

Combining Footwear with Public Health Iconography to Prevent Soil-Transmitted Helminth Infections

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Abstract. Shoes are effective for blocking soil-transmitted helminths (STHs) that penetrate the skin. Unfortunately, shoe-wearing is uncommon in many areas where STHs are prevalent, in part because local populations are unaware of the health benefits of wearing shoes. This is especially true in low-literacy populations, where information dissemination through written messages is not possible. We launched a public health intervention that combines a public health image with sandals. The image is a “lenticular image” that combines two alternating pictures to depict the efficacy of shoes for preventing STH infection. This image is adhered to the shoe, such that the message is linked directly to the primary means of prevention. To create a culturally appropriate image, we conducted five focus group discussions, each with a different gender and age combination. Results of focus group discussions reinforced the importance of refining public health messages well in advance of distribution so that cultural acceptability is strong. After the image was finalized, we deployed shoes with the image in communities in western Uganda where hookworm is prevalent. We found that the frequency of shoe-wearing was 25% higher in communities receiving the shoes than in control communities. Microscopic analyses of fecal samples for parasites showed a sustained reduction in infection intensity for parasites transmitted directly through the feet when people received shoes with a public health image. Our results show that combining culturally appropriate images with public health interventions can be effective in low-literacy populations.

INTRODUCTION

The Global Burden of Disease report (2010) estimated that neglected tropical diseases (NTDs) contributed 20.06 million disability-adjusted life years (DALYs) between 1990 and 2010, worldwide.^{1,2} The specific burden of hookworm, a soil-transmitted helminth (STH), was estimated at 3.23 million DALYs.¹ To address this problem, regular deworming programs have been advocated that target children and other at-risk populations through mass drug administration (MDA).^{3–5} However, effective chemoprophylaxis programs rely on established public health infrastructures and the continual availability of anthelmintics.⁶ Furthermore, MDA may reduce worm burdens in infected people, but cure rates are variable, and the effectiveness of the strategy for reducing transmission is unclear.^{1,7–9} Reduction of hookworm burden, or even eradication, requires complementary strategies that target the parasite transmission cycle.^{7,9–11}

The impact of MDA has been rigorously reviewed, resulting in vocal critics and supporters. For example, Hawdon attributes lack of progress associated with the MDA to poorly functioning drugs, risk of drug resistance, and constant reinfection, and suggests that improved sanitation might be more effective.⁷ Conversely, Bundy and others strongly support MDA as a way to control the burden of STH, citing cost-effectiveness and economic benefits to child health and development.¹²

Recently, there has been an increase in attention to shoe-wearing for preventing soil-related disease conditions like podoconiosis as well as STH infection.^{13,14} Shoes are a proven method for disrupting the transmission of STH. However, shoe-wearing is sporadic in areas where STHs are prevalent, due to low perception of health benefits, financial constraints, and limited availability.¹⁵ Eradication of hookworm and similar STH infections calls for integrated approaches that incorporate shoe-wearing and other social and environmental interventions along with medicinal deworming.^{5,6,16} Minimal health education about the risks and magnitude of STHs has been reported as one reason for lackluster engagement with community-based MDA programs.⁸

We implemented a novel intervention designed to increase shoe-wearing practices in hookworm-endemic regions. We designed a culturally appropriate image that depicts the benefits of shoe-wearing entirely through pictures. The image was a “lenticular image” that “flips” between two alternate pictures, so that information is densely presented and accessible to nonliterate populations. We then affixed the image onto a shoe, linking the public health message directly to the means of intervention. We first optimized the effectiveness and cultural appropriateness of the intervention in western Uganda. We then assessed the efficacy of the intervention by measuring shoe-wearing behavior in recipient and control communities, and by measuring prevalence and intensity of STHs in these same communities before and after shoe distribution coincident with a deworming event.

MATERIALS AND METHODS

The study took place in Kabarole District, western Uganda. The population of Kabarole is approximately 474,000.¹⁷ NTDs

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are endemic in this region, and regular deworming occurs in school settings, targeting children.^{18,19} Standard treatment guidelines are followed, which use mebendazole except for in pregnant women, in which case albendazole is preferred.²⁰

Study design. This study combined four different components to inform and assess the public health effects of the novel intervention based on public health imagery.

The first component was focus group discussions (FGDs), which were held from January to February 2014. The goal of the FGDs was to iteratively guide the design of the lenticular image (commonly, but erroneously, known as a “hologram”) with the input of participants. The lenticular image was then refined by graphic designers and mass-produced (Service Litho-Print, Oshkosh, WI). Images were adhered to 100 pairs of “slide” style sandals, such that the image was prominently visible to anyone holding or wearing the shoe (Supplemental Figure 1). This product (sandal with image adhered) was dubbed “the Holoflop.”

