A Cluster Randomized Controlled Evaluation of the Health Impact of a Novel Antimicrobial Hand Towel on the Health of Children Under 2 Years Old in Rural Communities in Nyanza Province, Kenya

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Abstract. To assess the health impact of reusable, antimicrobial hand towels, we conducted a cluster randomized, yearlong field trial. At baseline, we surveyed mothers, and gave four towels plus hygiene education to intervention households and education alone to controls. At biweekly home visits, we asked about infections in children < 2 years old and tested post-handwashing hand rinse samples of 20% of mothers for *Escherichia coli*. At study's conclusion, we tested 50% of towels for *E. coli*. Baseline characteristics between 188 intervention and 181 control households were similar. Intervention and control children had similar rates of diarrhea (1.47 versus 1.48, $P = 0.99$), respiratory infections (1.38 versus 1.48, $P = 0.92$), skin infections (1.76 versus 1.79, $P = 0.81$), and subjective fever (2.62 versus 3.40, $P = 0.04$) per 100 person-visits. Post-handwashing hand contamination was similar; 67% of towels exhibited *E. coli* contamination. Antimicrobial hand towels became contaminated over time, did not improve hand hygiene, or prevent diarrhea, respiratory infections, or skin infections.

INTRODUCTION

Diarrheal diseases contribute an estimated 3.6% of the total disability-adjusted life-year burden of disease.¹ Worldwide, among children 28–364 days old, diarrheal diseases are responsible for 17.4% of deaths.² An important contributing factor to this burden of disease is poor hygiene. It has been estimated that handwashing with soap can reduce the risk of diarrhea by 30–47%.^{3,4} However, at least one study has documented the difficulty of sustaining handwashing behaviors and the attendant health impact.⁵ Furthermore, a qualitative study of hand drying behavior in western Kenya suggested that, despite widespread messaging about the importance of using clean towels or air drying after handwashing, many people tended to use their pants or wraparound skirts for hand drying.⁶

In response to the challenge of promoting and sustaining effective handwashing, innovative technologies for improving hand hygiene have been developed that consist of reusable hand towels with antimicrobial properties that are nontoxic and stable over time. Initial laboratory testing of one type of antimicrobial hand towel (Earth-plus™) demonstrated that it could remove microbial contamination from hands.⁷ Field studies of another type of antimicrobial hand towel (Vestergaard-Frandsen, Lausanne, Switzerland) in western Kenya yielded equivocal findings regarding the ability of the towel to reduce contamination of hands with *Escherichia coli* (A. Brown, CDC, unpublished data). Previous research utilizing hand-culturing techniques suggests that documenting the impact of handwashing on hand contamination in fecal-contaminated environments is challenging.^{5,8} Understanding the acceptability of novel interventions to community members enables changes to be made to products early in their development, including the impact of product maintenance. To further evaluate the potential of antimicrobial hand towels as a hygiene intervention in a contaminated environment, we examined the use,

acceptability, and health impact of the Vestergaard-Frandsen towels in rural western Kenya over a period of 1 year.

METHODS

In March 2012, we initiated a prospective, cluster randomized, controlled field trial in Kisumu County, located in an area in western Kenya, which has the highest under-five mortality rate in Kenya with 149 childhood deaths per 1,000 live births.⁹ Our study was designed to evaluate the effectiveness of an antimicrobial hand towel (hereafter referred to as towel) in preventing diarrheal diseases, acute respiratory infections (ARIs), self-reported fever, and skin infections in children < 2 years old.

Participants. Our unit of selection included census enumeration areas (EAs) in Nyakach Subcounty, which were geographically separated to minimize spillover between intervention and control communities. We conducted a baseline feasibility assessment and census of eligible households by EA. We limited selection to EAs that would remain accessible for enumerator visits during the rainy season. EAs were randomized into intervention or control groups using a random number generator. All households with at least one child < 2 years old (hereafter referred to as the enrollment child) at the time of our study's census were eligible to enroll. If there was more than one eligible household within a multi-household compound, then a single household was randomly selected using a random number generator.

