Am. J. Trop. Med. Hyg., 104(1), 2021, pp. 357–371
doi:10.4269/ajtmh.20-0456

Formative Research for the Design of a Baby Water, Sanitation, and Hygiene Mobile Health Program in Bangladesh (CHoBI7 Mobile Health Program)

Shwapon Kumar Biswas,[1,2] Elizabeth D. Thomas,[3] Jahed Masud,[1] Fatema Zohura,[1] Tasdik Hasan,[1] Tahmina Parvin,[1] Md. Sazzadul Islam Bhuyian,[1] Md. Ismat Minhaj,[1] Fatema Johura,[1] Marzia Sultana,[1] Sanya Tahmina,[2] Shirajum Monira,[1] Jamie Perin,[2] Munirul Alam,[1] and Christine Marie George[3]*

[1]*International Centre for Diarrhoeal Disease Research, Bangladesh, Dhaka, Bangladesh;* [2]*Ministry of Health and Family Welfare, Dhaka, Bangladesh;* [3]*Department of International Health, Johns Hopkins School of Public Health, Baltimore, Maryland*

Abstract. Poor food hygiene practices, child feces not being disposed of in a latrine, child mouthing of contaminated fomites, and poor hand hygiene of caregivers have been associated with diarrheal diseases, environmental enteropathy, and impaired growth in young children. Mobile health (mHealth) programs present a low-cost approach to delivering water, sanitation, and hygiene (WASH) programs. We conducted a theory-driven and evidence-based approach to formative research and intervention development to design and pilot test a Baby WASH mHealth program targeting food hygiene, child mouthing, and child feces disposal behaviors in urban Dhaka, Bangladesh. Formative research activities included 31 semi-structured interviews, five group discussions, six mHealth workshops, and a three-phase iterative pilot study among 102 households. Findings from semi-structured interviews and group discussions indicate that caregivers of young children have relatively high awareness of the need for safer food hygiene, child mouthing, and child feces disposal practices, but are limited by existing household responsibilities and restricted access to enabling technology that would facilitate practicing recommended behaviors. The piloted Baby WASH mHealth program was well-received by households. This study presents a theory-driven and evidence-based approach for intervention development that can be implemented for the development of future WASH mHealth programs in low-resource settings.

INTRODUCTION

Diarrheal diseases continue to be a major cause of mortality among young children globally, causing 500,000 deaths annually.[1] The first 2 years of life are a critical window for child health and development, and the water, sanitation, and hygiene (WASH) behaviors of caregivers are important contributors to both during this time.[2,3] Exposure to fecal pathogens due to poor hygiene and water treatment practices in the home is associated with an increased risk of diarrheal disease and environmental enteropathy (EE) in young children.[3–6] EE is a disorder defined by abnormal intestinal morphology, which increases intestinal inflammation and reduces barrier function. This disorder has been associated with impaired growth in susceptible pediatric populations.[7,8] Previous studies have identified multiple risk factors for diarrheal diseases and EE among young children, including poor food hygiene practices,[9–11] child feces not being disposed of in a latrine, child mouthing of contaminated fomites, and hand hygiene of caregivers.[4–6,12–17] It is important to recognize the unique exposure routes to fecal pathogens for young children for WASH interventions to be tailored for susceptible pediatric populations.

Poor food hygiene practices among caregivers have been associated with diarrhea in young children in multiple settings.[9,11] Several interventions to improve food hygiene behaviors in the home have been developed for rural settings,[18,19] but effective interventions in urban settings are limited. A study conducted in Bangladesh found that 40% of complementary food samples taken from urban and rural homes were contaminated with *E. coli*; and contaminated food was associated with an increased risk of diarrhea among young children.[20] Our recent study in rural Bangladesh found that mouthing of contaminated fomites, such as bottles, toys, and wrappers with visible dirt, was observed in more than 60% of children younger than 2 years, and was associated with EE.[16,17] Despite evidence showing an association between childhood mouthing of contaminated fomites and poor child health outcomes,[17,21] there have been no intervention studies published in Asia targeting child mouthing. Finally, sanitation interventions typically focus on construction of improved sanitation facilities and target adult defecation practices.[11–13] There is minimal attention given to safe disposal of feces from child open defecation events,[22,23] despite unsafe child feces disposal being common globally and associated with pediatric diarrhea, EE, and impaired child growth.[13,14,20]

Community-based behavior change interventions are often expensive and difficult to implement in low-resource urban settings.[24] The use of mobile technologies for delivery of health information, referred to as mobile health (mHealth), is a promising, low-cost, scalable approach to facilitate behavior change.[25–29] Mobile phone subscriptions have grown enormously worldwide: more than doubling over the last 10 years.[30] It was estimated in 2017 that there were 85 million unique mobile phone subscribers in Bangladesh, half of the country's population.[31] Therefore, Bangladesh is an ideal setting for mHealth behavior change programs.

The Cholera Hospital-Based Intervention for 7 Days (CHoBI7). Household members of diarrhea patients are at a much higher risk than the general population of developing diarrheal diseases (> 100 times for cholera) during the 7-day period after the diarrhea patient presents at a health facility.[32–34] In an effort to develop an intervention for this high-risk population, we developed the CHoBI7 WASH mHealth program.[35,36] The intervention includes sending voice and text messages to diarrhea patient households to promote

*Address correspondence to Christine Marie George, Associate Professor, Department of International Health, Program in Global Disease Epidemiology and Control, Johns Hopkins Bloomberg School of Public Health, 615 North Wolfe St., Rm. E5535, Baltimore, MD 21205-2103. E-mail: cmgeorge@jhu.edu

handwashing with soap and water treatment. Our recent randomized controlled trial (RCT) of the CHoBI7 WASH mHealth program showed significant improvements in handwashing with soap and stored household drinking water quality and lower pediatric diarrhea and stunting over the 12-month study period.[37] This was the first RCT of a WASH mHealth program and demonstrates that mHealth is a promising approach to facilitate WASH behavior change. We are currently partnering with the Bangladesh Ministry of Health and Family Welfare to scale this mHealth intervention program across Bangladesh. Building on our previous work, the focus of this study was to conduct formative research to develop three WASH mHealth modules targeting safe child feces disposal, improved food hygiene, and safe child mouthing practices as a follow-on to the CHoBI7 WASH mHealth program. We refer to this intervention as the "Baby" WASH mHealth program, since this program focus on interventions targeting young children.

METHODS

Study setting and participation. This research was conducted in urban Dhaka, Bangladesh, from July 2018 to December 2019. Participants included caregivers of young children (mothers, fathers, and grandparents) mostly in slum areas, and government stakeholders. Caregivers of children younger than 5 years were our initial focus because children in this age group are considered at risk for enteric disease because of fecal-oral transmission of pathogens along our target routes of exposure: food, fomites, and feces. We later chose to focus on caregivers of children younger than 2 years based on preliminary findings that our Baby WASH behavioral recommendations were more relevant for this age group.

Theoretical approach. WASH programs for diarrhea prevention often focus on information-based health education in an effort to change health knowledge and behavior.[38] Although such programs may increase health knowledge, they are unlikely to lead to sustained behavior change.[38–40] Programs informed by behavior change theories to target multiple behavioral determinants are more likely to succeed than programs that focus on increasing knowledge alone.[41,42] It is also important for WASH programs to consider the larger context and multiple levels that influence WASH behaviors and enabling technology.[43] In their construction of the Integrated Behavioural Model for WASH (IBM-WASH), Dreibelbis et al.[43] point out that part of acknowledging that WASH behaviors operate in a multilevel framework is considering factors that influence habit formation. WASH behaviors are rarely one-time actions but rather require repetition and relative automaticity to be maintained.[43–45] Keeping this in mind, our approach to the formative research and intervention development process presented here was informed by IBM-WASH as well as basic habit science and "nudging theory" as outlined by Neal et al.[43,45]

IBM-WASH considers the contextual, psychosocial, and technological factors driving WASH behaviors at the structural, community, household/interpersonal, individual, and habitual levels, and has been applied for the development of several WASH interventions.[22,23,36,43,46,47] We applied IBM-WASH by developing our intervention with consideration of the influential behavioral determinants that exist at multiple levels and in multiple dimensions, as identified through our formative work.

With respect to habit science and nudging theory, Neal et al.[45] take guidance from psychology, behavioral economics, and cognitive science and assert that behavior is a product of two "brain systems": system 1 includes automatic, cue-driven factors (e.g., existing habits), whereas system 2 includes rational, motivational factors (e.g., intentions). Behaviors that are performed frequently in the same environment, like many WASH behaviors, are thought to be part of system 1. The authors subsequently outline eight principles that focus on system 1 "tactics" to disrupt existing habits and make small changes to the environment, called "nudges", that encourage the target behavior: 1) managing physical availability of enabling technology and infrastructure; 2) leveraging context changes to introduce new behaviors; 3) piggybacking on existing cues and behavior; 4) managing perceived and actual friction to performing a behavior; 5) supporting context-stable repetition; 6) embedding ritualized elements in the behavior change process; 7) leveraging point-of-action reminders and situational cues; and 8) highlighting descriptive and "localized" norms. Definitions and examples of these principles/tactics are expanded on in the Results section of this manuscript. In this study, we sought to incorporate both system 1 and system 2 tactics for behavior change into the Baby WASH mHealth modules.