The second component was an experiment to assess the efficacy of the Holoflop for reducing hookworm infection, conducted from June to December 2014. We selected three demographically similar but geographically separate communities. In the first community (Nyabinyungu, “Experimental 1”), we distributed the Holoflop to 112 individuals in 21 households. In the second community (Isule, “Experimental 2”), we distributed plain shoes (shoes without the image) to 62 individuals in 11 households. In the third community (Kijinjomi, “Control”), we enrolled 71 participants in 17 households but did not distribute shoes to them until the end of the experiment. We timed our shoe distribution to coincide with a community deworming event. We collected and analyzed fecal samples for STHs immediately before deworming (baseline sample), 2 weeks postdeworming, and 6 months postdeworming.

The third component was an observational study conducted from July to August 2014. Trained field assistants visited all participants on a “drop-in” basis and recorded whether they were wearing shoes and, if so, the type of shoe, the location, and the activity in which participants were engaged. Participants were observed two to eight times per week over the course of 6 weeks. The purpose was to assess individual- and treatment-level differences in shoe-wearing behavior.

The fourth component was a qualitative assessment of comprehension and acceptability, conducted through a series of semi-structured interviews with household members. Interviews were conducted from August to September 2014. We did not reveal the purpose of the study to participants until this final stage, so as not to influence shoe-wearing behavior beyond any effect elicited by the image alone.

Data and sample collection. Focus group guides were developed in English and piloted and administered in the local language, Rutooro. FGDs were structured to obtain information about perceptions of helminth infections, and to develop and refine iconography. FGDs were audio recorded, and a notetaker was also present to record verbal and nonverbal communications. Because one of the main goals of the FGD was to assist in the development of images, participants were invited to draw pictures representing concepts under consideration. Concepts explored through drawing included danger/warning, foot, pain, happy,

unhappy, healthy, unhealthy, no/do not, sad, sick, and worm. FGDs were iterative, such that refinements achieved in one FGD were carried forward to the next.

Five FGDs were conducted. The first FGD consisted of a mix of participants (male and female, aged 14–65 years) to pilot the FGD guide. Subsequent FGDs targeted participants based on age and gender only. FGD participants were not from the experimental or control communities, and the discussions themselves occurred in a separate location far from the study sites.

For the experiment, fecal samples were collected from participants over a period of 6 months. Shoe distribution was timed to coincide with a routine community deworming event, to assess the effectiveness of the intervention on reinfection. Fecal samples were collected at three time points from individuals in all three groups: baseline (approximately 2 weeks before deworming), 2 weeks postdeworming, and 6 months postdeworming. Sterile fecal collection cups were delivered to participants along with associated supplies and instructions, and samples were picked up the following day. Feces were fixed in 10% formalin (ratio of 3:1 formalin: feces, v/v) within 24 hours of collection. Fecal samples were then transported to the University of Wisconsin–Madison, for parasite identification. One gram of formalin-preserved feces was concentrated via formalin-ethyl acetate sedimentation.²¹ The sediment was then examined in its entirety at $\times 10$ and $\times 40$ objective magnification. All eggs and larvae were counted, and representative parasite life stages were measured with a calibrated ocular micrometer.

Data for the behavioral study were collected through “scan surveys” designed to record and contextualize shoe-wearing practices. Teams of two field assistants observed participants in up to four households on each day of data collection. On arrival, field assistants observed and recorded which participants were wearing shoes, the type of shoes worn, the time of day, the activity in which participants were engaging, and the location of the participants. If participants were encountered outside their households, observations on their shoe-wearing practice were recorded in the locations where they were encountered.

For the qualitative assessment of comprehension and effectiveness, semi-structured household interviews were conducted with a subset of participants who had been involved in both the parasitology and the behavioral arms of the study. Interviews were conducted with household members in each community. Using an interview guide, field assistants administered household interviews in teams of two or more. Interviews were conducted in the local language. The interview guide for each treatment group was largely the same, with the primary goal of ascertaining the effect of the image on knowledge of STH prevention as well as general shoe-wearing practices.

Data analysis. FGD data were immediately analyzed. After each session, the notetaker, facilitators, and investigators reviewed participants’ drawings and verbal information. Group discussion was used to achieve consensus regarding the most important lessons learned from that session, and this information was used to modify the discussion guide for the next session, if needed.

Shoe-wearing observational data were input into a Microsoft Access (Redmond, WA) database and transformed in

R Studio (Boston, MA) for analysis. One large data frame that included the demographic characteristics of each participant and his/her shoe-wearing practices by observation was assembled. Descriptive statistics of the study population were calculated using Microsoft Excel (Redmond, WA). Pearson's χ^2 was performed in R 3.2.4²² to detect a difference in shoe-wearing frequency between individuals in communities who received shoes and those who did not.