The intervention. Mothers of eligible children in intervention households received handwashing instructions and four towels for household use. Enumerators instructed mothers in the proper use of the towels to dry their hands after handwashing. Mothers were instructed to place towels in the following household locations, if feasible:

1. Tucked in her lesa (wraparound skirt).
2. In the kitchen, near the food preparation area.
3. Within 5 m of the latrine.
4. In an area of her choice that would best facilitate regular use.

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Mothers were instructed to clean their towels in the same manner that they would normally clean other household laundry (i.e., frequency of washing, source water, detergent, and drying method). Field staff also instructed mothers in the proper use of the towels to dry their hands after handwashing within or outside the home.

Mothers in comparison and intervention households received the same standardized handwashing education. Field staff used a standardized step-by-step visual aid to demonstrate appropriate handwashing technique including the following steps: palm to palm cleaning, right palm over left dorsum and left palm over right dorsum, palm to palm with fingers interlaced, backs of fingers to opposing palms with fingers interlocked, rotational rubbing of right thumb clasped in left palm and vice versa, and rotational rubbing, backward and forward, with clasped fingers of right and in left palm and vice versa, followed by rinsing. Mothers in comparison households were instructed to air-dry hands whereas mothers in intervention households were instructed to use the towels for hand drying.

Sample size. To calculate the sample size required, we assumed that at least 50% of mothers using the towels would report a 20% decrease in household illness incidence compared with mothers in the comparison households, who we assumed would have found no change in these health outcomes. Using these assumptions, a confidence level of 95% and power of 90%, we calculated a sample size of 80 households for each of the intervention and comparison groups (160 households in total). To account for the design effect of EA-level clustering of health behaviors and outcomes, we doubled the sample size to 320 total households or 160 per group. In addition, to account for attrition of 10%, we increased the estimated sample size by 10%. Thus, we targeted for recruitment into the study at least 175 households per group, recruited by EA, or a total recruitment of approximately 350 households.

Quantitative data collection. Data were collected with personal digital assistants and entered into Microsoft Access database (Microsoft Corp., Redmond, WA). At baseline, trained enumerators administered questionnaires that collected information on age and gender of all household members, ownership of goods, respondent's education, water source, storage and treatment practices, handwashing behaviors, and household toilets. Enumerators observed current handwashing practices and recorded whether appropriate technique was used. Illness among any household members in the last 48 hours was also assessed.

Enumerators made biweekly home visits to all study participants for 25 study rounds to collect information on water source and treatment, hand hygiene practices, observed presence of soap in the home, and illness in the enrollment child in the last 48 hours. In addition, for intervention households, enumerators visually inspected all towels during each biweekly visit and recorded the number of towels available for inspection. We recorded the placement of towels in the household, reported towel washing behaviors (frequency of washing, use of soap, and drying method), towel-use practices, and towel appearance (i.e., intact or damaged, appeared unused, wet, and dirty).

Microbiologic testing. We used a random number generator to select a random sample of 20% of intervention and comparison households to participate in post-handwashing microbiologic testing of participating mothers' hands for con-