Finally, this research recognizes that women, as mothers, grandmothers, or other caregivers of young children, are often the focus of WASH behavior change programs.[48] The focus of women as the target audience for WASH programs is a likely reflection of existing roles and responsibilities in the intervention context.[48,49] However, focusing interventions exclusively on women risks reinforcement of harmful social norms and puts the onus of behavior change on women, who are already disproportionately responsible for WASH-related responsibilities in the home.[50] In our formative research and intervention development, we sought to include male household members both in our intervention delivery and as targets for Baby WASH behaviors.

Study design. As noted, the Baby WASH mHealth program was initiated as a follow-on to the CHoBI7 mHealth program. As a result, much of the formative research presented here was conducted with households that had completed the CHoBI7 mHealth RCT. In addition, the structure of the Baby WASH mHealth program was predetermined by the CHoBI7 mHealth program design. The four intervention components predetermined by the CHoBI7 mHealth program design included 1) delivery of mobile and voice messages using the VIAMO platform, 2) inclusion of interactive voice response (IVR) messages as "quizzes" that participants could respond to, 3) initial program delivery through an in-person visit to deliver a pictorial module (pilot phases 2 and 3 only), and 4) involvement of two study "characters" for intervention delivery, Dr. Chobi and Aklima. These two characters were developed for the CHoBI7 mHealth program.[35] Dr. Chobi is a doctor at a hospital who calls and texts diarrhea patient households to share information and reminders on recommended WASH behaviors to keep children and household members healthy. She is sometimes called "Dr. Chobi Apa," meaning "Sister Dr. Chobi." Aklima is a woman who brought her child to a health facility for diarrhea treatment and learned WASH behaviors from Dr. Chobi. A complete description of the CHoBI7 mHealth program, including formative research and development of program characters, is reported elsewhere.[35] There was no fee to households for sending mHealth messages; sending biweekly mobile messages for 1 year costs 2 United States Dollars using the VIAMO platform.

The three topics for the Baby WASH mHealth modules were set a priori: food hygiene, child mouthing, and child feces disposal. The focus of the formative research presented here was on the development of intervention content for the Baby WASH mHealth modules and piloting of the developed intervention.

Formative research activities included three components: 1) exploratory interviews, 2) intervention development through mHealth workshops, and 3) pilot studies of the Baby WASH mHealth modules. The specific aims of the formative research were to 1) explore practices and perceptions related to food hygiene, child mouthing, and child feces disposal among caregivers of young children and their household members; 2) identify barriers and facilitators to performing the promoted WASH behaviors; 3) identify beneficiary preferences for delivering the Baby WASH mHealth program; and 4) determine the feasibility of program delivery.

Component 1: exploratory interviews. The field team conducted nine semi-structured interviews in July 2018 with a convenience sample of caregivers of young children from CHoBI7 mHealth RCT households (n = 7) and their neighbors (n = 2). The eligibility criteria for CHoBI7 mHealth RCT participants interviews is reported elsewhere.[35,37] Neighbors were eligible to participate in an interview if they had a child younger than 5 years in the home. Interviews followed a guide that covered the following topics: types of food consumed by young children, food storage and reheating practices, caregivers' experiences with child mouthing of dirt or dirty objects, child toileting practices, child feces disposal practices, male household member involvement in child and household activities, and preferences for mHealth message delivery.

In addition, two government stakeholders at the Bangladesh Ministry of Health and Family Welfare participated in semi-structured interviews in October 2018 to explore the feasibility of delivering the Baby WASH mHealth program as a national program.

Semi-structured interviews were conducted in Bangla (caregiver interviews) or English (government stakeholder interviews). Findings from exploratory interviews informed the content of the Baby WASH mHealth modules tested in the pilot studies.

Component 2: mHealth workshops. Six mHealth workshops were held from July 2018 to June 2019 to develop and refine text and voice messages and pictorial modules for each planned mHealth module. Workshops were half-day or full-day events involving the study team (including intervention and project coordinators, health promoters, and investigators) and ranged from 6 to 29 participants.

Workshops took place in parallel with other formative research activities. Hence, intervention content was initially informed by exploratory interview findings and later by the pilot studies. Exploratory and/or pilot study findings were presented during mHealth workshops to support the development of candidate mobile messages and content for pictorial modules. Following our theoretical approach, we applied findings to develop intervention content to incorporate system 1 principles, address identified barriers and facilitators across multiple levels and dimensions of influence, and to specifically target male household member engagement in the intervention. In each workshop, participants drafted candidate messages individually or in small groups. Candidate messages and other content were then presented to the larger group and refined in a collaborative process. Intervention content was continuously revised in an iterative process over the course of the six mHealth workshops.

Component 3: pilot studies of the developed intervention. We tested the developed mHealth modules over the course of three iterative phases of a pilot study. The overall objective was to refine intervention content and assess the feasibility and acceptability of implementing the Baby WASH program. The rationale for changes to the target population, intervention content, and program delivery between phases is provided in the Results. The pilot activities are summarized in Figure 1.

Pilot phase 1. In the first phase of the pilot study, we enrolled a convenience sample of 50 households that had completed the CHoBI7 mHealth RCT and currently had at least one child younger than 5 years. Thirty-four households were in an intervention arm of the CHoBI7 mHealth RCT and had previously received weekly mobile messages on handwashing with soap and water treatment for 12 months in addition to WASH-enabling technology (a handwashing station and water vessel with lid and tap) and an in-person visit for delivery of a pictorial module; 16 households were in the standard message arm and had received no prior WASH intervention.[35,37]

All pilot phase 1 households received at least bi-weekly voice and text messages for up to 3 months from the Baby WASH mHealth program.

Pilot phase 2. In the second phase of the pilot study, we enrolled a convenience sample of 20 households also drawn from the CHoBI7 mHealth RCT: 15 households were in an intervention arm and five were in the standard message arm. All households had at least one child younger than 2 years.

The 15 households previously enrolled in the CHoBI7 mHealth intervention arms received a modified Baby WASH program including two home visits during the first week of program delivery, cue cards on recommended behaviors, and biweekly delivery of voice and text messages for up to 1 month. The five households previously enrolled in the CHoBI7 mHealth standard message arm received no WASH intervention but were visited to assess behavioral outcomes (behavioral outcome results will be reported in a subsequent manuscript).

Pilot phase 3. In the third phase of the pilot study, we enrolled 32 new households that had a diarrhea patient admitted to the Dhaka International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b) hospital for treatment in the past 24 hours to mirror the original design of the CHoBI7 mHealth program.[37] The time patients and their household members spend at a health facility for treatment presents an opportunity to deliver WASH behavior change communication when perceived severity of diarrheal diseases and the perceived benefits of the promoted WASH behaviors are likely the highest.[32,51]

Twenty-four households received a further modified Baby WASH program including 1) a pictorial module delivered by a promoter in the health facility; 2) two home visits during the first week of program delivery; 3) a handwashing station and a bottle of soapy water[36] and cue cards on the recommended behaviors; and 4) biweekly voice and text messages for up to 1 month. Eight households again received no WASH intervention but were visited to assess behavioral outcomes.

Pilot study interviews and group discussions. Semi-structured interviews (n = 20) and group discussions (n = 5) were conducted with pilot study participants (caregivers of young children) to explore barriers and facilitators to performing the recommended behaviors and to obtain feedback on program content and delivery. Group discussions had between 8 and 15 participants and ranged in duration from 1.5 to 3 hours. Group discussions were facilitated by members of

Activity	Key Findings/Challenges	Intervention Revisions
Phase 1 (50 Households) ▪ Bi-weekly voice and text messages sent to households for 3 months (no home visits). ▪ Targeted households with children less than 5 years of age. ▪ Population: Households previously enrolled in CHoBI7 mHealth RCT.	➢ Some pilot participants reported that the mobile messages were not sufficient for them to understand the key behaviors promoted, and that in-person visits were needed. ➢ Child mouthing messages were less relevant for children 2 to 5 years old because the behavior decreased. ➢ CHoBI7 mHealth RCT standard message arm households had more challenges with a) opening text messages and responding to interactive voice response (IVR) quiz messages, and b) practicing the promoted handwashing with soap behaviors compared to previous intervention households. ➢ Male household members were not always sharing mHealth messages with female caregivers. ➢ Laboratory findings showed high fecal contamination on balls and plastic toys young children put in their mouth, and in rice given to young children.	✓ A pictorial module and cue cards were added for each key behavior. Modules provided in-person guidance on how to receive text messages and respond to IVR quiz questions before mobile messages were sent to households. ✓ Subsequent phases only enrolled households with a child under 2 years of age. ✓ Based on laboratory findings, cleaning child toys with detergent and water daily was added to the child mouthing module, and a section was added to the food hygiene module explaining the importance of reheating and safely storing rice given to young children. ✓ The length of text messages was reduced to less than 160 characters. ✓ Program households were sent voice calls at 5 PM.
Phase 2 (20 Households) ▪ Bi-weekly voice and text messages sent to households for 1 month and pictorial modules delivered during two home visits. ▪ Targeted households with children less than 2 years of age. ▪ Population: Households previously enrolled in CHoBI7 mHealth RCT.	➢ Male household members were not always engaged in key behaviors. ➢ Some beneficiaries were confused about how existing practices related to the promoted key behaviors presented in the pictorial module. ➢ Some households reported that they didn't use soapy water because young children played with it.	✓ Encouraged households during the recruitment process to provide the numbers of the primary caregiver in the household. ✓ Added a slide to the pictorial module encouraging sharing of mobile messages with other household members (including children). ✓ Added a slide encouraging men to be engaged in performing the key WASH behaviors. ✓ All captions under the photos in the pictorial module were removed to make the pictorial module delivery more interactive, and to not discourage those that could not read the captains. ✓ Photos that were reported to be unclear by beneficiaries were retaken and tested in subsequent pilot households.
Phase 3 (32 Households) ▪ Bi-weekly voice and text messages sent to households for 1 month ▪ Pictorial modules delivered at the health facility to diarrhea patients and attending household members and during two subsequent home visits. ▪ Handwashing station and soapy water bottle provided. ▪ Targeted households with children less than 2 years of age. ▪ Population: Households of diarrhea patients newly recruited from health facility.	➢ Participants requested a more detailed introduction on how to respond to IVR quiz messages. ➢ Pictorial modules allowed participants to more easily understand program messages.	✓ Instructions on the timing and duration of delivery of program mHealth messages were included on a slide with a photo of Dr. Chobi in the pictorial module. ✓ A recording of Dr. Chobi's IVR quiz message was played in the health facility and in the home to introduce beneficiary households to the sender of program messages and to teach them how to respond to IVR quiz messages.

