

Impact of Regular Soap Provision to Primary Schools on Hand Washing and *E. coli* Hand Contamination among Pupils in Nyanza Province, Kenya: A Cluster-Randomized Trial

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Abstract. We assessed whether supplying soap to primary schools on a regular basis increased pupil hand washing and decreased *Escherichia coli* hand contamination. Multiple rounds of structured observations of hand washing events after latrine use were conducted in 60 Kenyan schools, and hand rinse samples were collected one time in a subset of schools. The proportion of pupils observed practicing hand washing with soap (HWWS) events was significantly higher in schools that received a soap provision intervention (32%) and schools that received soap and latrine cleaning materials (38%) compared with controls (3%). Girls and boys had similar hand washing rates. There were non-significant reductions in *E. coli* contamination among intervention school pupils compared with controls. Removing the barrier of soap procurement can significantly increase availability of soap and hand washing among pupils; however, we discuss limitations in the enabling policy and institutional environment that may have prevented reaching desired levels of HWWS.

INTRODUCTION

Globally, 2010 estimates of pneumonia and diarrhea account for 18% and 11% of deaths in children under 5 years, respectively, and in Africa, they account for 17% and 12% of deaths in children under 5 years, respectively.¹ Hand washing with soap (HWWS) has been shown to reduce fecal contamination on hands and can decrease the risk of diarrheal diseases by 42–48% and respiratory infections by 16%.^{2–4} HWWS is one of the most low-cost and cost-effective hygiene improvements.⁵ However, HWWS on a regular basis at critical times, such as after defecation, remains low among various communities worldwide.^{6–11}

Children of all ages have a higher risk than adults of acquiring and transmitting communicable diseases both within the household and at school.^{12–14} There is evidence linking school hygiene programs to various educational and health benefits.^{15–18} Despite these encouraging outcomes, few school-based studies have observed HWWS practice or measured pupil hand contamination to determine whether the HWWS component of water, sanitation, and hygiene (WASH) programming is actually increasing HWWS practice and decreasing fecal hand contamination.^{19,20}

STUDY BACKGROUND AND OBJECTIVES

This study was conducted as part of a research program in Nyanza Province, Kenya, called Sustaining and Scaling School Water, Sanitation, and Hygiene Plus Community Impact (SWASH+), that was designed to identify effective, sustainable, and scalable strategies for improving WASH behaviors and educational outcomes for primary school children. The previous SWASH+ impact trial carried out 3-day training sessions for two teachers—selected by the school administration—per school on hygiene promotion, behavior change, and water

treatment methods for the prevention of diarrhea as well as the formation and training of pupil-run school health clubs that would encourage other pupils to carry out hygienic behaviors, such as hand washing. All intervention schools received multiple hand washing containers and stands, but no soap was provided. Additionally, schools received follow-up visits by SWASH+ staff to help reinforce the training throughout the school year. Results from the larger impact trial showed significant improvements in demonstrated hand washing behavior—where randomly selected pupils demonstrated hand washing methods—in intervention schools, although this measure does not necessarily correlate with regular behavior when not under observation.¹⁸ Additionally, provision of hand washing water by the school improved significantly in intervention versus control schools ($P < 0.0001$). However, although soap provision by schools improved, it was still not occurring in the majority of the schools, thereby decreasing the opportunity to wash hands on a regular basis.¹⁸

Several substudies conducted through the program identified various challenges related to hand washing in schools. A school sustainability assessment found 1 of 55 schools providing soap for hand washing 3 years after a hygiene intervention, with 61% of school officials citing cost as one of the barriers to soap provision. Inability to prevent the theft of bar soap and lack of prioritization of soap by school administrators were also cited as barriers.²¹ A hand rinse study measuring *Escherichia coli* contamination on pupils' hands in a subset of intervention schools—one arm receiving hygiene promotion and the other arm receiving hygiene promotion with the addition of newly constructed latrines—found that the risk of detecting *E. coli* on girl pupils' hands was 2.6 times higher in schools that had received sanitation improvements in addition to hygiene promotion compared with control schools that did not receive any intervention ($P < 0.01$).²² Greene and others²² suggested that, by providing new latrines without regular provision of soap and anal cleansing materials and without sufficient hygiene behavior change, increased use of school latrines may have resulted in increased fecal contamination on hands. One limitation was an inability to assess the degree of change in pupil hand washing practice after

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latrine use in the various study groups, because no observations were conducted.

These findings reflected a need to further understand the role of latrine and soap provision on pupil behaviors and fecal exposure in schools. In May of 2010, a cluster-randomized trial was implemented in 60 primary schools in Nyanza Province, Kenya, to supply and monitor the provision of latrine maintenance cleaning materials and powdered soap to make soapy water for hand washing. The primary objective of this trial was to determine whether improving conditions of school latrines would reduce absenteeism in schools. The justification and findings for the latrine cleaning component of this trial are discussed in a forthcoming paper. This paper aims to assess whether eliminating the challenge of school soap provision by supplying soap to schools on a regular basis increases hand washing and decreases presence of *E. coli* on pupils' hands in primary schools in Nyanza Province, Kenya. Additionally, this study investigates sex-specific effects and pupil perceptions of soapy water use and hand washing conditions.