For the experimental assessment of efficacy, parasitological measures of STH infection were compared across sampling periods for each treatment group. Prevalence (percent of individuals infected) with binomial proportion confidence limits, and mean intensity of infection (eggs or larvae per gram in infected individuals) with bias-corrected and accelerated bootstrap confidence limits were calculated using Quantitative Parasitology software.²³ Mean intensity was calculated as the arithmetic mean, with no adjustments made. Because of low sample sizes, hookworm and *Strongyloides stercoralis* were combined for analyses, since both parasites are transmitted directly through the feet. Prevalence and intensities were compared among baseline, 2-week postdeworming, and 6-month postdeworming samples using Fisher's exact and Kruskal–Wallis tests, respectively. After Kruskal–Wallis tests, nonparametric pairwise comparisons were performed using Dunn's test with a Bonferroni correction.

For the behavioral study, mixed effects logistic regression was performed with each independent variable to identify significant factors associated with shoe-wearing. The maximal model was built using the *glmer* function in the lme4 package in R 3.2.4, which is suitable for unbalanced data. Random effects were coded to account for repeated measures of individuals. Individuals were nested within household because of nonindependence of observations from individuals within the same households. Independent variables included gender, age group, household size, shoe ownership, highest level of education attained (none, primary school, secondary school, postsecondary school), occupation, location, and activity. In addition, two orthogonal contrast variables were coded to compare shoe-wearing between Experiment 1 + Experiment 2 with Control (Contrast 1: giving shoes versus not giving shoes); and Experiment 1 with Experiment 2 (Contrast 2: Holoflop versus plain shoe). Model selection was performed using backward elimination of independent predictor variables and first-order interaction terms between significant main effects. We accepted models that retained only significant predictor variables and first-order interactions among significant main effects, had variance inflation factors within reason (variance inflation factor/generalized variance inflation factor < 2; using the *vif* function in R), showed no significant overdispersion (scale parameter between 0.75 and 1.4 using the *dispersion_glmer* function in R), and explained significantly more variance than the null model (likelihood ratio test at $\alpha < 0.05$).^{22,24}

For the qualitative study of comprehension and effectiveness, household interview data were translated into English and transcribed in notebooks. Interviews were then entered into the EZ-Text software program (Centers for Disease Control and Prevention, Atlanta, GA). After repeated scanning of transcripts by two members of the research team, codes and subcodes about the comprehension of the

image, shoe-wearing practices, and suggestions of other public health messages suitable for similar iconography were constructed.²⁵ Comments, impressions, and suggestions of participants were also recorded to preserve the range and richness of individual reactions and viewpoints.

Ethics statement. Ethical clearance for the study was obtained from the Uganda National Council of Science and Technology (UNCST) and the University of Wisconsin–Madison Institutional Review Board (IRB). Elected and appointed leaders from multiple administrative units in Kabarole District were approached about the study, which commenced only after their approval. Because of low literacy rates, oral consent was obtained for study participants. Oral consent was approved by IRB and UNCST.

Focus groups consisted of individuals above the age of 14 years. Participants of all ages were observed for shoe-wearing practices and provided fecal samples. For those under the age of 14, parents provided oral assent. Household interviews were also conducted; all available members of the household were included in the interview and consented collectively.

RESULTS

Focus group discussions. The initial FGD (FGD 1) consisted of six men and four women ranging from 14 to 65 years of age. The FGD guide was piloted and modified based on input from this group. Four sequential FGDs were then held (FGD 2: six adolescent males, FGD 3: seven adult males, FGD 4: eight adolescent females, and FGD 5: eight adult females). FGD 5 responded to the final prototype.

All FGD participants reported that worms were common, especially among children, and that infected people were not stigmatized. FGDs also generated information (both verbal responses and drawings) useful for developing the image. In many cases, semiotics of specific elements matched the researchers' expectations; however, unexpected findings also emerged that led to abandonment of candidate images (Supplemental Figures 2 and 3). The final image is shown in Supplemental Figure 4.

Parasite reinfection trial. We recovered the eggs/larvae of five different STHs from 622 fecal samples (Supplemental Table 1). These included two parasites for which infectious forms transmit directly through the foot: hookworm (*Ancylostoma* sp. and/or *Necator* sp., the eggs of which are indistinguishable microscopically) and *S. stercoralis*. We found significant differences in the intensity of combined hookworm and *Strongyloides* infection between the three time points for the Holoflop treatment (Experimental 1; $H = 6.74$, $df = 2$, $P = 0.03$), but not the plain shoe treatment, or the control treatment. Pairwise comparisons showed that deworming led to a significant and sustained reduction in intensity of hookworm and *Strongyloides* infection in the community that received Holoflops only (Figure 1; $z = 2.80$, $P = 0.003$ for difference between baseline and 6-month postdeworming samples). Variation in prevalence across sampling times was not significant within individual communities or when data from all communities were combined ($P = 0.10$). None of the other parasites detected showed evidence of having been affected by the distribution of shoes. This was expected because these parasites are transmitted via