FIGURE 1. Pilot activities for refinement of the Baby WASH mobile health program.

the research team and took place at the icddr,b project office. Semi-structured interviews and group discussions were conducted in Bangla. Findings from pilot study interviews and group discussions informed further modifications to the content and delivery of the Baby WASH modules for subsequent pilot phases.

Data handling and analysis. Semi-structured interviews were audio-recorded and transcribed verbatim. Exploratory interviews were followed by debriefs and a discussion of findings among the research team to help guide subsequent interviews. Group discussions were audio-recorded and detailed summaries were compiled based on field notes and audio recordings. An in-depth, manual analysis of all transcriptions and summaries followed, with organization of findings by IBM-WASH factor block and by module topic (Supplemental Tables 1–3). Organization by IBM-WASH factor block facilitated the selection of determinants to target in our intervention program.

Throughout the formative research process, emergent findings and developed tables were discussed by the study team to identify salient themes related to the program's target behaviors. Additional target behaviors were developed as findings emerged.

Ethical approval. This study was approved by the Johns Hopkins Bloomberg School of Public Health Institutional Review Board and the icddr,b ethical review committee. All study participants provided written informed consent before the initiation of study activities.

RESULTS

The results presented here are those most salient to the development and refinement of the Baby WASH mHealth program, providing insights into existing food hygiene, child feces disposal, and child mouthing practices, barriers and facilitators to promoted Baby WASH behaviors, and preferences, acceptability, and feasibility related to delivering a Baby WASH mHealth program for caregivers of young children in this context. Table 1 presents the descriptive characteristics for households in each of the pilot phases. Tables 2 and 3 present examples of intervention content informed by formative research findings and our theoretical approach for each mHealth module.

Module 1: Food Hygiene. *Existing food hygiene practices.* Mothers of young children were typically the ones responsible

TABLE 1
Pilot participant and household characteristics at enrollment

	Phase 1 (% or *N*)	Phase 2 (% or *N*)	Phase 3 (% or *N*)
Number of households enrolled	50	20	32
Number of participants enrolled	141	55	116
Number of children younger than 5 years in the household	58	24	37
Number of children younger than 2 years in the household	47	23	32
Mean age of caregiver (years), Mean ± SD (min–max)	27 ± 6.6 (18–46)	27 ± 8.1 (18–51)	26 ± 6.2 (18–44)
Caregiver gender			
Female	98	95	100
Percentage of caregivers who can read or write	86	95	81
Percentage of households where at least one member can read and write	96	100	97
Household roof type			
Tin	68	35	72
Concrete	30	65	28
Other	2	0	0
Household floor type			
Mud	6	0	3
Concrete	90	100	97
Half concrete	0	0	0
Other	4	0	0
Household refrigerator ownership	52	65	31
Household latrine type			
Improved	96	70	100
Unimproved	4	30	0
Number of households sharing latrine*, Mean ± SD (min–max)	7.5 ± 5.3 (1–15)	4.9 ± 3.4 (2–14)	5.5 ± 3.1 (1–14)

* Mean/SD value based on those households who shared the latrine.

for food preparation in the home. However, this responsibility was delegated to the child's grandmother if the mother was busy with work outside of the home or household tasks.

Food preparation (e.g., cutting vegetables before cooking) was generally performed in the household's individual living space (typically a single room), followed by cooking in a communal kitchen. Vegetables and fruits eaten raw were soaked before use out of concern for formalin, which is commonly used as a preservative in Bangladesh; soaked items were then considered "safe" for consumption.

Caregivers reported preparing food for children one to three times per day, and two times a day for adults. Caregivers also prepared different types of food for younger children, such as *khichuri* (soft rice, vegetables, and lentils), eggs, cereal, or noodles, noting that young children could not tolerate foods eaten by older children or adults:

> *I do it because the food taken by us, like rice, meat, vegetable—all are spicy, and he cannot take these foods. As beef is fibrous, he cannot take it. How can he eat beef with only four teeth?*

Food prepared earlier in the day may be eaten throughout the day, or only for a single meal; households varied in this practice, often depending on access to stoves for cooking. Food prepared the previous night was often eaten the next morning. This food, referred to as "basi khabar," was usually reheated before eating if it had not become rotten overnight. Rotten food, referred to as "noshto khabar," was assessed to be rotten by sight or smell and then thrown away. Sometimes *basi khabar* was given to young children, but all households said that *noshto khabar* was not eaten. Some participants mentioned that they also throw away *basi khabar*, as it may cause an upset stomach. Relatives encouraged caregivers to cook food daily and feed the child in the home fresh food.

Cooked food was often covered with a metal or plastic lid, referred to as a "dhakna," immediately, or as soon as steam had settled; plastic lids, called "fly covers," had small holes for ventilation. Households primarily used a food rack ("khanaduli" or "meat safe") to store food to protect it from pests and animals, and to prevent children from playing with food (Figure 2):

> *I keep food in the food rack where ants can enter, but flies, mosquitoes, and cockroaches cannot.*

Some caregivers, however, did not completely cover food that was in the food rack.

Most households reported owning a refrigerator, but preferred not to keep cooked food in the refrigerator because it changed the taste of the food. Instead, fresh fruits and vegetables, raw fish and meat, and sometimes medicines were kept in the refrigerator. One participant who did keep cooked food in the refrigerator mentioned covering food to prevent "smells (being) transferred from one food to another food."

Participants varied in their practice of reheating food cooked earlier in the day or the night prior, often depending on whether or not they had access to a stove. Food might be reheated for guests or male household members because of preference and expectation, even if it was not reheated for children or other household members. Some households did not reheat refrigerated food before eating to save time and gas, instead allowing food to warm at room temperature. In cold weather, some participants mentioned that food can stay safe for a longer time without reheating, and food cooked in the morning could be taken at lunch without reheating. Other participants said that their food storage practice did not change seasonally.

Children were primarily placed on the bed or floor to eat, but caregivers mentioned that sometimes food fell on the ground and children then picked it up to eat it:

> *Many times, we see if we give children a tasty food and it drops on the ground, they put that dropped food in their mouth.*

TABLE 2

Example intervention content and target behaviors informed by formative research findings and IBM-WASH factor block

Formative Research Finding	IBM-WASH Factor Block	Intervention Content	Behavior Change System/ Driver	Target Behavior
Module 1: Safe Food Hygiene				
Hot and cold seasons may affect food storage and reheating habits. Perception that during cold weather leftover food can stay safe for longer times.	Contextual Dimension Structural Level Psychosocial Dimension Individual Level	Developed mobile messages to be delivered during winter months explaining that even though it was cold outside, food should still be reheated before eating to ensure that it was safe to eat.	System 1: Leveraging context changes	Reheat all leftover food thoroughly fed to young children.
Existing handwashing habits	Psychosocial Dimension Habitual Level	Included IVR messages where participants were rewarded with praise for reporting repeated handwashing before food preparation. Pilot Phase 3: Provided a handwashing station.	System 1: Supporting context stable repetition System 2: Reminders/Cues to action	Wash hands with soap or soapy water before food preparation.
Module 2: Safe Child Mouthing				
Young child during the first two years of life exhibit frequent exploratory play behavior as they learn about their environment.	Contextual Dimension Individual Level	Recommended that participants add children's toys to household laundry or dish washing.	System 1: Piggybacking on existing behaviors; Embedding ritualized elements	Clean toys with detergent or soap daily.
Low-cost toys for young children readily available for purchase in the market.	Technology Dimension Community Level	Requested households to purchase affordable, easy to clean toys.	System 2: Affordability	
Aspirations to have a clean play space for young children.	Psychosocial Dimension Household/Interpersonal Level	Asked households to sweep play spaces daily and use a designated dustbin for trash kept in the home.	System 2: Aspirations	Dispose of trash in a waste bin.
Young children often play with dirty objects such as sand, pieces of bricks, discarded, wrappers, match sticks, mobile phones, and sometimes feces.	Psychosocial Dimension Habitual Level	Emphasized that even objects such as toys, television remotes, mobile phones, and money could carry germs that could cause diarrhea in young children.	System 2: Knowledge	Watch young children closely when they are on the ground and stop them if they try to put 'dirty' things in their mouth, such as soil, dirt or wrappers.
Module 3: Safe Disposal of Child Feces				
Shared latrine facilities may limit access. Neighborhood open garbage piles are easy to access disposal sites for diapers.	Contextual Dimension Community Level	Developed mobile messages telling participants that the majority of their neighbors were disposing of child feces in a safe location.	System 1: Highlighting descriptive and localized norms	Dispose of child feces in the latrine
Perception that neighbors throw child feces, including diapers, in open spaces.	Psychosocial Dimension Household/Interpersonal Level		System 2: Descriptive norms; attitudes	Dispose of diapers and soiled clothes in a waste bin
Children may handle and spread their feces around the household.	Contextual Dimension Individual Level	Emphasized the importance of cleaning child feces immediately after a defecation event, noting that child feces were just as dangerous as adult feces. Given that not all households had access to a child potty, we recommended that older children be taught to defecate on a *raxine* designated for that purpose.	System 2: Disgust	Clean the child first after a defecation event, and then clean the site of defecation.
Concerns around neighbors seeing their child's feces on the bed or the floor of their home.	Psychosocial Dimension Individual Level		System 2: Convenience	Place young children on a raxine to defecate; teach older children to defecate on a raxine if a child potty is not available. Place young children on a raxine to defecate; teach older children to defecate on a raxine if a child potty is not available.
Raxines (plastic sheets) are low-cost, common in households, and readily available for purchase in the community. Child potties may also be available.	Technology Dimension Community Level			