METHODS

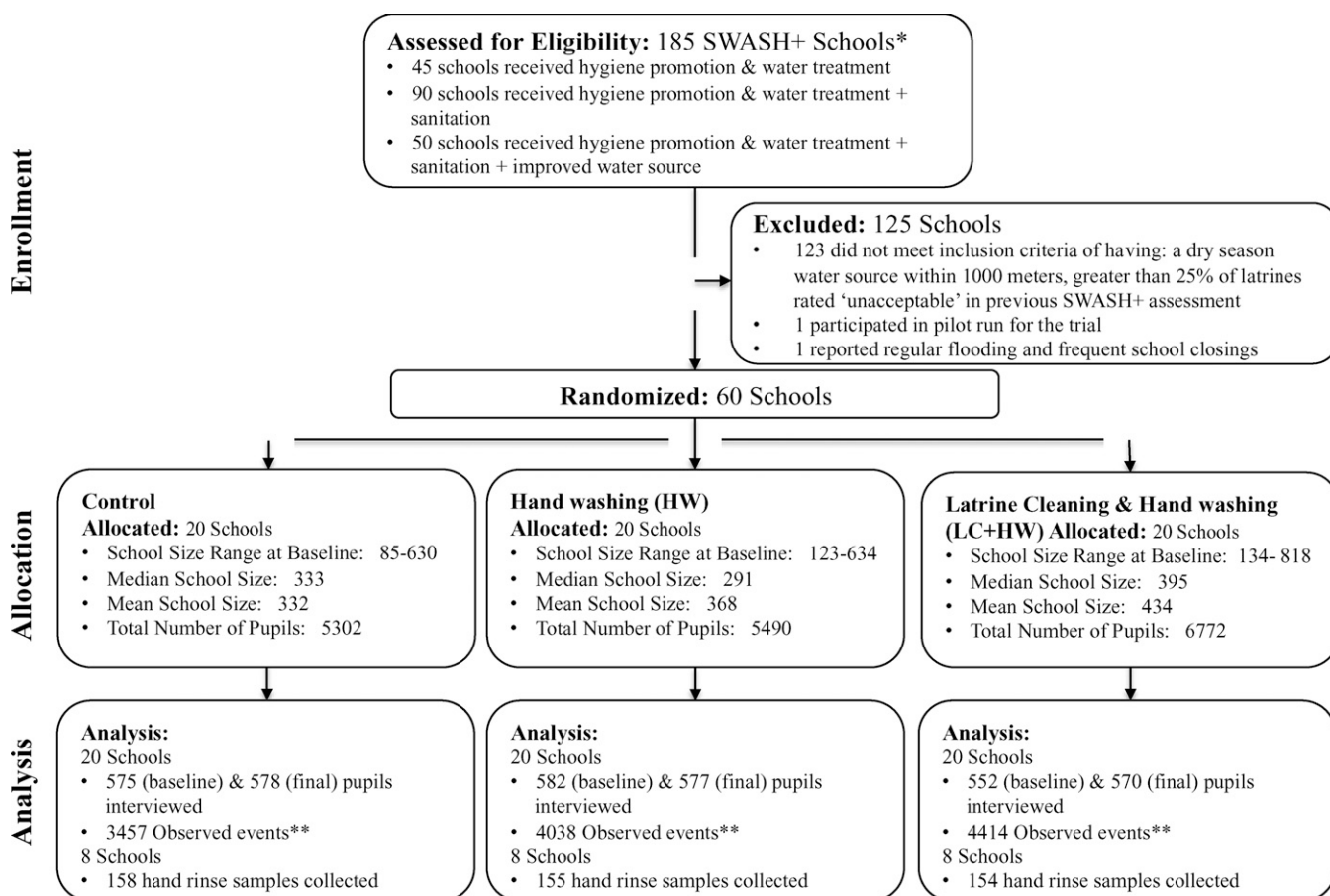
Study context. Between 2007 and 2009, a cluster-randomized trial assessing the health and educational impacts of various

school-based WASH interventions was carried out by the SWASH+ program in 185 schools in three geographic strata in Nyanza Province, Kenya.^{18,22–25} Schools for this study were selected from those schools in the former SWASH+ study.

Study setting. The study took place in two geographic strata—Kisumu/Nyando District and Rachuonyo District—in Nyanza Province, Kenya. The Kisumu/Nyando geographic stratum is generally less rural than Rachuonyo. The population of Nyanza Province is approximately 6.3 million, and 29% are primary school-aged children.²⁶

School selection and intervention assignment. The study comprised 60 public primary schools (Figure 1). Inclusion criteria included schools were previously enrolled in the SWASH+ impact study, at least 25% of latrines in each school were rated dirty by previous SWASH+ analysis, distance to dry season water source was not more than 1,000 m, and schools were located in the geographic strata of Kisumu/Nyando or Rachuonyo.

The trial consisted of three arms, including a hand washing (HW) intervention arm (*N* = 20), a latrine cleaning plus hand washing (LC+HW) intervention arm (*N* = 20), and a control arm (*N* = 20) that received no intervention. All interventions were administered at the school level. The selected schools were assigned to the study arms using stratified



*Schools received WASH interventions as part of the original 185 SWASH+ impact study between 2007 and 2009. The hygiene promotion + water treatment intervention included a 3-day training session for teachers on hygiene promotion, behavior change strategies, and water treatment methods with the addition of hand washing containers and stands and chlorine solution for water treatment. The sanitation intervention consisted of newly constructed latrines. The improved water source intervention comprised of either a newly constructed borehole or a large rainwater harvesting system.

**Number of total observed opportunities for pupil hand washing after latrine use events during baseline and four follow-up visits in each school.

FIGURE 1. Flow chart of school enrollment and allocation and study analysis.

random sampling. Schools were stratified by geographic stratum and the type of intervention that the school had previously received as part of the former SWASH+ study to ensure schools that received different interventions from the previous study would be distributed in similar proportions across all three arms of this trial; then, they were randomly allocated to intervention and control arms. All of the schools enrolled in this trial, including the control schools from the previous SWASH+ study, had received one of the SWASH+ interventions before the beginning of this study. A subset of 24 schools—8 schools in each study arm—was randomly selected for hand rinse sampling. Because the intervention status of a school was obvious based on the intervention supplies present or absent from schools during field monitoring visits, project field staff were not blinded to the intervention status.

The HW group received one 3.5-kg bag of powdered soap and 10 500-mL plastic bottles. Powdered soap to make soapy water was chosen as the method to supply soap for hand washing because of a previous pilot study that found that schools preferred powdered soap over bar or liquid soap, because it was easier to use, lasted longer, and prevented soap theft.²⁷ From unpublished laboratory tests, a solution of 10 g powdered soap mixed with 1 L water was estimated to be effective in removing fecal contamination from hands and creating lather during hand washing. Before receiving the intervention supplies, the head teacher and two designated teachers called health patrons were trained one time by project field staff on how to make soapy water solution from the materials given (two capfuls—2.5 g per cap—per 500 mL bottle filled with water).