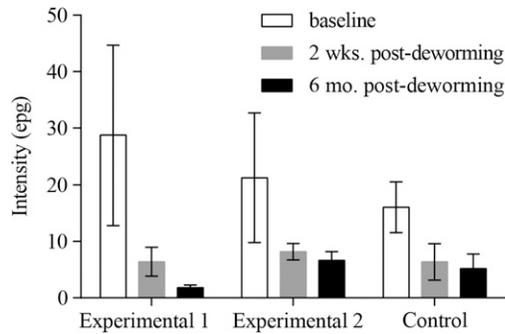


FIGURE 1. Mean intensity for parasites transmitted directly through the foot (hookworm and *Strongyloides stercoralis*) in three study communities: Control (no shoes distributed), Experimental 2 (plain shoes distributed), and Experimental 1 (Holo-flops distributed). Error bars indicate standard error of the mean.

the fecal–oral route (see Supplemental Table 1 for individual values).

Behavioral study. Across the three study communities, 245 participants were observed (mean [M] \pm standard deviation [SD] = 10.01 \pm 7.27 observations per individual). A total of 112 individuals were observed in Experimental 1 community (M \pm SD = 11.97 \pm 8.53); 62 in Experimental 2 community (M \pm SD = 9.68 \pm 5.08); and 71 in the Control community (M \pm SD = 7.25 \pm 5.71). Participant age and other demographic factors were similar among communities (Table 1).

Field assistants recorded 2,468 observations. Overall, 39% of the observations were of study participants wearing shoes while 61% were of barefoot participants. The proportion of observations of people wearing shoes was significantly higher in the communities that received shoes (43% in Experimental 1 community and 42% in Experimental 2 community), than in the Control community (17%) ($N = 2,453$; $\chi^2(1) = 117.2$, $P < 0.0001$) (Figure 2). Shoes were worn in a variety of locations and activities (Figure 3). Holo-flops were most often observed being worn in domestic spaces as well as in the agricultural fields. Specifically, Holo-flops were most

often observed while participants were cleaning, cooking, caring for children, planting, weeding, and tending animals. Participants typically wore other shoes when traveling or conducting business.

Results from mixed effects logistic regression showed that the shoe-wearing was significantly associated with gender (likelihood ratio test: $\chi^2(1) = 5.26$, $P = 0.02$), location ($\chi^2(4) = 50.97$, $P < 0.001$), activity ($\chi^2(4) = 27.84$, $P < 0.001$), and Contrast 1 (giving any shoe versus no shoe; $\chi^2(1) = 33.27$, $P < 0.001$) (Table 2). Gender, and specifically being male, was the only demographic factor significantly associated with higher odds of shoe-wearing (odds ratio [OR] = 1.57, $P = 0.02$). The odds of shoe-wearing were significantly higher for participants who had been given shoes as part of this study than for participants in the control community, who did not receive shoes at the onset of the study (OR = 7.31, $P < 0.001$). Participants had significantly lower odds of shoe-wearing in agricultural spaces, compared with the household compound (OR = 0.53, $P = 0.001$). However, the highest odds of shoe-wearing occurred when participants were on roads and paths (OR = 2.84, $P < 0.001$). Higher odds of shoe-wearing were also significantly associated with moving (e.g., travel by foot or vehicle [OR = 1.66, $P = 0.002$]) and hygienic activities (e.g., washing hands, bathing, or using the latrine [OR = 4.32, $P < 0.001$]) compared with domestic activities (e.g., cooking, caring for very young children, eating, and resting). There were no significant first-order interactions between main effects.

Household interviews. Final qualitative assessments of participant comprehension were administered to members of a total of 21 households (Experimental 1, $N = 9$; Experimental 2, $N = 6$; and Control, $N = 6$). The number of participants per interview ranged from one to seven for each household. Following a prompt to discuss the meaning of the image, and with no additional prompts, at least one participant in 18 of 21 households interviewed responded with the intended interpretation (85.7% household comprehension). Individual comprehension was more variable between communities, although 95% confidence intervals were largely overlapping (Supplemental Table 2).