tamination with *E. coli*, an indicator of fecal contamination. To test participants' hands for fecal contamination after washing and drying, we used the "glove juice" approach. In the laboratory, we filled a sterile plastic sampling bag (Labplas Inc., Quebec, Canada) with 150 mL sterile distilled water. In the field, we instructed intervention household participants to wash their hands following the handwashing procedure instructed and verified by enumerators and use the towels to dry hands. Comparison household participants were instructed on the same handwashing procedure and then air-dry their hands. Immediately after hands had dried, each participant's hands were then inserted into the bag and massaged for 30 seconds to elute microbes. Samples were placed on ice for transport back to the laboratory and analyzed that day. Membrane (0.45 μ m pore size) filtration was performed on 1 mL and 100 mL of each sample; filters were placed in petri dishes containing sterile pads saturated with m-ColiBlue24[®] broth (Hach Co., Loveland, CO) and incubated at 35–37°C for 18–24 hours. *Escherichia coli* (blue colonies) were enumerated and back calculation provided *E. coli* colony forming units (CFU) per 100 mL eluent. After 23 study rounds, a sample of 126 intervention households was randomly selected using a random number generator to participate in microbiologic testing of the self-reported "most used" towel in the household. Each towel was placed in a Ziploc bag with 150 mL sterile water with Tween 80 (a surfactant to aid in microbial removal) and sodium thiosulfate (to neutralize antimicrobial chemicals), massaged for 90 seconds, and wrung out while still inside the bag. Turbidity was measured and towel eluent (100 mL or a dilution if turbidity was > 10 nephelometric turbidity units (NTU)) was tested for *E. coli* using Colilert-18 (IDEXX, Inc., Westbrook, ME). To assess the impact of proper washing, 13 towels were cut in half; one half was assayed as described above and the other half was washed with soap, rinsed with sterile water, dried in sunlight, and assayed as described above. Descriptive *E. coli* contamination levels are presented in three categories using most probable number (MPN) counts per 100 mL eluent: < 1 MPN *E. coli* per 100 mL eluent, 1–1,000 MPN *E. coli* per 100 mL eluent, and > 1,000 MPN *E. coli* per 100 mL eluent.

Qualitative data collection. After all study rounds were completed, we randomly selected two control and four intervention villages for participation in focus group discussions. One focus group discussion was conducted per village; 6–10 female head of households from the selected village were recruited for participation. Focus groups were designed to collect detailed descriptive data intended to support and elucidate quantitative findings. Trained focus group moderators elicited information about routine towel use and handwashing from comparison and intervention villages. Intervention villages were also asked about patterns of towel use, towel washing behaviors, and towel attributes. Focus groups were audio recorded. All focus group discussions were transcribed and concurrently translated from Luo (local language) to English. Discussion themes were coded and analyzed using MAXQDA 11 (VERBI Software, Berlin, Germany).

Qualitative data were transcribed from the audio recordings and translated. Observational notes taken during the focus group discussions were incorporated into the transcriptions, thereby providing insight into nonverbal behaviors that could not be captured through audio recording alone. Using a grounded theory approach, open coding was used to identify

key themes that were later used to guide the coding structure and subsequent data analysis. Focus group transcriptions were organized by key themes. Related themes were grouped. Themes derived from intervention and comparison group discussions were compared and contrasted.

Statistical analysis. Statistical analysis was performed using SAS version 9.3 (SAS Institute, Cary, NC). We collapsed biweekly health outcome data because outcomes were rare. Households in which fewer than 19 (75%) of 25 potential home visits were completed were excluded from analysis. If there was more than one eligible enrollment child in a study household, then a single enrollment child was randomly selected using a random number generator. We used an intent-to-treat analysis to compare health outcomes in the intervention group with the comparison group. We compared baseline characteristics of households lost to follow-up to households retained in the study using the Rao-Scott χ^2 test for categorical variables and Wilcoxon rank-sum test. Counts of illness episodes were analyzed using Poisson regression with robust standard errors to account for village clusters. Incidence density ratios are reported to compare intervention

and comparison group health outcomes. We used a similar approach to assess hand contamination in a sample of our population. For participants' hand contamination, we dichotomized *E. coli* counts into undetectable and detectable categories and determined the percentage of visits with contaminated hands in intervention and comparison groups.

Informed consent. Institutional review boards of the Kenya Medical Research Institute (protocol 2162) and the Centers for Disease Control and Prevention (protocol 6102) approved this study. Written informed consent (signature or thumbprint) was obtained from all participants. The study's ClinicalTrials.gov identifier is NCT02512614.