The teachers were asked to review the hand washing component of the teacher's training manual provided to them during the previous SWASH+ program. They were encouraged to review the hand washing concepts and teach the soapy water preparation method to the school health club members as well as the rest of the pupils in the school. Soap was replenished 2–3 weeks after the start of the third school term.

The LC+HW arm also received the HW intervention supplies and training described above. Additionally, they received a latrine cleaning supply package that included two buckets, bleach, powdered soap, a measurement cup for soap use, a broom, and a hand brush for every four latrine doors, one-half of a roll of toilet paper per pupil per term (3 months in a term), and a binder with forms to monitor latrine conditions. The head teacher and health patrons received training on latrine cleaning methods and how to use the monitoring forms. They were encouraged to teach pupils the latrine cleaning methods. Consumables were replenished, and broken supplies were replaced 2–3 weeks after the start of the third term.

The intervention supplies were provided, and trainings took place in June of 2010 after the baseline data collection period. The control group received the same intervention as the LC+HW group (except for the latrine monitoring forms) 4 months after the conclusion of the trial in November of 2010.

Outcome. The primary goal for this study was comparing the effect of the HW and LC+HW interventions with the control group on observed pupil HWWS practice events after latrine use. The secondary goal was comparing the effect of the two interventions with the control group on the presence of *E. coli* on pupils' hands in a subset of schools.

Sample size. The sample size was calculated to detect changes in pupil absenteeism—the primary purpose of the overall trial—rather than assess the hand washing component of the trial—the primary objective of this paper. The sample size was based on absenteeism data determined in a previous cluster-randomized trial.¹⁸ The hand washing observations took place in all 60 schools. For the hand contamination outcome, the subset of 24 schools and 20 pupils per school was determined by available funds, staff time, and laboratory capacity.

Pupil and facility data collection. At baseline and final data collection rounds, we intended to interview 30 pupils per school between grades four and seven. Pupils were randomly selected using school rosters and administered structured interviews in the Dholuo language by enumerators to assess pupil perception of school hand washing conditions. School facility data were collected at baseline and every fortnight for seven subsequent rounds (excluding the school break in August). In each school, structured interviews were conducted in English with head teachers, and structured observations of school WASH facilities were performed during unannounced visits by field enumerators between May and November of 2010. All pupil and facility data were collected using Syware Visual CE v10 software (Cambridge, MA) on Dell Axim x51 (Round Rock, TX) personal digital assistants.

Hand washing measures. We conducted hand washing observations and measured hand contamination to assess pupil hand washing practice. There are several methods for assessing hand washing practice. Self-reported hand washing behavior uses structured or informal interviews to assess an individual's hand washing behavior.^{28–32} Direct observation of hand washing practices consists of an observer directly observing an individual's hand washing practices.^{33–36} One proxy measure of hand washing practice is measurement of hand contamination—often assessed through collection and microbiological analyses of hand rinse samples.^{37–42} There are only a few studies that have assessed schoolchildren's HWWS practice in low- or middle-income countries, and, of those studies, most used the self-reported method to assess HWWS practice.^{43,44} Household-based hand washing studies show differential rates between self-reported and observed hand washing practice and between self-reported knowledge and hand contamination.^{29,45} Self-reported assessments are often unreliable, and hand washing observations and hand contamination measurements are likely more accurate measures of assessing actual hand washing practice.⁴⁶

Hand washing observations data collection. Between May and November of 2010, hand washing observations took place at all 60 schools at baseline and during four subsequent unannounced monthly visits (excluding the school break of August) in the 30-minute school-allotted break times (typically from 11:00 to 11:30 AM). Two trained enumerators positioned themselves in a discreet place in view of the latrines and used structured observation sheets to record the number of events where pupils entered latrines and washed their hands with water only, soap and water, or neither after latrine use.

Hand rinse data collection and laboratory analysis. In October and November of 2010, one round of hand rinse data collection was conducted during designated break times. The schools were visited in random order. Ten schools had hand rinse samples collected from 10:30 AM to 12:00 PM, and the

remainder of the schools had hand rinse samples collected in the afternoon before 3:00 PM. Twenty pupils per school, between grades four and seven, were randomly selected using school rosters. Enumerators asked each selected pupil to place one hand in a 500-mL Whirl-Pak (Nasco, Fort Atkinson, WI) bag containing 250 mL sterile phosphate-buffered saline solution and wiggle fingers around while counting to 10 slowly; then, the student repeated the procedure with the other hand in the same bag. Samples were sealed, placed in a cooler, and transported at 4°C to the laboratory. The travel time by vehicle from the farthest school and the laboratory was approximately 2 hours. Hand rinse samples were analyzed for *E. coli* by the membrane filtration method using m-ColiBlue24 broth (Hach, Loveland, CO),^{47,48} and plates were incubated and counted using the methods described elsewhere.²²

Statistical methods. Frequencies of key indicators from the structured interviews with pupils were used to determine reported changes of hand washing conditions over time, and Student *t* test comparisons were used to test the school-aggregated difference in these indicators between baseline and final data collection rounds for the intervention arms compared with the control arm. Two school facility-level water accessibility indicators, current water source and distance to the source, were used to determine potential changes in water access over the course of seven follow-up data collection rounds. The facility-level follow-up data collection rounds were aggregated to have a representation of the entire trial period. Linear regression models were conducted using SAS 9.2 (Cary, NC) to test the mean proportions of the water accessibility indicators in each intervention arm versus controls. The baseline facility-level data, although presented, were not statistically compared with the follow-up facility-level data, because the baseline data represent one point in time, whereas the aggregated follow-up rounds represent seven points in time. Comparing the baseline with the aggregated follow-up data would have given too much weight to the baseline time point.