TABLE 1
Characteristics of study population in three communities, each receiving a different experimental treatment

Variable	Control* ($N = 71$)	Experimental 2* ($N = 62$)	Experimental 1* ($N = 112$)	Total ($N = 245$)
Age, mean, median (range)	21.26, 11 (0–91)	20.40, 13 (1–78)	21.08, 14 (0–73)	21.00, 13 (0–91)
Gender, male/female	29/42	28/34	60/52	117/128
Cultural group, %				
Mutooro	69.01	33.87	26.79	40.82
Mukiga	29.58	66.13	68.75	56.73
Other†	1.41	0.00	4.46	2.445
Education level, mean‡	2.16	3.42	3.87	3.26
Occupation, %				
Student	39.44	33.87	41.96	39.18
Farmer	35.21	27.42	30.36	31.43
No occupation§	23.94	32.26	22.32	25.31
Formal sector employee	0.00	3.23	3.57	2.04
Other¶	1.41	3.23	1.79	2.04
Pairs of shoes owned at baseline, mean (range)	1.97 (0–5)	2.41 (1–5)	2.11 (0–6)	2.14 (0–6)

*Experimental 1: given Holo-flops; Experimental 2: given plain shoes; Control: no shoes distributed during the study period.

†Muganda, Munyoro, and “unknown.”

‡Based on school-eligible participants (age ≥ 4 years), education level is in years, ranging from primary school (1–6) to postsecondary education (7–13).

§Typically participants under age 5.

¶Tea picker, shopkeeper, self-employed.

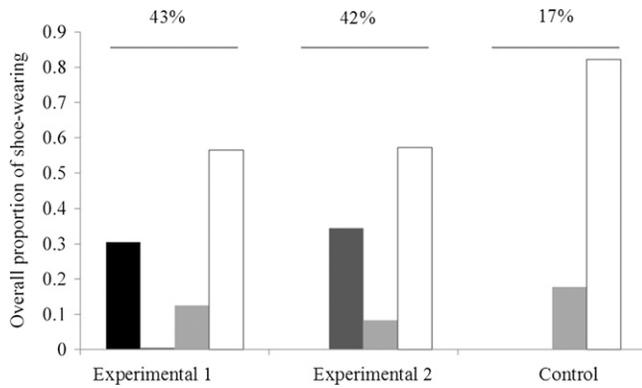


FIGURE 2. Overall shoe-wearing by community and shoe type. Columns indicate the proportion of total observations of shoe-wearing behavior in each treatment community: Control (no shoes distributed), Experimental 2 (plain shoes distributed), and Experimental 1 (Holo-flops distributed). Different colored columns represent the wearing of Holo-flops (black bars), plain shoes (dark gray bars), other shoes (light gray bars), and barefoot (white bars). Percentages at top of graph show overall shoe-wearing frequency for each village.

When asked about reasons for wearing shoes in general, respondents reported that shoes were worn when going to work, school, church, or during social visits to “look smart” and to protect feet against physical injury (stones and thorns)

and “germs.” Respondents also stated that they went without shoes primarily because they could not afford them.

DISCUSSION

Shoes are an effective way to block infection with STH that penetrate the skin, but conveying the message that shoe-wearing is beneficial for health is challenging, especially in low-literacy populations. Our results suggest that culturally appropriate public health iconography can help overcome this challenge. Specifically, our results demonstrate that our image, without additional prompting or education, was effective in conveying the intended message. We found that shoe-giving, even without education about the associated health benefits, increases shoe-wearing. Further, we found that people tended to wear shoes in appropriate contexts (e.g., around the latrine), and that shoe-wearing practices improved among participants receiving the intervention. Results from parasitological analyses suggest that the intervention was effective for reducing the intensity of infection, but the effects on prevalence were less clear.

Overall shoe-wearing frequency was higher in the communities that received Holo-flops and plain shoes. Further, Holo-flops were worn at similar or higher rates than other shoes when participants were at home cleaning, which was