TABLE 3
Example behavior change techniques and mobile messages informed by system 1 principles/tactics of behavior change

System 1 principle	System 1 principle/tactics definition	Intervention component/technique	Example mobile messages
Managing physical availability	Ensure critical products and infrastructure are immediately and consistently physically available.	Provided instructions on market availability of water, sanitation, and hygiene behavior–related hardware.	Flies can carry diseases. Keep flies off your food by using a food cover over cooked food. You can purchase a cover ("dhakna" in Bangla) at any bazar for 15–50 taka.
Leveraging context changes	Create or capitalize on context change to drive new behavior.	Included specific recommendations for changes in season and life stage changes for young children.	Look at how your child is growing! So beautiful are our little ones as they learn to walk. Now when they defecate they spread feces everywhere. It is a big mess! Do you think cleaning your child first after defecation will reduce this mess? If you think "yes" press 1 and if "no" then press 2.
Piggybacking on existing behaviors	Piggyback on other existing established behaviors in a community.	Added the behavior of cleaning child toys and other objects with existing washing/cleaning behaviors.	At the same time you wash your clothes each day, clean the toys and objects your child normally plays with using detergent powder and water. Dirt on these objects can make your child sick with diarrhea. Keep your child health and happy!
Managing friction to performing behaviors	Strategically increase friction for the undesired behaviors and lessen it for desired ones.	Highlighted the ease and convenience of recommended behaviors.	It may seem hard at first to always wash your hands with soap. However, handwashing with soap can be easy. A soapy water bottle is easy to make. Just add six capfuls of detergent to a half-liter plastic bottle and then add water. Now your soapy water is ready!
Supporting context stable repetition	Reward repeated use at the same place and time.	Rewarded repetition of recommended behaviors.	Have you disposed of your child's feces in the toilet today? Press "1" if yes or press "2" if no. Pressed 1: "Great Job! Always dispose of your child's feces in the toilet, and wash your hands after with soapy water. Keep your family healthy!" Pressed 2: "Keep trying! Always dispose of your child's feces in the toilet, and wash your hands after with soapy water. Keep your family healthy!"
Embedding ritualized elements	Inclusion of ritualized elements in the new behavior to promote adoption.	Integrated promoted behaviors into ritualized cultural practices.	When we dispose of our child's feces here and there, this brings dirtiness to where we live and can contaminate our water. We are required to always keep ourselves and our homes clean as it is said "cleanliness is the part of holiness." Share the message!
Leveraging point of action reminders and cues	Reminding people of the promoted behavior periodically, especially when they are in the appropriate context.	Created and called attention to salient cues at sites to remind individuals of the new meaning of the space.	When you look at your courtyard, what do you see? You see a special place where your child plays, not a toilet. If your child defecates in the courtyard, use a scooper to remove the feces, dispose of the feces in a latrine, and wash your hands and your child's hands with soapy water. Keep your courtyard a fun and safe space for your child to play.
Highlighting descriptive and localized norms	Highlight descriptive and localized norms that reduce cognitive demands.	Conveyed information on existing practices in the community based on responses from households enrolled in the study.	80% of caregivers in your neighborhood reported stopping their child when they put dirty objects in their mouth when they were playing. Like others in your neighborhood, protect your child from diarrhea by always watching your child when they play outside and stopping them from putting dirty objects in their mouth.

FIGURE 2. Food rack for storage. This figure appears in color at www.ajtmh.org.

Some mothers placed their child on a "gamcha" (a multipurpose cloth) or "raxine" (plastic sheet) to eat on. However, children ages 2–5 years were generally not supervised while eating.

Barriers and facilitators to performing safe food hygiene behaviors. In our discussions with caregivers, we identified availability of gas for cooking, low self-efficacy to safely prepare and store food because of a busy work schedule or household tasks, perceived change in taste or smell if food is stored in the refrigerator, and cold weather being viewed as a time when food did not need to be reheated to be barriers of safe food hygiene behaviors. On the other hand, facilitators to performing safe food hygiene behaviors included perceived risk of diarrhea from eating leftover food, perceived risk of exposure to formalin from not washing fruit, and understanding that reheating food will make it safe to eat and that covering food will protect it from dirt, insects, and rodents.

Intervention content to promote safe food hygiene behaviors. Based on exploratory and pilot study findings, the existing literature on food hygiene recommendations,[52,53] and a fecal exposure analysis (results reported separately), we identified five target behaviors for the food hygiene module: 1) handwashing with soap or soapy water (detergent powder mixed with water as a low-cost alternative to bar soap) before food preparation, 2) completely covering stored food, 3) reheating thoroughly all leftover food fed to children, 4) washing food eaten raw with running water, and 5) placing children on a mat when eating.

Given that soaking fruits and vegetables was already a common practice, we emphasized the importance of using running water to fully remove dirt before soaking. We included mobile messages stressing that a food rack alone was not sufficient for safe food storage and that food always needed to be completely covered. Based on the finding that food given to young children was often prepared separately, we emphasized the need to store food given to young children in a refrigerator (if available) within 2 hours and to always reheat food for children to a boil (foods with a liquid consistency). Information explaining the importance of safely storing and reheating rice given to young children was also added based on the high fecal contamination found in rice during the fecal exposure pathway analysis. For storing food in a refrigerator, we encouraged households to keep food covered tightly to ensure it kept its taste.

Following system 1 tactics, we included IVR messages where participants were rewarded with praise for reporting repeated handwashing before food preparation (principle 5). We also developed mobile messages to be delivered during winter months explaining that even though it was cold outside, food should still be reheated before eating to ensure that it was safe to eat (principle 2).

Module 2: Child Mouthing. *Existing child mouthing practices.* All caregivers mentioned that young children played during the day and never "stayed put." Children played both inside and outside of the house, with some children playing on the street. As one participant said:

> *My child mostly plays in the road. Since there is no playground anywhere in Dhaka City they play on the roadside.*

However, caregivers primarily preferred children play inside the household with toys rather than be outside getting dirty. Participants reported that children liked to play with sand, mud, pieces of brick, utensils, toys, and an array of other objectives, including wrappers, match sticks, mobile phones, plastic bottles, television remotes, cigarette butts, discarded fruit, and leaves. We were also told stories of children brushing their teeth with sand, putting detergent powder in their mouth thinking it was sugar, mouthing human and animal feces, or licking the walls in their home. Children were stated to put everything in their mouth that they came close to because they did not understand what could be harmful for them:

> *Children are small, they do not understand what things can make their stomach upset and what things they should not eat. We, the guardians, forbid them, but they do not understand. . . They can put anything into their mouth, if they wish they can put even put snakes and scorpions into their mouth.*

> *They [children] play the whole day. They put whatever dirt they get from anywhere in their mouth, as they do not consider this dirt.*

Most caregivers did not like when their children put dirty things into their mouth because they thought dirt could cause stomach aches and diarrhea. Caregivers did assert that it was normal for children to put some items, such as toys, television remotes, mobile phones, and money in their mouth, but that it was not good for them to put feces and bricks into their mouth.

A few caregivers, mostly elder caregivers, thought eating soil was not a problem for child health:

> *Mothers-in-laws believe that children will eat the soil amount for which they are made up of by Allah [God]. . . usually children will grow up by eating soil and dirt. . . usually all children in the village eat soil and dirt. . . Senior people say, "Don't worry, they will definitely be fine growing up eating soil."*

During play activities, children were often with other children in the neighborhood, or older siblings or adult caregivers were with them. Caregivers reported that it was difficult to supervise young children all the time because of lack of support and busyness with household tasks.

Caregivers stated it was important to build awareness around child mouthing behavior and that it was very important to supervise children closely when they played, to wash their hands if they get dirty, and to keep the household, child play spaces, and toys clean.