For the primary outcome measure of pupil hand washing behavior events after latrine use, two indicators—hand washing with water only and HWWS for girls, boys, and pupils—were modeled using multivariable logistic regression using the SURVEYLOGISTIC procedure to test the effect of the intervention on the odds of hand washing after latrine use comparing the school-aggregated averages from all follow-up data collection rounds in each intervention arm with the controls. This study did not observe the same pupils in each school over the entire study period; therefore, observations and the subsequent analyses were conducted at the event rather than pupil level. Observed hand washing water and soap availabilities at the school were also assessed. Models accounted for correlated observations within the school caused by cluster sampling and sampling stratification by geographical strata. In addition to the primary predictor of interest, each model contained both school–community socioeconomic status (SES) and geographic stratum; the inclusion of SES and geographic stratum was determined *a priori* to model fitting because of a previous study.¹⁸ School–community SES was estimated on an asset index for sample households within each community.¹⁸ A random sample of households was identified, and information was collected on a standardized set of household assets and dwelling characteristics. Principle component analysis was used to estimate a wealth index, and

households were grouped in quintiles.⁴⁹ School population size was also assessed and found not to be a confounder. The potential differences between the HW and LC+HW study arms were also assessed using the aforementioned method. Hand washing conditions and practice after latrine use were graphed at baseline and the four subsequent follow-up observation visits to show the variability observed between visits and overall trends over time within each study arm and between study arms. Frequencies of post-baseline school compliance with hand washing water and soap provision were also assessed for each study arm.

For the secondary impact analysis of *E. coli* detection on hands, individual pupil hand rinse data and multivariable logistic regression using the SURVEYLOGISTIC procedure were used to test the effect of the intervention on the odds of *E. coli* contamination. Models accounted for correlated observations within the school caused by cluster sampling and pupil sampling weights as well as sampling stratification by geographical strata. Model 1 contained the primary predictor of interest, intervention group, and the following covariates: sex, grade, SES, geographic stratum, and school pupil population; the first four covariates were determined *a priori* to model fitting because of their importance in a previous study.¹⁸ School pupil population was assessed to be a potential confounder and included in the model. Additionally, model 2 was fitted separately for sex because of an *a priori* determination. Sex differences in WASH provision are of interest in the WASH sector and were found to be present in a previous school-based hand contamination study conducted in this region.⁵⁰

Ethics. Approval from the Institutional Review Board at Emory University and the Great Lakes University of Kisumu's Ethical Review Committee was received before carrying out this trial. The head teacher provided consent in *loco parentis* for pupils' participation and a school's inclusion in the trial. Before conducting a structured pupil interview or collecting a hand rinse sample, oral assent was collected from each pupil.

RESULTS

Pupil and facility characteristics at baseline. Baseline levels of key indicators from the pupil structured interviews (school-aggregated) and the school facility assessments are presented in Table 1. There were 1,709 pupils interviewed during the baseline data collection period in May of 2010. In all study arms, the demographic characteristics of pupils interviewed were similar. The current drinking water source was improved in 65% of schools in the HW and control arms and 85% of schools in the LC+HW arm. An improved water source in this context may have been a borehole, rainwater harvesting tank, protected spring, or protected well. The current water source was greater than 1 km away from between 20% and 25% of schools. The pupil-reported school hygiene conditions were similar in all study arms. Between 70% and 75% reported that their school always provided water for hand washing, whereas only 14–18% reported that soap was always available.

Pupil and facility characteristics at follow-up. There were 1,725 pupils interviewed during the final data collection period in October and November of 2010. There was a significant 13% point increase in the number of pupils that reported that there was always enough water for hand washing at their schools in the HW arm compared with the controls

TABLE 1

Aggregated pupil and school characteristics and pupil-reported school hygiene conditions at baseline between primary schools in the HW, LC+HW, and control groups in Nyanza Province, Kenya, in May of 2010

Variable	Control (<i>N</i> = 20 schools; 575 pupils)	HW (<i>N</i> = 20 schools; 582 pupils)	LC+HW (<i>N</i> = 20 schools; 552 pupils)
Pupil demographics*			
Mean age (years)	12 (0)	13 (0)	13 (0)
Mean grade	5 (0)	6 (0)	6 (0)
Female (%)	53 (9)	49 (7)	51 (10)
School conditions (%)†			
Current water source improved‡	65 (49)	65 (49)	85 (37)
Distance to current water source > 1 km	25 (44)	25 (44)	20 (41)
Pupil-reported school hygiene conditions (%)*			
Reported designated place to wash hands	89 (22)	91 (20)	96 (17)
Reported water always enough for hand washing	73 (27)	70 (29)	75 (21)
Reported soap always available to wash hands	18 (16)	14 (11)	17 (16)

* Pupil results are mean number (SD) or mean percent (SD) of school-aggregated values.

† School conditions are mean percent (SD) calculated from school-level means.

‡ Improved source includes boreholes, rainwater harvesting tanks, protected springs, and protected wells.

($P = 0.03$) between the baseline and final assessment (Table 2). Both the HW and LC+HW arms had significant percentage point increases (51 and 61, respectively) in pupils reporting that soap was always available for hand washing at their schools compared with the controls ($P < 0.0001$ for each intervention arm). There was no significant difference between schools in each intervention arm compared with the controls in the percent of pupils who reported having a designated place to wash hands in schools. Water accessibility indicators—whether the current water source was improved and distance to the current water source was greater than 1 km—did not significantly change in either intervention arm compared with the controls throughout the duration of the trial (data not shown).

The majority of pupils surveyed during final data collection in both the HW and LC+HW arms reported having used soapy water in their schools (93% and 98%, respectively). Among those pupils, 72% and 81% reported the scent of soapy water was better compared with bar soap in the HW and LC+HW study groups, respectively, and 67% and 78% reported soapy water made hands feel better compared with bar soap in the HW and LC+HW study groups, respectively (data not shown).