RESULTS

Baseline characteristics. Of 449 enrolled households, 369 (82%) completed > 75% of biweekly visits and were included in the analysis (Figure 1). At baseline, both intervention and control households had a median of two children ≤ 5 years old in the household; intervention households had a median size of six members and comparison households had a median

FIGURE 1. Study recruitment outline.

TABLE 1

Baseline demographic and socioeconomic characteristics of intervention and comparison households, antimicrobial hand towel study, Nyakach Subcounty, Kenya, March 2012

	Intervention households		Comparison households		<i>P</i> value*
	Median	Range	Median	Range	
Number of children < 5 years old	2	1–5	2	1–3	0.25†
Number of household members at baseline	6	2–13	5	3–10	0.24†
Number of rooms in house	2	1–4	1	1–3	0.20†

	Intervention households			Comparison households			<i>P</i> value
	<i>n</i>	<i>N</i>	%	<i>n</i>	<i>N</i>	%	
Male child < 5 years	90	181	50	103	176	59	0.10
Rotavirus vaccination	0	181	0	0	176	0	–
Electricity at home	5	181	3	7	176	4	0.61
Asset ownership							
Radio	122	181	67	134	176	76	0.13
Television	20	181	11	32	176	18	0.16
Refrigerator	0	181	0	2	176	1	–
Bicycle	48	181	27	56	176	32	0.33
Motorcycle	8	181	4	9	176	5	0.78
Car	2	181	1	0	176	0	–
Landline telephone	0	181	0	0	176	0	–
Mobile phone	144	181	80	133	176	76	0.36
Domestic house staff	1	181	< 1	2	176	1	0.53
Ownership of no goods	15	181	8	15	176	9	0.94
Land ownership and tending							
Own land	153	181	85	148	176	84	0.90
Family land	18	181	10	14	176	8	0.61
Rent land	8	181	4	14	176	8	0.26
Does not work the land	0	181	0	0	176	0	–
Mother's education							
No formal schooling	4	181	2	4	176	2	0.97
Some primary school	62	181	34	64	176	36	0.73
Completed primary	81	171	47	66	176	38	0.18
Some secondary school	19	181	10	31	176	18	0.02
Completed secondary school	12	181	7	8	176	5	0.42
Any trade school or university	2	181	1	2	176	1	0.98

*Using the Rao–Scott design adjusted χ^2 test for categorical variables.

†Indicates Wilcoxon rank-sum test performed and village clusters not accounted for.

of five members (Table 1). Baseline characteristics of households completed $\leq 75\%$ of biweekly visits were not significantly different from households that completed $> 75\%$ of visits. No children enrolled in the study had received rotavirus vaccination. There were no significant differences in asset ownership, land ownership, or mother's education between groups. The primary water source for more than two-thirds of both intervention and control households was rainwater. Piped water was the primary water source for 8.9% of intervention and 14.5% of comparison households.

Towel usage and placement. In study rounds 2–25, enumerators visually confirmed the presence of all four study towels in 56.8–76.2% of households. Between 84.9% and 93.7% of households had at least three towels available for visual inspection at biweekly enumerator visits in each study round. Only 1–3 households per round ($< 1\%$) reported that they were not using the study towels. More than two-thirds of households had at least one towel available for observation in the kitchen at biweekly visits. Placement of towels within a household did not vary substantially by study round. Almost half of the households had a towel inside or near the latrine, and one-third of households had at least one towel located in the living room. Only 8% of respondents reported keeping a towel tucked in their lesos (Table 2).