Barriers and facilitators to performing safe child mouthing behaviors. The perception that all children in their neighborhood put dirty things in their mouth, the lack of support for child supervision and access to clean play spaces, and elders asserting that eating soil was not a problem for child health were considered barriers to performing safe child mouthing practices. However, high perceived risk of illness from mouthing dirty things was a facilitator for safe child mouthing behavior.

Intervention content to promote safe child mouthing behaviors. We identified three target behaviors for the safe child mouthing module: 1) cleaning toys with detergent or soap and play spaces daily, 2) disposing of trash in a waste bin, and 3) watching young children closely when they are on the ground and stopping them if they try to put "dirty" things in their mouth, such as soil, dirt, or wrappers.

We developed mobile messages that emphasized that even objects such as toys, television remotes, mobile phones, and money could carry germs that could cause diarrhea in young children. Given the finding that children often mouthed household trash (e.g., discarded wrappers) if discarded outside on the ground, we asked households to sweep play spaces daily and use a designated dustbin for trash kept in the home.

In terms of system 1 tactics, we recommended that participants add children's toys to household laundry or dishwashing (principles 3 and 6). This recommendation was also based on the fecal exposure pathway analysis, which showed high fecal contamination on balls and plastic toys children put in their mouth.

Module 3: Child Feces Disposal. *Existing child feces disposal practices.* We asked participants to describe defecation practices of their children over multiple ages. Caregivers had learned cues children gave before defecating. Infants were said to defecate on bed covers, rags, or on a raxine; these items were sometimes kept uncovered in a bowl overnight to be washed at a later time. Caregivers were often busy with household tasks during a child defecation event and did not have time to dispose of child feces right away. Some caregivers also used disposable diapers for infants; it was said that households sometimes threw these diapers in an open place (e.g., ditch) and that children had been observed playing with them. Older children (primarily once ambulatory) used a children's potty or household latrine to defecate. Potties were not always cleaned immediately after defecation events, with participants again citing busyness with household chores. Cleaning practices of used potties varied, with some cleaning potties with only water and others using detergent powder or liquid soap. Some caregivers mentioned that if potties were washed with water alone, germs could still be present.

Some caregivers reported cleaning a child's feces/the place of defecation first, and cleaning the child second. One reason given for this order was the feeling that it would be "disgusting" if someone came and saw feces in the home. However, one caregiver mentioned that the order of cleaning might change depending on the state of the child:

> *If the child cries after defecation, then I clean the child first, if the child remains playful, then I clean the place of defecation first.*

Other caregivers said they cleaned the child first, with one mentioning that if she did not clean the child first, then they would "make all these (things/places) dirty."

Feces in potties were primarily disposed of in the household latrine. When feces were deposited elsewhere, caregivers used old clothes to remove the feces, and then put it in a plastic bag, dustbin, drain, ditch, or neighborhood garbage pile.

Some caregivers said it was "disgusting" when a child defecated around the household, and that their feces could be spread by feet. Others mentioned that if a child defecated around the household, flies could sit on the feces and spread diarrhea.

We asked participants about different seasonal practices, and were told that in the rainy season it was difficult to dispose of child feces in the latrine because latrines were often far away and the rain outside was heavy. During this time, some caregivers would throw their child's feces outside their room on the ground or kept their child's potty with feces in the room until the rain stopped.

We also explored perceived differences between child and adult feces, with most caregivers saying there was no difference—both were considered dangerous for child health. However, a few caregivers thought adult feces were more dangerous than child feces. As one participant said:

> *Child feces are different as they have no foul smell. Adult feces have a fouler smell, thus they are dangerous.*

Barriers and facilitators to performing safe child feces disposal behaviors. Low perceived self-efficacy to clean child feces right away because of other household tasks and the far distance of latrines, particularly during the rainy season, were notable barriers to safe child feces disposal. High perceived risk of diarrhea from not disposing of child feces in a latrine, disgust around feces being present in the home, concerns that neighbors might see undisposed child feces, and the availability of child potties were identified as facilitators of safe child feces disposal behaviors.

Intervention content to promote safe child feces disposal behaviors. We included six target behaviors in the safe child feces disposal module: 1) disposal of child feces in the latrine; 2) disposal of diapers and soiled clothes in a waste bin; 3) cleaning the child first after a defecation event, and then

cleaning the site of defecation; 4) cleaning child potties right after defecation events; 5) handwashing with soap or soapy water after a defecation event; and 6) defecating on a raxine if no child potty was available or if children were too young to sit on a potty.

Based on the exploratory research findings, we recommended that caregivers clean their child first and the area of defecation second to prevent a child from crawling around and spreading their feces, or playing with it. Mobile messages also emphasized the importance of cleaning child feces immediately after a defecation event, noting that child feces were just as dangerous as adult feces. Given that not all households had access to a child potty, we recommended that older children be taught to defecate on a raxine designated for that purpose.

In terms of system 1 tactics, we sent messages to households' mobile phones telling them that most of their neighbors were disposing of child feces in a safe location (principle 8). We also reminded participants that the area surrounding their homes should be seen as the child's play space, not the child's potty, in an effort to encourage immediate removal of child feces from these spaces (principle 7).

Involvement of male household members in Baby WASH behaviors. We explored opportunities for male household members to participate in Baby WASH behaviors and other household activities to support mothers and other female caregivers. Men were not usually involved in food preparation. Participants mentioned that many husbands in their neighboring households did not help their wives to prepare food and had even stopped their older children from helping. Female participants mentioned the need for men to help with household tasks, and suggested that men could help by bringing water jugs, onions, chili, and plates needed for food preparation, or watching children while food was being prepared. Participants had several suggestions for more balance in household responsibilities around food preparation:

> *Every father needs to come forward to keep their child safe. You should not be dependent only on one person. The person who does all household chores, also has to take care of the child, that will not work. . .. He (the husband) must have something to offer for her (his wife). Men can help in many ways.*

> *Suppose you (the husband) came home and she (the wife) was working on something. Small tasks where (she) needs assistance, you (the husband) can assist her with tasks such as cutting vegetables. . . taking care of the child. You (the husband) can have a walk with your baby [while] your wife is doing other work for you. That helps a lot.*

Male participation was absent in narratives about feces disposal practices. Participants suggested that men could provide additional assistance by supervising young children and helping to complete household tasks, which might alleviate some of the busyness that made watching children closely during play, or cleaning up child feces immediately after a defecation event, difficult. We asked men to help supervise children during play, reminding them to discourage children from putting dirty things into their mouth. Finally, we recommended that men assist with child feces disposal, highlighting that this was a job for both parents.

Acceptability and feasibility of the Baby WASH mHealth program. *Feedback from program beneficiaries.* Across the pilot studies, voice and text messages were well-received by participants. Pilot participants said that mobile messages were clear and easy to remember, and that the content had made them more aware of, and motivated to practice, recommended WASH behaviors. Many caregivers also mentioned that their family members were encouraging them to practice the recommended behaviors. Participants reported changes in their existing behaviors as a result of the intervention:

> *Before receiving the [program] messages, I used to use soap pasted on the wall and this is also used by many families. Now we use soapy water. My neighbor wanted to know how to make a soapy water bottle; I helped him to make a soapy water bottle.*

Some pilot participants preferred both voice and text messages, whereas others preferred either/or. When voice messages were preferred, it was because the call came directly and was easy to understand, even by those that could not read. A challenge, however, with voice calls was that sometimes calls came at a time when the person in the household was busy, or was difficult to understand in a noisy place. Text messages were viewed as better by some because they could be shared easily with others and could be saved to be read at a later time:

> *Both voice calls and text messages are good, sometimes when I am busy at work I cannot receive the call, in this case a text message is better as I can read it later.*

A challenge with text messages, on the other hand, was that some phones did not support Bangla script. In this case, Bangla phonetic using English characters was sent; however, this was not always easily understood. In addition, if text messages were longer than 160 characters, they were split into separate text messages that sometimes came in the wrong sequence. Based on this feedback, during phase 1 of the pilot study, the length of text messages was reduced to less than 160 characters, and language was further simplified.

Participants were mostly enthusiastic about IVR quiz calls:

> *I like the quiz because I can know whether I was able to give the answer correctly.*

However, it was difficult for some to respond to quiz calls because they did not know how to press the buttons to answer. Additional challenges identified with the messages included not receiving messages due to a full inbox, changing sim cards frequently, and children deleting text messages while playing games.

One additional challenge is that female household members reported lower phone ownership than male household members, and some said that mobile messages received by men on their phones were not always shared with female household members. As one participant said:

My husband receives messages, but I do not know.

By contrast, participants also reported sharing mobile messages with household members and neighbors. One male participant also mentioned asking for help from others to read mobile messages:

I get text messages but I cannot read them as I am not very educated, so my wife helps me to read the text messages. When Dr. Chobi Apa calls me, I share this information with my family.

To limit some of the challenges reported, participants recommended that mobile messages be sent to both husbands and wives. However, some female participants did not want to share their contact number during recruitment because of concerns that their husbands may be suspicious of whom they were talking to on the phone. We asked households to provide the numbers of the primary caregiver, when available, and encouraged message sharing among household members. Most participants wanted to receive mobile messages between 4 PM and 8 PM and on Fridays (a day off in Bangladesh). They preferred this time because this was when most household members, including men, were available in the home. Following this, we sent our messages at 5 PM on Fridays.