Observed hand washing after latrine use. At least 50% of schools in all three study arms had hand washing containers with water at baseline, and at least 65% had them in the aggregated follow-up visits (Table 3). The odds of having hand washing water present were 65% ($P = 0.01$) less in the Rachuonyo geographic stratum versus Kisumu/Nyando, irrespective of study arm (data not shown). Soap was absent near the hand washing containers in most schools at baseline in all three study arms, and the resulting aggregated soap provision in the four

follow-up observation visits significantly increased in the HW and LC+HW arms—54% and 73%, respectively—compared with the controls. The odds of having soap present near the hand washing containers was 2.2 ($P = 0.04$) times greater in the LC+HW arm compared with the HW arm (data not shown).

Washing hands only with water—no soap—after latrine use at baseline was observed less than 14% of the time in all study arms, and it increased significantly to 32% in the control arm in the aggregated follow-up visits compared with the HW and LC+HW arms. Practicing HWWS events after latrine use at baseline was observed less than 7% in all three study arms and increased significantly to 32% and 38% in the HW and LC+HW arms, respectively, in the aggregated follow-up visits compared with the controls. The proportion of observed girls compared with boys practicing HWWS events after latrine use at baseline and aggregated follow-up observation visits was similar in all three study arms.

Figures 2 and 3 display the observed hand washing conditions and practice after latrine use at baseline and the four subsequent follow-up observation visits in the three study arms. Provision of soap peaked at the second follow-up visit in the intervention arms (Figure 2). The hand washing with water only events after latrine use peaked at the third follow-up visit in the control arm (Figure 3). The HWWS events after latrine use peaked during the second follow-up visit in the interventions arms (Figure 3).

Individual school compliance in relation to consistently providing hand washing water across all four follow-up visits occurred in at least one-half of the schools in the intervention arms and one-quarter of the controls (Table 4). Individual

TABLE 2

Percentage point changes from baseline to final follow-up of pupil-reported school hand washing conditions between primary schools that received an HW intervention or LC+HW intervention compared with control schools in Nyanza Province, Kenya, from May to November of 2010

Variable	Change in pupil-reported school hand washing conditions*				
	Control (%)†	HW†		LC+HW†	
		Percent	<i>P</i> value‡	Percent	<i>P</i> value‡
Designated place to wash hands	6	9	0.64	3	0.56
Water always enough for hand washing	-5	13	0.03	3	0.32
Soap always available to wash hands	-3	51	< 0.0001	61	< 0.0001

* Data are percentage point changes from baseline in school-aggregated values adjusting for cluster sampling and unequal probability of pupil selection.

† The control study arm had 20 schools with 575 and 578 pupils interviewed at baseline and final interviews, respectively; the HW study arm had 20 schools with 582 and 577 pupils interviewed at baseline and final interviews, respectively, and the LC+HW study arm had 20 schools with 552 and 570 pupils interviewed at baseline and final interviews, respectively.

‡ *P* value of Student *t* test comparing difference from baseline to follow-up between intervention and control study arms.

TABLE 3

Observed hand washing conditions and practice at baseline and four (aggregated) follow-up visits in 60 primary schools in the HW, LC+HW intervention, and control groups in Nyanza Province, Kenya, from May to November of 2010

Variable (mean %)	Control		HW		P value*	LC+HW		P value*
	Baseline (n = 20; y = 629)	Follow-up (n = 20; y = 2,828)	Baseline (n = 20; y = 628)	Follow-up (n = 20; y = 3,410)		Baseline (n = 20; y = 840)	Follow-up (n = 20; y = 3,574)	
Hand washing station conditions†								
Schools with hand washing water present	60 (11)	65 (7)	50 (12)	76 (8)	0.31	90 (7)	82 (5)	0.07
Schools with soap present	20 (9)	5 (2)	10 (7)	54 (6)	< 0.0001	25 (10)	73 (6)	< 0.0001
Hand washing with water only after latrine use‡								
Pupil events	8 (12)	32 (31)	13 (24)	18 (22)	< 0.001	13 (14)	14 (19)	< 0.0001
Girl events	9 (17)	31 (35)	14 (27)	19 (24)	< 0.01	12 (19)	13 (19)	< 0.001
Boy events	7 (11)	30 (30)	8 (17)	16 (22)	< 0.001	9 (13)	14 (28)	< 0.0001
Hand washing with soap and water after latrine use‡								
Pupil events	4 (10)	3 (13)	1 (4)	32 (33)	< 0.0001	6 (21)	38 (35)	< 0.0001
Girl events	1 (3)	3 (15)	3 (11)	34 (36)	< 0.0001	9 (24)	41 (37)	< 0.0001
Boy events	8 (26)	2 (13)	0 (0)	30 (33)	< 0.0001	4 (18)	41 (57)	< 0.0001

n= number of schools; y = number of opportunities for hand washing after latrine use events.

*P values derived from logistic regression tested the differences in the aggregated follow-up observation visits in the intervention versus controls controlling for community SES and geographic stratum.

†Data are mean percent (SD) of time point observations of hand washing water and soap availability clustered at the school level, and follow-up values are aggregated across follow-up visits.

‡Data are mean percent (SD) of time point observations of pupil hand washing practice after latrine use events clustered at the school-level, and follow-up values are aggregated across follow-up visits.

school compliance in terms of consistently providing soap across all four follow-up visits was low in both intervention arms and did not occur at all in the control arm.