Microbiologic testing. We sampled 28 intervention and 24 comparison household mothers for post-handwashing hand rinse testing each round over the course of our study. The

percentage of rounds in which mothers' hands had no detectable *E. coli* (< 1 CFU *E. coli* per 100 mL eluent) ranged from 0% to 33% for intervention households and 0% to 42% for comparison households. There were no significant differences in dichotomized post-handwashing hand contamination between intervention and control participants ($P = 0.9175$). Across the 25 study rounds, the percentage of hand rinse samples of intervention group mothers in each of the three categories of *E. coli* CFU per 100 mL eluent varied widely: < 1 CFU

TABLE 2

Percentage of households observed to have at least one antimicrobial hand towel present (by location in home), antimicrobial hand towel study, Nyakach Subcounty, Kenya, March 2012–2013

Location	Number of visits with towels observed (<i>n</i>)	Total number of observations (<i>N</i>)	Percent of households with at least one towel in this location*
Kitchen	3,043	4,499	68
Latrine	2,183	4,498	49
Living room	1,524	4,498	34
Bedroom	358	4,498	8
Lesos	362	4,501	8
Basin	233	4,498	5
Outside drying	230	4,498	5
Other†	507	4,498	11

*Does not sum to 100% because this column indicates the number of households with at least one of the four intervention towels in this location. Households could have multiple towels in a single location.

†Examples of other locations include in a pile of dirty laundry, in a bag, soaking, on a table, on a chair, or on a door.

(4–50%), 1–1,000 CFU (21–93%), and > 1,000 CFU (4–50%). Similar variation was found among comparison group mothers' hand rinse samples: < 1 CFU (0–29%), 1–1,000 CFU (58–92%), and > 1,000 CFU (0–29%).

At the end of the study, towels from 120 of 126 randomly selected households were collected for microbiological testing. These towels, identified as “most used,” were obtained from the kitchen (63%), latrine (17%), multiple sites (10%), and tucked into mothers' lesos (9%). *Escherichia coli* contamination was detected in rinsate samples from 80 (66.7%) of 120 treated towels in intervention households. Turbidity measurements of rinsate ranged from 37.1 to > 5,221 NTU. After washing and drying a random sample of 13 towels in the sun, none of the tested towels had detectable *E. coli*.

Health outcomes. We collected data during home visits at 188 intervention and 181 comparison households over 25 rounds of household follow-up during the yearlong study period. There were 4,204 person-visits to intervention households and 4,115 person-visits to comparison households contributing to this analysis. In total, respondents reported that the enrollment children had a total of 123 episodes of diarrhea (62 episodes in intervention versus 61 episodes in control households), 119 episodes of ARI (58 versus 61 episodes), 250 episodes of self-reported fever (110 versus 140 episodes), and 152 episodes of skin infections (74 versus 70 episodes). There were no statistically significant differences between intervention and control children in rates per 100 person-visits of diarrhea (1.47 versus 1.48, $P = 0.99$), ARI (1.38 versus 1.48, $P = 0.92$), or skin infections (1.76 versus 1.79, $P = 0.81$), although subjective fever was significantly lower in intervention children (2.62 versus 3.40, $P = 0.04$) (Table 3).

Qualitative data. The focus group discussions provided a complementary perspective to the data collected in the biweekly home visits. During the discussions, women from intervention households reported frequent towel use. In general, intervention participants noted that towels were used by all household members, though the person in the household responsible for cooking and completing most household chores was reported to use the towels most frequently. “I use them most of the time because I am the only one who does the household chore[s] . . . I am the one who cooks, and so I use the towel. Be it sweeping or washing plates . . . I am the one who uses it quite often” (intervention group participant). One woman who shares the cooking responsibilities with other women in her family shared, “Anyone who wants to cook must use towel, not only me, because I will not be cooking each and every day” (intervention group participant). The activities women or family members engaged in determined towel use. Women cited using the towels in conjunction with a number of varied activities: during cooking, after using

the latrine, before or after eating, before or after changing or feeding a child, and for general hand wiping, such as in the market, even when no water was present. Towels were used in conjunction with and independent of handwashing.

Towel use and placement were heavily related. Though there was some variation based on the setup of the compound and size of their home, women largely kept the towels in places instructed by the enumerators. Rather than being strictly organized by the location of the towel, there was more a patterning around uses for the towel. Most women offered extended descriptions of towel placement.

