02$) compared with students in control schools.

Knowledge and perceptions. A total of 858 surveys was conducted with teachers (12%) and students (88%) at baseline and the end of the study. Three in-depth interviews were conducted with teachers at each soap and sanitizer school for a total of 12 interviews.

All (100%) teachers interviewed at sanitizer schools stated that they would prefer provision of sanitizer over provision of soap at their school. The majority (91%) of students at sanitizer schools also stated that they would choose sanitizer to clean their hands over soap and water. One teacher said, "I find it [sanitizer] easy to use than soap ... If both were given, then you will find the hand sanitizer being used more than soap and water." Students at sanitizer schools reported that they perceived cleaning hands with sanitizer to take a shorter time than handwashing with soap and water. When asked, 80% of students said that they disagreed with the statement that sanitizer has an unpleasant odor, and 87% of students disagreed that using sanitizer made their hands feel dry.

TABLE 3
Hierarchical (Poisson) model results of self-reported student health symptoms at handwashing with soap and hand sanitizer intervention schools compared with control schools

	Sanitizer vs. control		Soap vs. control		Sanitizer vs. soap	
	RR (95% CI)	P value	RR (95% CI)	P value	RR (95% CI)	P value
Diarrhea (defined as three or more loose/watery stools in 24 hours)	0.75 (0.52–1.10)	0.14	0.84 (0.58–1.22)	0.36	0.89 (0.61–1.30)	0.56
Any loose/watery stool in 24 hours	0.87 (0.72–1.04)	0.12	1.09 (0.92–1.30)	0.33	0.80 (0.67–0.95)	0.01*
Loose/watery stool identified on stool chart	0.87 (0.70–1.08)	0.19	1.04 (0.85–1.29)	0.69	0.83 (0.67–1.03)	0.09
Vomiting	0.69 (0.44–1.09)	0.11	0.95 (0.62–1.46)	0.81	0.93 (0.53–1.63)	0.80
Cough	0.89 (0.75–1.05)	0.16	1.03 (0.88–1.21)	0.73	0.86 (0.73–1.01)	0.07
Observed rhinorrhea	0.77 (0.62–0.95)	0.02*	0.77 (0.62–0.95)	0.01*	1.00 (0.84–1.18)	0.99
Difficulty breathing	0.77 (0.55–1.08)	0.14	0.95 (0.70–1.29)	0.74	0.81 (0.59–1.12)	0.21
Skin rash	0.79 (0.48–1.29)	0.34	1.10 (0.68–1.77)	0.70	0.72 (0.44–1.16)	0.17

All models control for week of follow-up, child age, sex, and clustering at the student level. All models include 4,636 observations.
*P < 0.05.

Teachers at soap intervention schools identified water availability as a major barrier to regular handwashing for students. As one teacher explained, "[W]e cannot afford the water and it was straining us to get water." Teachers and older students typically have responsibility for fetching and refilling water tanks at schools. Teachers reported having to spend more time and money keeping the water tanks full because of the increased rates of student handwashing post-intervention. One teacher noted that "[a]t times you forget to refill [the tank with water], then you find kids are there trying to pull the tank down to check if it has water so you have to stop teaching to fill the tanks first."

Attendance. At baseline, 22% of students reported missing at least 1 school day in the week before the interview because of illness. There were no significant differences between intervention groups at baseline ($P > 0.9$). At the conclusion of the study, students in control schools reported similar absenteeism rates to baseline (20%). Significantly fewer students (11%) in sanitizer intervention schools reported missing at least 1 day of school because of illness in the prior week compared with students at control schools (OR = 0.51, SE = 0.1, $P < 0.01$). Students in handwashing intervention schools also reported lower rates (14%) of illness-related absenteeism at follow-up than students at control schools, although the difference was not significant (OR = 0.66, SE = 0.3, $P = 0.37$).

DISCUSSION

The provision of sanitizer to urban water-limited schools markedly improved hand hygiene practices in this pilot study in a low-income community in Kenya. Access to sanitizer resulted in significantly higher hand cleaning rates after using the toilet and before eating lunch, times during which hands could easily become contaminated or pathogens could be transferred from hands to mouth. Sanitizer was well-accepted by teachers and students alike. The high degree of acceptability and proven improvements in hand cleansing behavior should motivate development of strategies for sustainable dissemination of sanitizer to schools in settings with limited or unreliable water supplies.