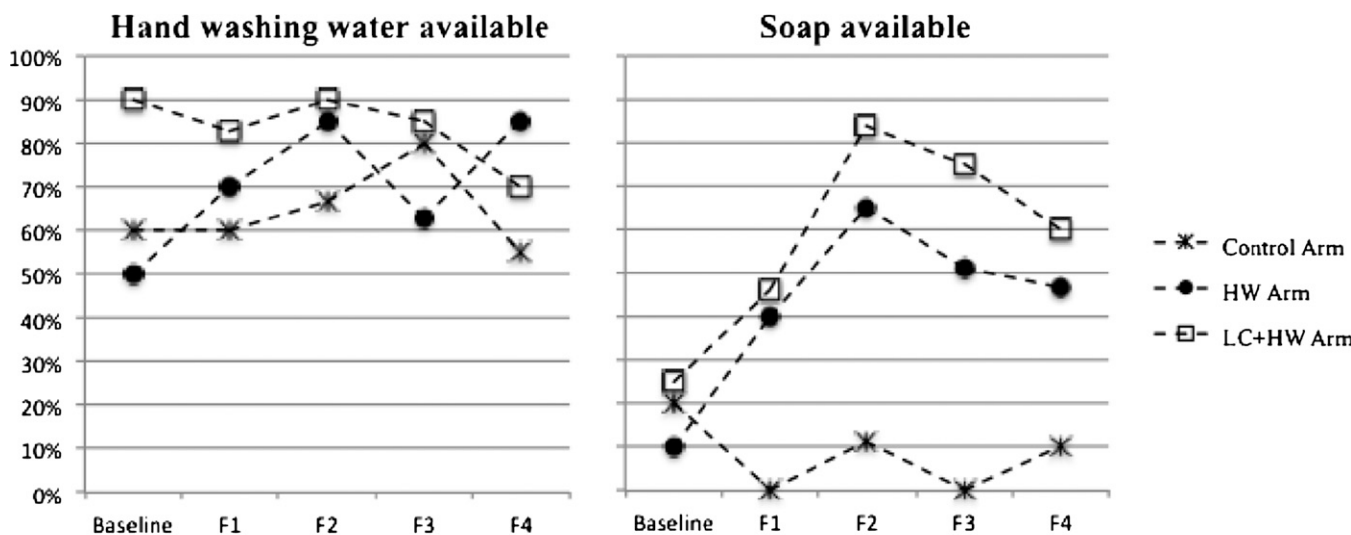
Pupil hand contamination results. The base 10 log distributions of *E. coli* colony forming units (CFUs) per two hands were categorized into four levels (< 1, 1–2, 2–3, and 3–4) and displayed graphically to show the variability in concentration within each study arm as well as between the study arms (Figure 4). Most of pupils' hands that were sampled—between 60% and 70%—had no detectable *E. coli* contamination. The distribution of *E. coli* concentrations on pupils' hands was similar in all three study arms at follow-up.

Given the sample size (a design effect of two) and assuming an *E. coli* prevalence of 37% among the unexposed (control study arm), we would have been able to detect at least a 59%

reduction in the odds with 80% power and $P = 0.05$. Being in a school in either intervention group did not significantly affect whether pupils altogether or girls and boys separately were likely to have any *E. coli* contamination present on their hands, although there was a trend to reduced odds after adjusting for other factors (Table 5). The odds of having *E. coli* contamination on hands was 4.1 ($P < 0.001$) times greater among pupils in the Rachuonyo geographic stratum compared with pupils in Kisumu/Nyando, irrespective of intervention status (data not shown).

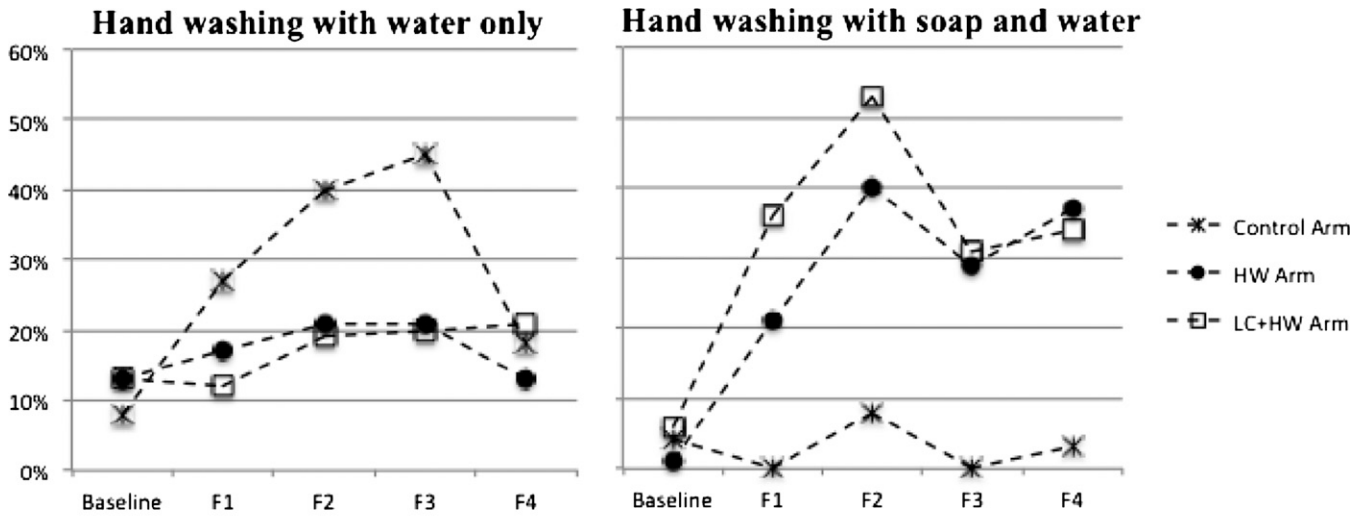
DISCUSSION

This study found that an intervention that regularly supplied soap to primary schools in Nyanza Province, Kenya,



F1=June 7-July 2; F2=July 5-July 30; F3 = September 13-October 8; and F4= October 12- November 3

FIGURE 2. The percent of primary schools with hand washing water and soap available in 60 primary schools in the HW, LC+HW, and control groups during baseline (May) and four follow-up visits in Nyanza Province, Kenya, from May to November of 2010.



F1=June 7-July 2; F2=July 5-July 30; F3 = September 13-October 8; and F4= October 12- November 3

FIGURE 3. The proportion of pupils observed practicing hand washing with water only and hand washing with soap and water after latrine use in 60 primary schools in the HW, LC+HW, and control groups during baseline (May) and four follow-up visits in Nyanza Province, Kenya, from May to November of 2010.

significantly increased the proportion of pupils observed practicing HWWS events after latrine use in the intervention arms compared with the controls. However, there was no significant difference in *E. coli* contamination on pupils' hands between the intervention and control arms. A school-based six-country final evaluation of a United Nations Children's Fund (UNICEF) hygiene program observed that less than one-third of pupils practiced HWWS.⁵¹ In this study, the aggregated proportion of pupils observed practicing HWWS events after latrine use during the follow-up visits was approximately one-third in the intervention arms, which is consistent with the UNICEF study. The aggregated proportion of pupils observed practicing hand washing with only water events after latrine use remained similar to baseline levels in both intervention arms. The addition of soap increased the overall proportion of pupils observed practicing hand washing events after latrine use—with only water or soap and water—in both intervention arms. Therefore, supplying soap to the schools with a limited degree of hand washing promotion improved hand washing practice overall.