[O]ne I placed in the main kitchen, because I don't cook in my house, so anyone who is cooking in the kitchen can use it to wipe their hands. One I've hung behind my door so that anyone from the latrine can use it . . . One I've hung behind the bedroom door. Anyone within the house can use it. The pin got lost; therefore, the one that I was given to pin on the skirt I walk with it everywhere. (Intervention group participant)

Perceptions of the best and worst place to keep the towels seemed in conflict. Best placement was most often based on accessibility while worst placement was based on the towel being soiled too quickly or where the towel could be easily stolen. However, frequent use often resulted in dirtier towels. A respondent explained optimal towel placement as such:

Germs in the kitchen are things like dust that are in the kitchen. So I put it far from the reach of the children so that they don't touch it with dust. You know when the children are playing, they touch many things like dust and they might touch the towel with it. So I put it far from where the children can reach it . . . I don't put it inside the latrine. When I put it in the latrine then it will be like putting it in the feces. (Laughter) So it is like you are taking the towel from the feces and using it to wipe your hands. So I put it away from the latrine, inside the main house where everyone can access it. (Intervention group participant)

All women who responded reported positive changes in the overall health of their household noting perceived reductions in diarrhea, fever, and skin rashes, emphasis was placed on the marked improvement of infant and child health. The women were certain that the towels worked to kill germs and limit contamination in the home. They would often make before and after comparisons within their home and between their home and other non-study households in the village. According to them, the towel improved the “cleanliness.” A respondent described the impact on household health as follows, “[I]t has helped has a lot because disease like diarrhea cannot attack our children because we use it a lot hence most of the time our hands are clean and so there's nothing you can touch with your dirty hands and it has also protect us from many diseases.” (Intervention group participant)

Though not specifically explored in the moderators guide, women noted that towels served as a reminder for handwashing, both for themselves and for other family members. A respondent noted that, “Before they were not aware of this issue of cleanliness because they could leave the latrine and not wash their hands but since these towels came they can come from the

TABLE 3

Incidence density ratios of illness episodes per 100 person-visits (by diagnosis, by intervention and comparison household), antimicrobial hand towel study, Nyakach Subcounty, Kenya, March 2012–2013

	Intervention households (per 100 person-visits)	Comparison households (per 100 person-visits)	P value
Diarrhea	1.47	1.48	0.98
ARIs	1.38	1.48	0.92
Fever	2.62	3.40	0.04
Skin infections	1.76	1.79	0.81

ARIs = acute respiratory infections.

latrine and wash their hands and dry with these towels there I've seen change and diseases that might attack any member of this family is not there." (Intervention group participant)

DISCUSSION

Findings of this study suggest that use of antimicrobial hand towels over a period of 1 year did not reduce the risk of diarrhea, ARI, or skin infections in children < 2 years, when compared with children whose mothers only received education on proper handwashing. These results occurred despite our belief that, based on biweekly observations and results of focus group discussions, the towels were regularly used. Between 84.9% and 93.7% of intervention households had at least three towels available for visual inspection in each round, and the majority of towels appeared to have been used and were located in places that facilitated use; < 1% of household participants per round reported that they were not using the study towels. The rate of self-reported fever was lower in intervention than control households, a finding that, in the context of no change in diarrhea or ARI risk, is difficult to explain.

There are several possible explanations for these findings. First, the active components of the antimicrobial hand towels may not have inhibited bacterial growth on the fabric. Microbiologic data from the end of the study demonstrated that nearly two-thirds of towels exhibited detectable *E. coli* growth. These findings were consistent with a recent study in which novel hospital curtains with antimicrobial properties were significantly less likely to become contaminated with *Staphylococcus aureus* or *Enterococcus* spp. early in the study, but developed a similar degree of contamination over time.¹⁰ If microbes are able to survive and grow on the towel fabric, then microbes could potentially be transferred from fabric to hands during the drying process. Although we did find that the towels could be effectively decontaminated by washing and drying them in the sun, this procedure is also recommended for less expensive, untreated towels.