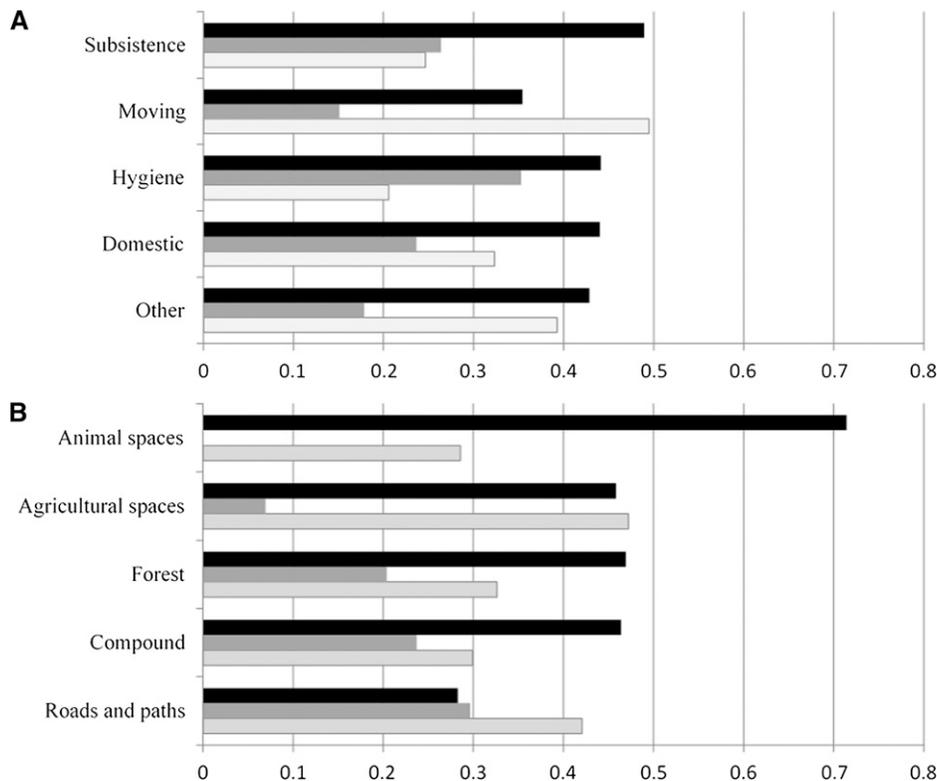


FIGURE 3. Shoe-wearing by (A) participant activity and (B) location. Bars indicate the proportion of different shoe types worn during different activities and locations only for participants observed wearing shoes. Different colored bars represent different shoe types: Holo-flop (top, black), plain shoe (middle, gray), and other shoes (bottom, white). “Subsistence” refers to activities to maintain a rural livelihood, such as working in gardens and plantations, collecting poles and timbers, preparing charcoal, and children’s activities, such as playing, carrying firewood, fetching water, and working alongside adults; “Moving” describes travel by foot or vehicle such as a bicycle or a motorcycle; and “Hygiene” refers to washing hands, bathing, or using the latrine. “Domestic” refers to household-based activities such as cooking, caring for very young children, eating, and resting; “Other” refers to activities such as conducting business, standing and waiting, or sharpening machetes.

TABLE 2
Results from mixed effects logistic regression for factors associated with odds of shoe-wearing

Variable*	β	OR	95% CI	P value
Intercept	-1.39			
Gender (ref = female)	0.45	1.57	1.07–2.31	< 0.05
Contrast 1 (giving any shoe vs. not giving)	1.99	7.31	3.99–13.38	< 0.001
Location (ref = household compound)				
Agricultural spaces	-0.63	0.53	0.36–0.78	< 0.01
Animal spaces	0.07	1.08	0.34–3.39	NS
Forest	0.26	1.30	0.81–2.08	NS
Roads and paths	1.04	2.84	1.94–4.15	< 0.001
Activity (ref = domestic)				
Hygiene	1.46	4.32	2.12–8.78	< 0.001
Moving	0.50	1.66	1.21–2.29	< 0.01
Other	-0.09	0.91	0.50–1.65	NS
Subsistence	0.01	1.01	0.78–1.32	NS

CI = confidence interval; OR = odds ratio. Dispersion scale parameter = 0.99; variance inflation factor/generalized variance inflation factor < 2 for all model terms; likelihood ratio test P values < 0.05 for all single-term deletions.

*Individuals nested within households were included as random effects. There was no effect of education, age, or Contrast 2 (HoloFlo versus plain shoe).

our expectation. This changed when people were on roads and paths, en route for a social visit, or going to church or school. In addition, being male was positively associated with shoe-wearing. Thus, shoe-wearing practices result from a combination of individual and contextual factors. We attribute lack of stronger trends between the distribution of HoloFlops and shoe-wearing practices to 1) the small sample size of participants in our study, 2) the fact that we could not randomize treatments within communities (due to “cross contamination” from information dissemination among households within communities), 3) the fact that resource limitations prevented us from replicating treatments in multiple communities, and 4) that the causal pathway between seeing/comprehending the image and changing shoe-wearing behavior is likely complex.

Nevertheless, high rates of comprehension of the image and positive responses from participants about the overall strategy bode well for the ultimate effectiveness of this type of intervention for increasing appropriate shoe-wearing behavior and decreasing infection rates with STH. Low-cost pictorial education may be able to modify behaviors such as shoe-wearing. We also point out that other public health educational campaigns (e.g., focused on handwashing or seatbelt wearing) have not achieved appreciably better results than ours, despite highly intensive and costly intervention strategies.²⁶

We documented effects of our intervention only for parasites with infectious stages that transmit through the feet. Deworming resulted in a significant reduction in hookworm and *Strongyloides* intensity when combined with distribution of shoes with the public health image adhered to them (Figure 1). However, due to small numbers of incident infections following deworming, these results are based on small sample sizes and should be interpreted with caution. Intensity is a measure of worm “burden,” reflecting the number of infective stages shed into the environment. Therefore, by reducing infection intensity, interventions such as ours also reduce transmission at the community level. MDA is currently the principal control measure for STH infections.^{27–29} However, such chemotherapy alone has not effectively controlled STH infections, and water, sanitation, hygiene, and personal preventative measures, such as wearing shoes, are receiv-

ing increased attention.^{14,30,31} Our results suggest that shoe-giving, when combined with public health iconography, could be a valuable complementary approach for reducing the intensity of hookworm and similar pathogens.