In phase 1 of the pilot study, participants who had previously been enrolled in the standard message arm of the CHoBI7 trial and therefore had no mHealth intervention experience, struggled with the technical side of the intervention, reporting more difficulty opening text messages and responding to IVR quiz messages. As a result, we included a phone tutorial in the subsequent pilot phases, including an introduction of Dr. Chobi Apa's voice and character.

The character of Dr. Chobi Apa was viewed as a credible source of health information because she was a physician speaking from a hospital. However, one caregiver mentioned that she did not consider health information coming to her phone to be of high importance, as she received many calls and messages from different places. Other participants said they wanted to meet Dr. Chobi in person:

Definitely we like and believe Dr. Chobi Apa, but if we can see her then we would have more satisfaction, she gives us advice, makes us aware of how to better our life.

Some participants reported difficulty understanding the mobile messages. Several phase 1 pilot participants recommended we visit homes to explain the behaviors before sending mobile messages:

Before sending [mobile] messages you have to make them understand.

It is not sufficient to tell them over phone, they should be taught in-person.

Participants preferred home visits on the weekends between 3 PM and 5 PM. Participants also recommended showing pictures in addition to mobile messages. Based on this feedback, we added pictorial modules and cue cards, delivered during home visits, to households in pilot phases 2 and 3.

The developed pictorial modules and cue cards were also well-received. Participants reported that the pictorial modules helped them to understand the key behaviors promoted, especially when the behaviors were new:

When you speak (send a voice message) we listen, but showing us the photos makes us do the work exactly as it is shown in the photo.

I liked the book (pictorial module) because it made us understand by showing pictures and discussing how germs can spread, how one can get diarrhea, risky period for diarrhea... all these [things] matter, then discussing how to get rid of diarrhea, when to wash hands with soap, covering of food, having child sit on a mat...

Cue cards were considered good reminders to perform the promoted behaviors, and a way to share intervention content:

The [cue] cards are hanging on my wall; I see them the whole day. Always when I look around I see them..... [these cue cards] allow me to be more careful and check to make sure what I am doing is okay.

We... can learn from looking at the photos of the cue cards... other people who come to visit or guests can also learn.

However, one caregiver mentioned that no photos of any type can be kept in the same room where prayer is performed, and she kept the pictures facing the wall as a result.

We made several modifications to the pictorial module based on pilot participant feedback. We changed the order of the pictorial modules to start first by showing the current practices observed in many households and following this by explaining the promoted key behaviors. We also added specific content encouraging men to practice Baby WASH behaviors. Finally, all captions under the photos in the pictorial module were ultimately removed to make delivery more interactive, and to not discourage those that could not read the captions.

In pilot phase 3, we provided households a handwashing station and a soapy water bottle. After observing in pilot phases 1 and 2 that households not previously enrolled in a CHoBI7 mHealth RCT intervention arm had difficulty following handwashing with soap recommendations because of the absence of enabling technology, we decided to provide pilot phase 3 households with these materials.

Feedback from government stakeholders. Government stakeholders were very receptive to the use of mobile phone messages to deliver the Baby WASH program and expressed an interest in incorporating this program in their National Operational Plan. They mentioned that mobile messages could be delivered using the government platform and that this would reduce the cost of message delivery. Government stakeholders stated that the government does not currently have a program solely focused on diarrhea management, but one stakeholder suggested adding such a program:

[We] do not have a program for direct management of diarrhea patients; however, we want to prevent diarrhea by advocacy communication, social mobilization, and early detection of patients.

Government stakeholders also recommended both voice and text messages be sent to households, mentioning that they currently deliver both for their ongoing government programs and emphasizing the importance of voice calls for nonliterate individuals.

DISCUSSION

The formative research conducted was a theory-driven and evidence-based approach to developing a Baby WASH mHealth program targeting food hygiene, child mouthing, and child feces disposal behaviors in urban Dhaka, Bangladesh. This is the first study, to our knowledge, to conduct formative research and intervention development for a Baby WASH mHealth program. We explored current practices and barriers and facilitators related to Baby WASH behaviors and developed mobile messages and other intervention content based on our findings, guided by behavior change theories that acknowledge multilevel, multidimensional factors that influence behavior change and habit formation.[43,45] We then tested our developed intervention in an iterative pilot study, and modified the intervention content and delivery based on beneficiary preferences and acceptability and feasibility of the Baby WASH mHealth program.

We added a pictorial module to the mobile component of the intervention based on beneficiary feedback, which was well-received. Based on reported difficulty understanding mobile messages and accessing and responding to IVR quiz messages, we added an in-person tutorial on mobile phone use. We also observed that female beneficiaries had lower rates of phone ownership than male beneficiaries, and did not always receive program messages. This finding is consistent with that of previous reports, which found that 82% of male adults are mobile phone owners compared with only 55% of adult females in Bangladesh.[54] Therefore, our behavioral recommendations, if delivered solely through mobile messages, may not have reached all female household members. Delivery of the pictorial modules in-person helped us ensure that program content was accessible to more program beneficiaries. Our findings highlight the importance of considering intervention approaches that ensure equity in access to intervention content to household members.

Few WASH studies focused on young children have explored caregiver perceptions around child mouthing behaviors.[56] Most exploratory work has focused on child feces disposal and food hygiene.[3,11,19] Our child mouthing findings show that caregivers are aware of what children are mouthing and recognize risks of mouthing certain objects. In a separate study, we showed that child mouthing of soil and contaminated fomites in Bangladesh was frequent and associated with EE and impaired growth, and that soil collected from child play spaces contained pathogenic *E. coli*.[17,61] These findings are consistent with those of a previous study in rural Zimbabwe.[62] In this present research, some participants considered mouthing soil important for encouraging child growth. Future studies might develop easy to clean, affordable toys to facilitate safe mouthing behavior in this setting.

Our formative research took guidance from both IBM-WASH and basic habit science and "nudging theory" as outlined by Neal et al.[45] and their tactics to target system 1 drivers of behavior change and habit formation.[43] Although IBM-WASH has been applied to the development of WASH interventions in several contexts,[22,23,36,43,46,47] explicit incorporation of system 1 tactics is relatively rare.[63,64] System 1 tactics are particularly relevant to WASH behavior change programs.[45] One study in rural Bangladesh observed that physical availability of soap and water at designated handwashing places increased handwashing practices with soap behaviors (principle 1).[63] Another study conducted in Bangladesh among primary school students used nudges to encourage handwashing with soap after using the toilet.[64] Because our intervention incorporated multiple behavior change techniques, we were unable to disentangle the relative effect of system 1 tactics compared with other techniques. Future studies could compare the relative effects of system 1 versus system 2 tactics for WASH behavior change and habit formation.

This study has several strengths. First, the 18-month duration of the formative research gave us a detailed understanding of the facilitators and barriers to the promoted WASH behaviors, and allowed us to modify the intervention to address these findings. Second, we tried multiple approaches to program delivery. Exploring mobile-only and mobile plus in-person delivery of intervention content helped to identify which modalities were best for program delivery. Third, we made efforts in both program design and implementation to incorporate multiple caregivers of young children, both men and women, to promote balance among household members for performing the promoted behaviors.

This study had some limitations. We focused our formative research on two specific populations: previous CHoBI7 mHealth RCT households and recent diarrhea patient households. Therefore, these findings may not be generalizable to other populations. Given the type of intervention, we also focused only on households that reported mobile phone ownership, so this intervention is not designed for households that share their phone with another household. Finally, this intervention focused on behavior change at the household and individual levels, as well as habit formation. However, we identified several behavioral determinants at the community level, such as availability of playgrounds and sharing access to stoves for cooking, that were outside the scope of our mHealth program but should be targeted through future neighborhood or city-wide programs.

There are several applicable recommendations for future WASH or Baby WASH mHealth programs to be taken away from this study:

1. Introduction of new and unfamiliar behaviors may be difficult to communicate through mobile messages alone. An in-person visit and pictorial materials (e.g., cue cards) or demonstrations may be required. Adapting pictorial materials, such as a flip-book or cue cards, for mHealth delivery may be possible in a setting where smart phone ownership is high.
2. Households are likely to have variable access to WASH-enabling technology and infrastructure that would facilitate Baby WASH behavioral recommendations (e.g., access to a refrigerator or child potty, and uninterrupted access to stoves). When enabling technology is not provided by an intervention, alternative behavioral recommendations may

need to be developed depending on what households have. Mobile health programs might consider sending mobile messages that are tailored specifically to household infrastructure and available technology.

3. Better balance in targeting men and women in WASH behavior change programs for child health is needed.[48,50] We identified two barriers to more equitable delivery of WASH mHealth programs to both men and women. First, men may be the primary owner of mobile phones and not always share the mobile message content with female household members. In addition, female household members may not feel comfortable sharing their mobile number (when they have one) because of concerns that their husbands may be suspicious of whom they were talking to on the phone. Mobile health programs should enroll all household member with phones to receive mobile intervention content to maximize chances of reaching women in the household. Mobile message content should also be sent at a time when all household members are likely to be at home (e.g., the evening) to facilitate message sharing. Second, men were largely absent from female caregivers' narratives on existing Baby WASH practices, often because they are away from the home during the day. Baby WASH programs should identify behavioral recommendations specifically for men that they are able to practice when at the home (e.g., help with evening food preparation and child care).
4. Finally, mobile literacy may vary substantially in a target population. We recommend that future mHealth programs assess mobile literacy in their target audience and design mobile tutorials accordingly—this may require an in-person tutorial, as was the case in this setting.