Second, the active components of the towel may not have inactivated microbes present on the hands during the drying process. Our evaluation of post-handwashing hand contamination testing demonstrated that about two-thirds of participants drying their hands with the towel had detectable *E. coli* on their hands, suggesting that the towel either transferred *E. coli* to the hands or was unable to remove *E. coli* from the hands. The finding that approximately two-thirds of the air-drying group also had detectable *E. coli* on the hands suggests that the latter possibility may have been more likely. Neither of the two handwashing and drying procedures was able to effectively decontaminate the hands. This finding is troubling because it raises the possibility that rinse water may have contributed to post-handwashing hand contamination, which contradicts a prevalent belief that the microbiologic quality of water used to rinse hands is not of central importance to the achievement of adequate hand hygiene.^{11,12} The implications of the above findings are unclear because there is little understanding of the threshold of microbial contamination of hands that is associated with disease transmission.

Third, the towels may not have been present in locations where they could have had the greatest health impact, such as near latrines. Qualitative data suggested that several factors influenced towel placement, including concern about theft, but there was no indication that these considerations affected

towel use. Biweekly interview and observational data suggested that most or all of the towels were placed in visible, convenient locations and were used regularly; these data were corroborated by focus group findings.

Fourth, mothers may not have washed their young children's hands frequently enough, which is an important consideration because of the natural tendency of children to put themselves at risk of disease by exploring their environment and placing their hands in their mouths. We collected categorical information about frequency of towel use, but data on reported handwashing practices are notoriously unreliable.¹³⁻¹⁵ Without direct observations, it is not possible to verify handwashing practices of the children of participants.

Qualitative data suggest that the presence of the towels served as a handwashing reminder to mothers, for themselves and their children. We collected no objective data that verified whether handwashing frequency actually increased in intervention households, but, given the challenges in motivating and sustaining handwashing behavior, the use of hand towels as a behavioral cue merits further study.⁵ The promotion and use of clean towels for hand drying could improve the effectiveness of handwashing because previous research suggests that, despite promotion of air-drying as a safe hand drying method, the behavior is often not practiced, most likely because it is time consuming and inconvenient.⁶ More vigorous promotion of hand towels based on the results of this study would also require promotion of frequent (i.e., at least daily) towel washing and drying to prevent contamination and potential disease transmission.

Our study had several limitations. First, among both intervention and comparison households, there may have been a social desirability bias when responding to biweekly questions about hand hygiene behaviors. This potential overreporting of appropriate hand hygiene behaviors likely affected both intervention and comparison households equally, as suggested by similar results of microbiologic hand testing after observed handwashing and similar health outcomes. We had insufficient funding to conduct random, structured observation of handwashing for the duration of the study. Second, we were unable to detect a difference in hand contamination between intervention and control group participants because of the wide variability in hand-rinse *E. coli* levels in both groups over time. Third, we had insufficient funding to allow the study to be blinded with a third arm of households receiving a placebo towel, which would have improved the quality of the study and created similar conditions for the intervention and control groups. The belief that the towel had "magical powers" was evident in the focus group discussions and may have biased results toward finding an effect of towels. In practice, this possibility did not alter study findings, with the possible exception of reported fever. Finally, the study population was located in one subcounty in Kisumu County and was not necessarily representative of western Kenya.

In conclusion, the antimicrobial hand towels evaluated in this study did not appear to reduce the risk of diarrhea, respiratory, or skin infections when compared with standard hygiene promotion; the finding of lower fever risk in the intervention group is difficult to interpret in the context of other evaluation results. There are many potential interventions that could be used to decrease the burden of infectious diseases in developing countries, and by quantifying the health impact of novel interventions, we are supporting evidence-based

decision making. Because of the apparent lack of antimicrobial performance or health impact, dissemination of the antimicrobial hand towel is not recommended. However, the possibility that the presence of a hand towel motivates improved handwashing behavior merits further research. Research on the risk of diarrheal diseases and ARI posed by different levels of hand contamination by *E. coli* is also warranted.

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