A previous trial within the SWASH+ project, in which hygiene promotion but not soap was provided to schools, found

that 36% of schools provided soap during the first year of implementation followed by 21% and 8% during the second and third year follow-up visits, respectively (unpublished data). With lack of school funds and theft being two identified barriers to soap provision, this study addressed these barriers by supplying powdered soap, which has been reported to reduce soap theft compared with bar soap in a previous study to schools at no cost.²⁷ The resulting aggregated soap provision in the four follow-up observation visits in this trial improved significantly in the intervention arms versus controls. This result provides additional evidence that cost and theft of bar soap were, indeed, likely barriers to soap provision.

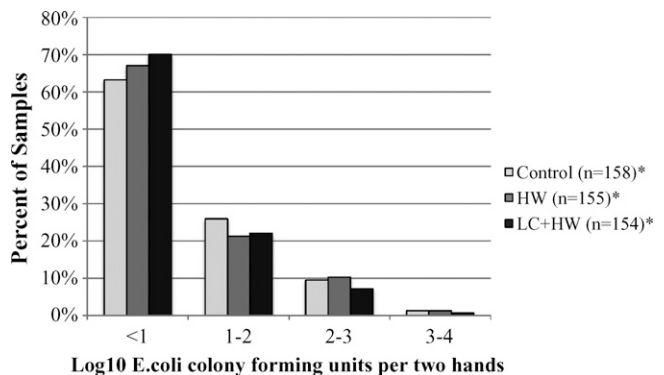
Barriers to the provision of hand washing materials still remain. In this study, one-half of the intervention schools did not consistently provide hand washing water during all four follow-up observation visits. Although all intervention schools were supplied soap, the majority of schools did not consistently provide soap for hand washing during all four follow-up observation visits. Potential reasons for lack of

TABLE 4

Schools attaining high observed compliance with provision of hand washing water and soap during four follow-up observation visits in 60 primary schools in the HW, LC+HW, and control groups in Nyanza Province, Kenya, from June to November of 2010

Variable	Control (N = 20)	HW (N = 20)	LC+HW (N = 20)
Schools that provided hand washing water (%)*			
During all follow-up rounds	5 (25)	11 (55)	10 (50)
During at least three of four follow-up rounds	11 (55)	14 (70)	14 (70)
Schools that provided soap (%)*			
During all follow-up rounds	0 (0)	2 (10)	7 (35)
During at least three of four follow-up rounds	0 (0)	7 (35)	12 (60)

*Data are mean number of schools (%).



*n= total number of pupils sampled

FIGURE 4. Distribution of log₁₀ *E. coli* contamination on pupils' hands in schools (n = 24) in the HW, LC+HW, and control groups in Nyanza Province, Kenya, from October to November of 2010.

TABLE 5

Odds of having any *E. coli* hand contamination for pupils in 24 primary schools in the HW, LC+HW, and control groups in Nyanza Province, Kenya, from October to November of 2010

	HW				LC+HW			
	<i>n</i>	OR*	95% CI	<i>P</i> value†	<i>n</i>	OR*	95% CI	<i>P</i> value†
All pupils	155	0.43	0.15–1.23	0.12	154	0.52	0.21–1.26	0.15
Girls	79	0.37	0.11–1.28	0.12	80	0.53	0.20–1.39	0.20
Boys	76	0.45	0.14–1.45	0.18	74	0.47	0.15–1.43	0.18

95% CI = 95% confidence interval.

*Both the all pupils and sex-stratified models adjusted odds ratios (ORs) control for grade, community SES, school pupil population, and geographic stratum. The adjusted OR in the all pupils model also controls for sex.

†*P* value of logistic regression coefficient on the difference between the HW and LC+HW study arms compared with controls.

hand washing water and soap provision by school administrations may include water accessibility difficulties, prevailing social norms among teachers themselves, and lack of institutional incentives and accountability.^{11,21} Within the schools that provided hand washing water and soap, not all pupils observed using the latrine practiced HWWS. Potential reasons may include insufficient or ineffective hand washing promotion or prevailing social norms in the household.¹¹ Additionally, the low compliance in soap provision within schools during the duration of the trial may have been an impediment to habit formation.¹⁰ Compliance during the third follow-up visit may have been more if project soap had been replenished before observation.

Two previous SWASH+ analyses found differential effects of educational and fecal exposure outcomes among girls and boys after the implementation of a WASH intervention in schools. One analysis found a significant reduction in the odds of girls missing school in intervention arms that received hygiene promotion and hygiene promotion with the addition of sanitation improvements in two geographic strata.¹⁸ The other study found the most significant increases in *E. coli* hand contamination among girls in the intervention arm that received hygiene promotion with the addition of sanitation improvements.⁵⁰ Reasons postulated by both studies for these sex differences were potential disparate hand washing and latrine usage behaviors between girls and boys, and both studies recommended additional research on sex differences in sanitation and hygiene behavior to implement WASH interventions more effectively. Our study found that hand washing rates were similar for both girls and boys at baseline and the aggregated follow-up observation visits. Therefore, differential hand washing rates among girls and boys may not have been the mechanism that explains the differences found between girls and boys in the previous studies.

The only difference found between the HW and LC+HW intervention arms for this study was soap availability. The LC+HW arm schools provided soap for hand washing in significantly more schools over the duration of the trial. This difference may have been because the LC+HW arm received additional powdered soap as part of the latrine cleaning supplies component of the intervention and therefore, had a greater quantity of soap overall for use. Alternatively, attention to the latrine cleaning component of the intervention in the LC+HW schools may have had positive added effects for soap provision.