CONCLUSION

Young children have unique exposure routes to fecal pathogens in the home environment, and Baby WASH interventions need to be developed and tested to limit exposure for susceptible pediatric populations. We conducted a theory-driven and evidence-based approach to developing a Baby WASH mHealth program to target food hygiene, child mouthing, and child feces disposal behaviors in urban Dhaka, Bangladesh. Future studies are needed to determine the feasibility of scaling this program and to assess its effectiveness. This research provided several recommendations for future WASH mHealth programs, and provides a model for formative research for mHealth programs that could be adapted and applied in similar settings.

Received May 11, 2020. Accepted for publication August 17, 2020.

Published online October 5, 2020.

Note: Supplemental tables appear at www.ajtmh.org.

Acknowledgments: We thank the study participants and the following individuals for their support with the implementation of this study: Abul Khair Mohammad Shamsuzzaman, Be-Nazir Ahmed, Jahed Masud, Ismat Minhaj Uddin, Rafiqul Islam, S. M. Maynul Hasan, Arifur Rahman, Abdullah Al Morshed, Zakir Hossain, Kabir Hossain, Amal Sarker, Abul Bashar Sikder, Abdul Matin, Sadia Afrin Ananya, Lubna Tani, Farhana Ahmed, Tahera Taznen, Marufa Akter, Akhi Sultana, Nasrin Akter, Laki Das, Abdul Karim, Shirin Akter, Khan Ali Afsar, Wasim Ahmed Asif, and Ronald Saxton. We also thank the hospital staff for their support. icddr,b acknowledges the governments of Bangladesh, Canada, Sweden, and United Kingdom, for providing core/unrestricted support.

Financial support: This study received financial support from the U.S. Agency for International Development.

Disclosure: The funder did not have a role in the design, implementation, or evaluation of the study.

Authors' addresses: Shwapon Kumar Biswas, Center for Communicable Diseases, International Centre for Diarrheal Disease Research, Bangladesh (icddr,b), Dhaka, Bangladesh, and Department of Medicine, Rangpur Medical College Hospital, Rangpur, Bangladesh, E-mail: shwapon6@gmail.com. Elizabeth D. Thomas and Christine Marie George, Department of International Health, Johns Hopkins University Bloomberg School of Public Health, Baltimore, MD, E-mails: liz.thomas@jhu.edu and cgeorg19@jhu.edu. Jahed Masud, Tasdik Hasan, Md. Ismat Minhaj, Fatema Johura, and Marzia Sultana, Department of Infectious Diseases, International Centre for Diarrheal Disease Research, Bangladesh, Dhaka, Bangladesh, E-mails: jahed@icddrb.org, tasdikhdip@yahoo.com, ismat.minhaj@icddrb.org, mfjohura@icddrb.org, and msultana@icddrb.org. Fatema Zohura and Md. Sazzadul Islam Bhuyian, CDC, International Centre for Diarrheal Disease Research, Bangladesh, Dhaka, Bangladesh, E-mails: fzohura@icddrb.org and sazzadul.islam@icddrb.org. Tahmina Parvin, Centre for Nutrition and Food Security (CNFS), International Centre for Diarrheal Disease Research, Bangladesh (icddr,b), Dhaka, Bangladesh, E-mail: tparvin@icddrb.org. Sanya Tahmina, Department of Communicable Diseases, Government of Bangladesh Ministry of Health and Family Welfare, Dhaka, Bangladesh, E-mail: sanya.tahmina@gmail.com. Shirajum Monira, Department of International Health, International Centre for Diarrheal Disease Research, Dhaka, Bangladesh, E-mail: smonira@icddrb.org. Munirul Alam, IDD, International Centre for Diarrheal Disease Research, Dhaka, Bangladesh, E-mail: munirul@icddrb.org.

REFERENCES

1. GBD Diarrhoeal Diseases Collaborators, 2017. Estimates of global, regional, and national morbidity, mortality, and aetiologies of diarrhoeal diseases: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet Infect Dis 17:* 909–948.
2. Victora CG, de Onis M, Hallal PC, Blossner M, Shrimpton R, 2010. Worldwide timing of growth faltering: revisiting implications for interventions. *Pediatrics 125:* e473–e480.
3. Wodnik BK, Freeman MC, Ellis AS, Ogutu EA, Girard AW, Caruso BA, 2018. Development and application of novel caregiver hygiene behavior measures relating to food preparation, handwashing, and play environments in rural Kenya. *Int J Environ Res Public Health 15:* 1994.
4. Esrey SA, 1996. Water, waste, and well-being: a multicountry study. *Am J Epidemiol 143:* 608–623.
5. Saha D, 2013. *Acute Diarrhoea in Children in Rural Gambia: Knowledge, Attitude and Practice, Aetiology, Risk Factors and Consequences Among Children Less than Five Years of Age*. Doctor of Philosophy Thesis, University of Otago.
6. George CM, Perin J, Neiswender de Calani KJ, Norman WR, Perry H, Davis TP, Jr., Lindquist ED, 2014. Risk factors for diarrhea in children under five years of age residing in peri-urban communities in Cochabamba, Bolivia. *Am J Trop Med Hyg 91:* 1190–1196.
7. George CM et al., 2018. Enteric infections in young children are associated with environmental enteropathy and impaired growth. *Trop Med Int Health 23:* 26–33.
8. Owino V, Ahmed T, Freemark M, Kelly P, Loy A, Manary M, Loechl C, 2016. Environmental enteric dysfunction and growth failure/stunting in global child health. *Pediatrics 138:* e20160641.
9. Agustina R, Sari TP, Satroamidjojo S, Bovee-Oudenhoven IM, Feskens EJ, Kok FJ, 2013. Association of food-hygiene practices and diarrhea prevalence among Indonesian young children from low socioeconomic urban areas. *BMC Public Health 13:* 977.
10. Esrey SA, Potash JB, Roberts L, Shiff C, 1991. Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. *Bull World Health Organ 69:* 609–621.
11. Takanashi K, Chonan Y, To Quyen D, Cong Khan N, Poudel K, Jimba M, 2009. Survey of food-hygiene practices at home and