Results from FGDs and household interviews enriched our quantitative data. For example, we learned that worms are a common experience and that participants were able to list many reasons to wear shoes beyond “fashion,” including for safety and health. Further, participants reported wearing shoes for school, work, church, or visiting friends and family, and participants desired shoes even though most did not have the resources to purchase them. Indeed, our dissemination of shoes in this region significantly increased shoe-wearing frequency, indicating not only that people want to wear shoes but also that shoe-giving programs are measurably effective for increasing shoe-wearing. Although this conclusion may seem obvious, there are many examples of distribution programs of products intended to benefit public health (e.g., bed nets to reduce malaria transmission) that have fallen short because people have used the product for unintended purpose (e.g., converting bed nets to other uses, such as fishing nets).³²

Our findings contribute to a growing body of literature on the role of footwear in preventing STH infection. For example, a recent meta-analysis of footwear and NTDs showed that wearing shoes is associated with significantly lower odds of infection with hookworm, *Strongyloides*, and other STHs.¹⁴ However, studies associating shoe-wearing behavior with hookworm infection have been largely cross-sectional, with very few cohort, case-control, or experimental studies.^{33–35} Measures of shoe-wearing behavior in parasite surveys are largely self-reported and provide limited information on types of footwear, frequency of use, or contextual use of shoes.^{14,19} In this study, we collected observational data on individual shoe-wearing behavior to quantify heterogeneity in footwear use. We show that footwear use varies across space, according to shoe type and activity, and demographically. Such differences are likely to contribute to the efficacy of footwear interventions.

In addition, we are unaware of any studies investigating the effect of shoe giving on parasitic infection. By giving shoes, we were able to increase shoe-wearing

by approximately 25% compared with a community where we did not give shoes. Previous research estimates that shoe-wearing lowers the odds of hookworm infection from 18–47%³¹ to 48–61%¹⁴; thus our results could lead to large reductions in hookworm infection rates. Because we timed our intervention to coincide with a community deworming event, we were able to demonstrate that reductions in hookworm intensity lasted longest in areas that also received shoes with adhered public health iconography.

Our qualitative assessments of poststudy impressions from household interviews revealed dimensions of perception, education, and motivation that would be difficult to quantify. Notably, participants fell into categories based on their comprehension of the intended meaning of the image. Some people understood the intended meaning immediately while others did not, even within the same household. Once the intended meaning was explained, some participants spontaneously offered suggestions for improvement or application to alternative public health issues. These findings indicate that certain subsets of community members could serve as focal points for educational intervention, perhaps serving as “agents of change” for their communities.^{26,36–40}

On the basis of our findings, we suggest that deployment of footwear, coupled with low-cost educational interventions, can be an effective strategy for reducing STH infection in endemic areas. The role for public–private partnership in this regard, similar to the pharmaceutical industry’s chemoprophylaxis engagement, could be seen as an example to leverage resources. However, future cost-effectiveness studies are needed to fully explore the feasibility and sustainability of these interventions.¹⁴ Our particular form of coupled educational intervention—the “holographic” image—has distinct advantages. It is cheap, small, requires no electricity, and can be adapted easily to different cultural contexts. This and similar technologies could significantly enhance the effectiveness of a variety of biological interventions targeting STHs and NTDs in general.

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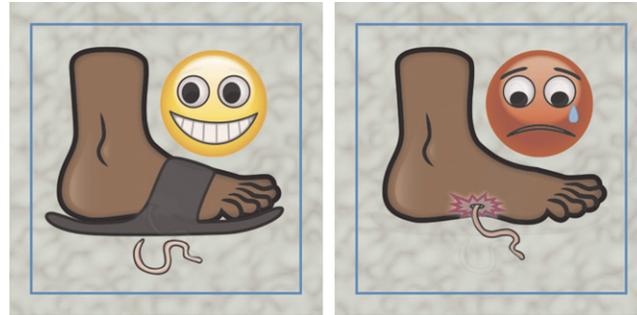
SUPPLEMENTAL FIGURE 1. The “Holoflop.”



SUPPLEMENTAL FIGURE 2. Picture of a sick person used during focus group discussions to inform the design of the public health image. Focus group participants described this as a picture of a man smoking and carrying luggage, demonstrating the importance of assessing cultural appropriateness during the design of public health iconography.