Students provided with waterless sanitizer were much more likely to clean their hands after toileting than students in soap intervention and control schools. The average rate of hand cleaning with sanitizer was 82% after using the toilet, which is much higher than observed hand cleaning rates post-toileting reported among other studies. For example, a handwashing intervention among pre-school students in Israel recorded observed rates of handwashing with soap after toilet use in the range of 43–47% (although pre-school children might be expected to have lower compliance).[8] Observational data from other school-based studies are not available; however, these rates are also high compared with observed hand hygiene by caregivers in similar settings. A review of data from 11 low-income countries found that just 17% of caregivers were observed to wash their hands with soap after using the toilet.[32] Another study in Kenya found that only 25% of household members washed their hands with soap after fecal contact.[33]

The lower hand hygiene compliance rates after toileting in soap intervention schools compared with sanitizer schools may be the result of a preference for sanitizer over soap and/or limited water availability. Students and teachers reported that they believe that sanitizer takes less time to use, is more con-

venient, and is better at killing germs than handwashing with soap and water. Notably, soap intervention schools struggled to keep handwashing tanks filled with water. The high variability in hand cleaning behavior observed at soap and control schools (shown in Figures 1 and 2) is likely caused by the variation in water availability. Indeed, when water was present, hand cleaning rates were significantly higher at soap intervention schools than when water was not available. These findings imply that a school-based handwashing intervention is more likely to succeed if it includes an explicit soap and water procurement plan, particularly if water must be fetched or purchased from sources off campus.

Patterns of hand cleaning before lunch were different from patterns observed post-toileting. Rates of any type of hand cleaning before lunch were not significantly different between sanitizer (82%), soap (90%), and control schools (69%). At the same time, students at control schools almost never used soap to clean their hands before lunch, whereas students at soap intervention schools and sanitizer schools used soap or sanitizer, respectively, the majority of the time. The rate of hand cleaning with a product before lunch was slightly higher at soap intervention schools than sanitizer intervention schools. In Kenya, it is common to eat with one's hands instead of utensils. One potential explanation for the lower use of sanitizer versus soap before lunch is that teachers and students disliked the product's odor. During an in-depth interview, one teacher reported that "[i]t smells alcoholic. For me I can't use it and eat directly, I have to use a spoon. I have to wash my hands with water again, but the problem is the water may be contaminated." Indeed, at sanitizer schools, a small subset of teachers and students was observed to rinse their hands with water combined with sanitizer use before eating. This behavior was observed at least once during 44% of student lunch sessions at sanitizer intervention schools (data not shown). These results suggest that students and teachers may prefer to use soap and water over sanitizer directly before eating.

This study found some evidence that hand cleaning with sanitizer in primary schools in low-income settings reduces both diarrheal and respiratory illness. Provision and promotion of sanitizer at schools resulted in reductions in all health outcomes measured, including a significant reduction in observed rhinorrhea ($P = 0.02$) and reductions in diarrhea, vomiting, cough, and difficulty breathing suggestive of an effect ($P < 0.2$). Notably, this trend was not observed across all health outcomes in soap intervention schools (Table 3). Furthermore, students in sanitizer intervention schools were significantly less likely to report loose/watery stool than students in soap intervention schools, suggesting more frequent or more effective hand cleansing in sanitizer intervention schools.

Students in sanitizer schools reported missing fewer days of school because of illness after the intervention compared with students in control schools. Whereas this result corresponds with reductions in student-reported illness, it should be interpreted with caution considering that it was measured by student self-report. It was not feasible to collect valid daily attendance data during the study, because the schools did not keep accurate records; also, the student population in each school fluctuated during the study period. Furthermore, determining cause-specific absenteeism would have required contact with parents, which time and resource constraints precluded.

Additional research should be conducted to document the impact of hand hygiene interventions on absenteeism in urban low-income schools.

No adverse events were reported during the study period, although teachers did report that some students attempted to lick or eat both the sanitizer and liquid soap. The sanitizer product used in the study includes isopropanol, which has an unpleasant taste that discourages consumption. News reports in the United States of children consuming alcohol-based sanitizers suggest that close supervision of child sanitizer use is warranted. In this study, sanitizer dispensers were installed at a height that was out of reach of very young (crawling) children; the installation locations were chosen based on where teachers could easily view them and oversee use.

There are several limitations to this study. The enrollment of only six schools and the short length of the study (8 weeks of follow-up) may have prevented detection of statistically significant health impacts. Reported diarrhea and other symptoms were highly correlated within students, limiting the study's power to detect changes in health because of the interventions. Treatment assignment was not blinded, and the self-reported compliance data and health data could be subject to bias. In addition, there may have been differential reactivity by students during structured observation of hand hygiene behavior at treatment schools versus control schools. An extended follow-up period of 12 months or more would have been ideal to understand long-term compliance with the interventions, because the use of sanitizer might have decreased over time as the novelty of the new product wore off. A longer-term study powered to detect changes in objective outcomes, such as illness-related absenteeism, would be useful in determining the health impact of a sanitizer intervention among primary school students.

The high rates of compliance with sanitizer use by students indicates that provision of waterless sanitizer can be an effective strategy for increasing the rate of hand cleaning behavior at critical times in water-constrained school settings. The interventions delivered in this study contained minimal behavior change promotion (only one teacher training session per school), suggesting that high uptake of sanitizer may not require intensive promotional efforts, which is an advantage for future scale-up of use. Alcohol-based hand sanitizers are becoming increasingly available in Kenya and other low-income countries. Efforts to build local manufacturing capacity, develop product delivery supply chains, design bulk-refilling systems, and generate demand could contribute to the financial and logistical feasibility of implementing sustainable sanitizer interventions in primary schools and other settings.

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