childhood diarrhoea in Hanoi, Viet Nam. *J Health Popul Nutr 27:* 602–611.
12. Pathela P, Zahid Hasan K, Roy E, Huq F, Kasem Siddique A, Bradley Sack R, 2006. Diarrheal illness in a cohort of children 0–2 years of age in rural Bangladesh: I. incidence and risk factors. *Acta Paediatr 95:* 430–437.
13. D'Souza RM, 1997. Housing and environmental factors and their effects on the health of children in the slums of Karachi, Pakistan. *J Biosoc Sci 29:* 271–281.
14. Ghosh S, Sengupta PG, Mondal S, Banu M, Gupta D, Sircar B, 1997. Risk behavioural practices of rural mothers as determinants of childhood diarrhea. *J Commun Dis 29:* 7–14.
15. Sobel J, Gomes TA, Ramos RT, Hoekstra M, Rodrigue D, Rassi V, Griffin PM, 2004. Pathogen-specific risk factors and protective factors for acute diarrheal illness in children aged 12–59 months in Sao Paulo, Brazil. *Clin Infect Dis 38:* 1545–1551.
16. Burrowes V et al., 2017. Risk factors for household transmission of *Vibrio cholerae* in Dhaka, Bangladesh (CHoBI7 trial). *Am J Trop Med Hyg 96:* 1382–1387.
17. Morita T et al., 2017. Mouthing of soil contaminated objects is associated with environmental enteropathy in young children. *Trop Med Int Health 22:* 670–678.
18. Islam MS et al., 2013. Hygiene intervention reduces contamination of weaning food in Bangladesh. *Trop Med Int Health 18:* 250–258.
19. Gautam OP, Schmidt WP, Cairncross S, Cavill S, Curtis V, 2017. Trial of a novel intervention to improve multiple food hygiene behaviors in Nepal. *Am J Trop Med Hyg 96:* 1415–1426.
20. George CM et al., 2016. Unsafe child feces disposal is associated with environmental enteropathy and impaired growth. *J Pediatr 176:* 43–49.
21. Perin J et al., 2016. Geophagy is associated with growth faltering in children in rural Bangladesh. *J Pediatr 178:* 34–39.e1.
22. Hussain F, Luby SP, Unicomb L, Leontsini E, Naushin T, Buckland AJ, Winch PJ, 2017. Assessment of the acceptability and feasibility of child potties for safe child feces disposal in rural Bangladesh. *Am J Trop Med Hyg 97:* 469–476.
23. Luby SP et al., 2018. Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Bangladesh: a cluster randomised controlled trial. *Lancet Glob Health 6:* e302–e315.
24. Qadri F et al., 2015. Feasibility and effectiveness of oral cholera vaccine in an urban endemic setting in Bangladesh: a cluster randomised open-label trial. *Lancet 386:* 1362–1371.
25. Zurovac D, Sudoi RK, Akhwale WS, Ndiritu M, Hamer DH, Rowe AK, Snow RW, 2011. The effect of mobile phone text-message reminders on Kenyan health workers' adherence to malaria treatment guidelines: a cluster randomised trial. *Lancet 378:* 795–803.
26. Cole-Lewis H, Kershaw T, 2010. Text messaging as a tool for behavior change in disease prevention and management. *Epidemiol Rev 32:* 56–69.
27. Free C, Phillips G, Galli L, Watson L, Felix L, Edwards P, Patel V, Haines A, 2013. The effectiveness of mobile-health technology-based health behaviour change or disease management interventions for health care consumers: a systematic review. *PLoS Med 10:* e1001362.
28. Higgs ES, Goldberg AB, Labrique AB, Cook SH, Schmid C, Cole CF, Obregón RA, 2014. Understanding the role of mHealth and other media interventions for behavior change to enhance child survival and development in low-and middle-income countries: an evidence review. *J Health Commun 19 (Suppl 1):* 164–189.
29. Gibson DG, Ochieng B, Kagucia EW, Were J, Hayford K, Moulton LH, Levine OS, Odhiambo F, O'Brien KL, Feikin DR, 2017. Mobile phone-delivered reminders and incentives to improve childhood immunisation coverage and timeliness in Kenya (M-SIMU): a cluster randomised controlled trial. *Lancet Glob Health 5:* e428–e438.
30. Biganzoli EM, Boracchi P, Ambrogi F, Marubini E, 2006. Artificial neural network for the joint modelling of discrete cause-specific hazards. *Artif Intell Med 37:* 119–130.
31. GSMA, 2018. *Mobile Industry Driving Growth and Enabling Digital Inclusion*. Available at: http://bd2041.com/index.php/2018/04/09/mobile-industry-driving-growth-and-enabling-digital-inclusion/. Accessed April 9, 2018.
32. Weil AA, Khan AI, Chowdhury F, Larocque RC, Faruque AS, Ryan ET, Calderwood SB, Qadri F, Harris JB, 2009. Clinical outcomes in household contacts of patients with cholera in Bangladesh. *Clin Infect Dis 49:* 1473–1479.
33. George CM et al., 2015. *Shigella* infections in household contacts of pediatric shigellosis patients in rural Bangladesh. *Emerg Infect Dis 21:* 2006–2013.
34. Black RE, Merson MH, Rowe B, Taylor PR, Abdul Alim AR, Gross RJ, Sack DA, 1981. Enterotoxigenic *Escherichia coli* diarrhoea: acquired immunity and transmission in an endemic area. *Bull World Health Organ 59:* 263–268.
35. George CM et al., 2019. Formative research for the design of a scalable water, sanitation, and hygiene mobile health program: CHoBI7 mobile health program. *BMC Public Health 19:* 1028.
36. Thomas ED et al., 2020. Formative research to scale up a handwashing with soap and water treatment intervention for household members of diarrhea patients in health facilities in Dhaka, Bangladesh (CHoBI7 program). *BMC Public Health 20:* 831.
37. George CM et al., 2019. Effects of a water, sanitation, and hygiene mobile health program on diarrhea and child growth in Bangladesh: a cluster-randomized controlled trial of the cholera hospital-based intervention for 7 days (CHoBI7) mobile health program. *Clin Infect Dis*. ■: ciaa754.
38. Curtis V, Schmidt W, Luby S, Florez R, Toure O, Biran A, 2011. Hygiene: new hopes, new horizons. *Lancet Infect Dis 11:* 312–321.
39. Vindigni SM, Riley PL, Jhung M, 2011. Systematic review: handwashing behaviour in low-to middle-income countries: outcome measures and behaviour maintenance. *Trop Med Int Health 16:* 466–477.
40. Rabbi SE, Dey NC, 2013. Exploring the gap between hand washing knowledge and practices in Bangladesh: a cross-sectional comparative study. *BMC Public Health 13:* 89.
41. Briscoe C, Aboud F, 2012. Behaviour change communication targeting four health behaviours in developing countries: a review of change techniques. *Soc Sci Med 75:* 612–621.
42. Inauen J, Mosler HJ, 2014. Developing and testing theory-based and evidence-based interventions to promote switching to arsenic-safe wells in Bangladesh. *J Health Psychol 19:* 1483–1498.
43. Dreibelbis R, Winch PJ, Leontsini E, Hulland KRS, Ram PK, Unicomb L, Luby SP, 2013. The integrated behavioural model for water, sanitation, and hygiene: a systematic review of behavioural models and a framework for designing and evaluating behaviour change interventions in infrastructure-restricted settings. *BMC Public Health 13:* 1015.
44. Wood S, Foster J, Kols A, 2012. Understanding why women adopt and sustain home water treatment: insights from the Malawi antenatal care program. *Soc Sci Med 75:* 634–642.
45. Neal D, Vujcic J, Burns R, Wood W, Devine J, 2016. *Nudging and Habit Change for Open Defecation: New Tactics from Behavioral Science (English)*. Water and Sanitation Program. Washington, DC: World Bank Group. Available at: http://documents.worldbank.org/curated/en/905011467990970572/Nudging-and-habit-change-for-open-defecation-new-tactics-from-behavioral-science.
46. Hulland KR, Leontsini E, Dreibelbis R, Unicomb L, Afroz A, Dutta NC, Nizame FA, Luby SP, Ram PK, Winch PJ, 2013. Designing a handwashing station for infrastructure-restricted communities in Bangladesh using the integrated behavioural model for water, sanitation and hygiene interventions (IBM-WASH). *BMC Public Health 13:* 877.
47. Yeasmin F et al., 2017. Piloting a low-cost hardware intervention to reduce improper disposal of solid waste in communal toilets in low-income settlements in Dhaka, Bangladesh. *BMC Public Health 17:* 682.
48. Cavill S, Huggett C, 2020. Good mums: a gender equality perspective on the constructions of the mother in handwashing campaigns. *wH2O J Gend Water 7:* 4.
49. WHO, 2002. *Healthy Villages: A Guide for Communities and Community Health Workers*. Geneva, Switzerland: World Health Organization.
50. Kraft JM, Wilkins KG, Morales GJ, Widyono M, Middlestadt SE, 2014. An evidence review of gender-integrated interventions in reproductive and maternal-child health. *J Health Commun 19 (Suppl 1):* 122–141.

51. Figueroa ME, Lawrence Kincaid D, 2010. *Social, Cultural and Behavioral Correlates of Household Water Treatment and Storage*. Center Publication HCI 2010-1: Health Communication Insights. Baltimore, MD: Johns Hopkins Bloomberg School of Public Health, Center for Communication Programs.
52. WHO, 2002. *WHO Global Strategy for Food Safety. Lower Risk Diet for Better Health*. Geneva, Switzerland: World Health Organization.
53. Rahman MJ et al., 2016. Toward a scalable and sustainable intervention for complementary food safety. *Food Nutr Bull 37:* 186–201.
54. Rowntree O, 2018. *The Mobile Gender Gap Report 2018*. London, UK: GSMA. Available at: https://wwwgsmacom/mobilefordevelopment/programmes/connected-women/the-mobile-gender-gap-report-2018.
55. Bauza V, Byrne DM, Trimmer JT, Lardizabal A, Atiim P, Asigbee MAK, Guest JS, 2018. Child soil ingestion in rural Ghana–frequency, caregiver perceptions, relationship with household floor material and associations with child diarrhoea. *Trop Med Int Health 23:* 558–569.
56. Reid B, Seu R, Orgle J, Roy K, Pongolani C, Chileshe M, Fundira D, Stoltzfus R, 2018. A community-designed play-yard intervention to prevent microbial ingestion: a baby water, sanitation, and hygiene pilot study in rural Zambia. *Am J Trop Med Hyg 99:* 513–525.
57. Garn JV, Sclar GD, Freeman MC, Penakalapati G, Alexander KT, Brooks P, Rehfuess EA, Boisson S, Medlicott KO, Clasen TF, 2017. The impact of sanitation interventions on latrine coverage and latrine use: a systematic review and meta-analysis. *Int J Hyg Environ Health 220:* 329–340.
58. Lanata CF, 2003. Studies of food hygiene and diarrhoeal disease. *Int J Environ Health Res 13 (Suppl 1):* S175–S183.
59. Majorin F, Torondel B, Ka Seen Chan G, Clasen T, 2019. Interventions to improve disposal of child faeces for preventing diarrhoea and soil-transmitted helminth infection. *Cochrane Database Syst Rev 9:* CD011055.
60. Cairncross S, Hunt C, Boisson S, Bostoen K, Curtis V, Fung IC, Schmidt WP, 2010. Water, sanitation and hygiene for the prevention of diarrhoea. *Int J Epidemiol 39 (Suppl 1):* i193–205.
61. George CM et al., 2015. Geophagy is associated with environmental enteropathy and stunting in children in rural Bangladesh. *Am J Trop Med Hyg 92:* 1117–1124.
62. Simango C, 2006. Prevalence of *Clostridium difficile* in the environment in a rural community in Zimbabwe. *Trans R Soc Trop Med Hyg 100:* 1146–1150.
63. Luby SP, Halder AK, Tronchet C, Akhter S, Bhuiya A, Johnston RB, 2009. Household characteristics associated with handwashing with soap in rural Bangladesh. *Am J Trop Med Hyg 81:* 882–887.
64. Dreibelbis R, Kroeger A, Hossain K, Venkatesh M, Ram PK, 2016. Behavior change without behavior change communication: nudging handwashing among primary school students in Bangladesh. *Int J Environ Res Public Health 13:* 129.