SUPPLEMENTAL FIGURE 3. “Happy face” does not necessarily mean “happy.” Some focus group discussion participants described this as a picture of a person who was annoyed. To show “happy” in the local culture, a picture should show teeth, as teeth connote laughter.



SUPPLEMENTAL FIGURE 4. The final image designed through focus groups to convey the health benefits of shoe-wearing for blocking soil-transmitted helminths such as hookworm. The image is a “lenticular image,” in which the two images shown are superimposed and “flip” back and forth depending on the angle of view (an effect achieved through thin lines of parallel lenses that refract light at different angles). Such images are dense with information, are inherently interesting, and do not require electricity or any other special conditions to view.

SUPPLEMENTAL TABLE 1
Parasite prevalence and intensity at baseline, 2 weeks after, and 6 months after anthelmintic treatment

Treatment	Measure	Time point	Hookworm	<i>Strongyloides stercoralis</i>	<i>Ascaris lumbricoides</i>	<i>Trichuris trichiura</i>	<i>Oesophagostomum</i> sp.
Control	Prevalence*	Baseline (N = 75)	0.19 (0.12–0.29)	0.01 (0.00–0.07)	0.37 (0.26–0.49)	0.16 (0.09–0.26)	0.03 (0.00–0.09)
		2 weeks (N = 64)	0.11 (0.05–0.21)	0.02 (0.00–0.08)	0.11 (0.05–0.21)	0.17 (0.09–0.29)	0.02 (0.00–0.08)
		6 months (N = 71)	0.06 (0.02–0.14)	0.01 (0.00–0.08)	0.28 (0.19–0.40)	0.16 (0.08–0.26)	0.01 (0.00–0.08)
	Intensity†	Baseline	16 (8.64–26.1)	1 (NA)	797 (307–1,850)	37.2 (15.5–90.1)	2 (1–2)
		2 weeks	7.14 (2.76–17.7)	1 (NA)	423 (131–918)	12.5 (4.91–41)	2 (NA)
		6 months	6.25 (2–12.5)	1 (NA)	760 (281–2,100)	16.9 (10.3–28.6)	8 (NA)
Experimental 1	Prevalence	Baseline (N = 99)	0.07 (0.03–0.14)	0.07 (0.03–0.14)	0.07 (0.03–0.14)	0.22 (0.15–0.32)	0.05 (0.02–0.11)
		2 weeks (N = 91)	0.04 (0.01–0.11)	0.01 (0.00–0.06)	0.01 (0.00–0.06)	0.19 (0.11–0.28)	0 (0–0.04)
		6 months (N = 67)	0.06 (0.02–0.15)	0.02 (0.00–0.08)	0.09 (0.03–0.19)	0.12 (0.05–0.22)	0 (0–0.05)
	Intensity	Baseline	36.7 (6.71–121)	12.6 (5.71–19.7)	126 (72.1–273)	17.3 (11.4–26.4)	1.6 (1–1.8)
		2 weeks	5.75 (1.5–12.5)	9 (NA)	725 (NA)	32.7 (11.2–124)	NA
		6 months	1.5 (1–2)	3 (NA)	203 (57.2–566)	20.8 (4.38–49.1)	NA
Experimental 2	Prevalence	Baseline (N = 50)	0.14 (0.06–0.27)	0.02 (0.00–0.11)	0.10 (0.03–0.22)	0.02 (0.00–0.11)	0.06 (0.01–0.17)
		2 weeks (N = 57)	0.07 (0.02–0.17)	0.02 (0.00–0.09)	0.02 (0.00–0.09)	0 (0–0.06)	0
		6 months (N = 48)	0.17 (0.07–0.30)	0.06 (0.01–0.17)	0.02 (0.00–0.11)	0.02 (0.00–0.11)	0.02 (0.00–0.11)
	Intensity	Baseline	23.7 (7.29–62.3)	4	34 (2.2–75)	2	6.33 (2–9.33)
		2 weeks	9 (5.75–11)	5 (NA)	27 (NA)	NA	NA
		6 months	7 (3.75–10.8)	5.67 (1–9)	85 (NA)	3 (NA)	1 (NA)

*Prevalence estimates are given with binomial proportion 95% confidence limits.

†Intensity (eggs per gram) estimates are given with bootstrap confidence limits. NA indicates prevalence that was too low to construct intensity estimates and/or confidence intervals.

SUPPLEMENTAL TABLE 2
Frequency of individuals who comprehended the image with no additional prompting during household interviews*

	Experimental 1	Experimental 2	Control	Total
Comprehended	44 (28–63)	55 (34–74)	78 (54–92)	57 (45–68)
Did not comprehend	56 (37–72)	45 (26–66)	22 (9–46)	43 (32–55)
Total individuals	27	20	18	65

*Values are percentages of total individuals, with 95% confidence intervals in parentheses.