The majority of school-based studies to date have used pupil self-reported structured interviews, scoring of demonstrated

hand washing acumen of selected pupils, or absenteeism and illness measurements to assess the effectiveness of a hand washing intervention.^{15,19,20,44} To our knowledge, this study is the first school-based, cluster-randomized study to conduct multiple observations of pupils practicing HWWS after latrine use. Conducting multiple observation visits allowed for variability over a 6-month time period to be measured. The variability may reflect lack of consistent hand washing habits within the study population, insufficient provision of soap by schools, or lack of periodic reinforcement of hygiene messaging. By studying the impact of soap provision on pupil hand washing behavior, this paper is able to examine the extent to which removing the barriers of budget and procurement can lead to the desired intermediate outcome of increased HWWS in the absence of additional interventions, such as governance or intensive behavior change communications.

No significant differences were found in *E. coli* contamination between intervention arms and the controls at follow-up. The majority of pupils sampled in all three arms had no detectable *E. coli* on their hands. One potential reason for not seeing a difference between the intervention and control arms may be a result of the significantly increased hand washing with only water observed in the control arm compared with the intervention arms. Studies have shown that even hand washing with only water can have a protective effect on diarrhea and hand contamination.^{2,52} Additionally, hand washing observations confirmed that soap was not always available for hand washing in all the intervention schools during all of the visits; therefore, lack of compliance decreased the likelihood that all pupils sampled from the intervention schools had the opportunity to wash hands with soap.

The significant differences found in *E. coli* presence between geographic strata may be because of differences in overall SES and rural versus less rural areas between Kisumu/Nyando and Rachuonyo. Rachuonyo is more rural and resource-poor compared with Kisumu/Nyando. Additionally, schools in Rachuonyo were significantly less likely to have hand washing water present irrespective of study arm—decreasing the opportunity for pupils in Rachuonyo to practice hand washing compared with pupils in the Kisumu/Nyando geographic stratum.

Limitations. Structured observational hand washing studies can introduce bias by prompting individuals under observation to carry out good hygienic behavior; however, bias may be reduced by conducting multiple observational visits in a set period of time to normalize the presence of the observer and the behavior of the observed.^{45,53} The proportion of pupils observed hand washing with water only after latrine use significantly increased in the control arm, although there was no direct hand washing intervention implemented in those schools. This increase likely occurred as a direct consequence of being under observation. However, by conducting multiple observation rounds, the proportion of pupils observed hand washing—with soap in the intervention arms and only water in the control arm—after latrine use decreased after reaching a peak, which may be an indication that conducting multiple observation visits reduced bias overall.

Hand contamination was only measured during one time point. Therefore, potential variations in hand contamination across the 6-month duration of the trial were not captured. A hand contamination measurement study conducted in Bangladesh reported variability in hand contamination levels

on the same individual's hand within several hours and concluded that single hand rinse measurements are not valid proxy measures for hand washing practice.⁵⁴ In light of the role of environmental contamination described by the aforementioned study, our single hand contamination measure may have been more indicative of pupils' transmission risk through hands rather than hand washing behavior. Other hand measurements studies have reported that fecal streptococci, *Clostridium perfringens*, or enterococci may be better indicators of fecal contamination on skin compared with *E. coli* because of longer survival times.^{40,42,55,56} However, because our goal was to estimate fecal contamination of hands that occurred at school, the shorter survival time of *E. coli* on hands made it a more suitable indicator for our study. Additionally, as a secondary analysis, the number of schools included in the hand rinse portion of the study was limited by laboratory capacity, and there may have been an insufficient sample size to see a significant reduction in the odds of hand contamination as a result of the intervention—large, non-significant reductions in the odds of hand contamination were observed in both intervention arms.

A great majority of pupils in both intervention arms reported preferring soapy water use over bar soap in terms of feel and scent. However, given that the intervention only provided soapy water materials, it is uncertain whether the positive feedback was truly a reflection of pupils' preferences or a result of courtesy bias.

Finally, although hand washing training was conducted with teachers in the two intervention arms before implementation, it is uncertain whether the trained teachers conducted hand washing promotion and education at the schools after training and whether the school health clubs were continuing to conduct hand washing promotion activities. Varying levels of hand washing promotion within the intervention schools may have influenced the proportion of proper hand washing practice events observed among pupils. Additionally, this study relied on simple refresher trainings and continued school health club activities rather than a new concerted effort at hand washing behavior change. As such, the focus of the intervention was more on the effect of soap provision, and greater effects may have been seen if a stronger, more rigorous hand washing promotion strategy had been undertaken.

CONCLUSIONS

Removing the barriers of soap procurement can greatly increase both provision of soap by schools and hand washing among pupils. The non-significant decrease in *E. coli* hand contamination among pupils in the intervention arms may suggest that compliance by approximately one-third of pupils with HWWS in a resource-challenged environment is insufficient to substantially reduce fecal exposure on hands. However, the study design for *E. coli* contamination may not have been robust enough to detect decreases. In contrast to some studies that observed differential health outcomes from school WASH interventions and hypothesized that there were differential behaviors of hand washing among boys and girls, this study found essentially identical rates of hand washing across sex.

Multiple observations of hand washing practice can be useful for describing variability, compliance, and time trends. Future studies should consider this method when assessing

hand washing interventions versus the more common but unreliable measure of self-reported behavior.⁴⁶

In this study, a system of regular soap provision to schools was associated with a significant increase in hand washing rates in approximately one-third of the school population, but barriers to hand washing in school remain. Future research should assess the additional benefit of institutional incentives and accountability for school administrators as front-line service providers. The interface of school hand washing improvements with wider prevailing social norms around hand washing behavior also needs additional examination. Researchers and program implementers working in resource-challenged settings will need to get beyond direct delivery of hand washing services and should use learning to address relevant concerns in the enabling environment. Greater attention to the role of the following factors is needed: increased budgets for soap and hand washing facilities, improved accountability systems, and more regular promotion of hand washing behavior to foster sustained improvements in pupil hand washing practice.

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