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Process evaluation for the delivery of a water, sanitation and hygiene mobile health program: findings from the randomised controlled trial of the CHoBI7 mobile health program

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Abstract

OBJECTIVE The Cholera-Hospital-Based Intervention for 7-days (CHoBI7) mobile health (mHealth) program delivers mobile messages to diarrhoea patient households promoting water treatment and handwashing with soap. The randomised controlled trial (RCT) of the CHoBI7 mHealth program demonstrated this intervention was effective in significantly reducing diarrhoea and stunting amoung young children. The objective of this study was to assess the implementation of the CHoBI7 mHealth program in delivering mHealth messages during this RCT.

METHODS 517 diarrhoea patient households with 1777 participants received weekly text, voice and interactive voice response (IVR) messages from the CHoBI7 mHealth program over the 12-month program period. The program process evaluation indicators were the following: the percentage of CHoBI7 mHealth messages received and fully listened to by program households (program fidelity and dose), and household members reporting receiving and sharing an mHealth message from the program in the past two weeks (program reach).

RESULTS Ninety two percent of text messages were received by program households. Eighty three percent of voice and 86% of IVR messages sent were fully listened to by at least one household member. Eighty one percent of IVR quiz responses from households were answered correctly. Program households reported receiving a CHoBI7 mHealth message in the past two weeks at 79% of monthly household visits during the 12-month program. Seventy seven percent of participants reported sharing a program message with a spouse, 55% with a neighbour and 49% with a child during the program period.

CONCLUSION There was high fidelity, dose and reach of mobile messages delivered for the CHoBI7 mHealth program. This study presents an approach for process evaluation that can be implemented to evaluate future mHealth programs.

keywords mobile health, diarrhoea, randomised controlled trial, water, sanitation and hygiene

Sustainable Development Goals (SDGs): SDG 3 (good health and well-being), SDG 6 (clean water and sanitation), SDG 9 (industry, innovation and infrastructure), SDG 17 (partnerships for the goals)

Introduction

Diarrhoeal diseases result in an estimated 500,000 deaths amoung young children annually in low- and middle-income countries (LMICs) [1]. Previous studies have found that lack of handwashing with soap and water treatment are important risk factors for paediatric diarrhoeal disease [2-4]. Water, sanitation and hygiene (WASH) interventions have the potential to reduce diarrhoeal diseases globally [5]. However, encouraging households to sustain WASH behaviours over time remains a significant public health challenge [6]. Effective and scalable WASH interventions are needed to improve child health in LMICs.

Phone-based reminders of public health information have been shown to reduce disease morbidity and increase health-protective behaviours [7-9]. A recent systematic review found that 15 randomised controlled trials (RCTs) of mobile health (mHealth) interventions resulted in significant improvements in health-protective behaviours, and 16 RCTs resulted in significant improvements in clinical outcomes [10]. In the past 10 years, mobile phone access and ownership have doubled globally [11,12]. The total number of mobile phone subscribers in Bangladesh reached over 160 million registered users in 2019, according to the Bangladesh Telecommunication Regulatory Commission [13]. This presents an ideal opportunity to use mobile phones to deliver public health information in Bangladesh. Mobile technology can be used to create automated systems to deliver voice and text messages to a large number of individuals at a low cost [14]. However, there are only two published studies, to our knowledge, that have evaluated the use of mHealth for delivery of WASH programs to households and no randomised controlled trials of WASH mHealth programs [15,16]. Henry et al. was conducted in Tanzania, and this study targeted 60 youth 18 to 25 years old [15] and focused on text messages on hygiene promotion. This study found that 92% of participants received and responded to program text messages. Tidwell et al. was conducted in India and focused on mobile phone messaging for mothers of young children; it found a modest (~5%) significant improvement in handwashing with soap behaviour [16]. There is an urgent need for rigorous methods to evaluate delivery of WASH mHealth programs.

In an effort to reduce diarrhoeal diseases in Bangladesh, our research group developed the Cholera-Hospital-Based Intervention for 7 days (CHoBI7) mHealth program. This program delivers automated text, voice and interactive voice response messages promoting handwashing with soap and water treatment behaviours. Messages are sent by a character named Dr Chobi, a doctor at a hospital who calls and texts participants about the promoted WASH behaviours [17]. All diarrhoea patient households receive weekly interactive voice response (IVR), voice and text messages from the CHoBI7 mHealth program for a 12-month period. Mobile messages are sent using the web-based VIAMO platform [18]. The recent RCT of the CHoBI7 mHealth program demonstrated this program was effective in significantly increasing handwashing with soap and stored drinking water quality, and reducing diarrhoea and stunting in young children [19]. In this study, we assessed the fidelity, dose and reach of the CHoBI7 mHealth program through process evaluation conducted during the RCT of this intervention. We used data obtained from the VIAMO platform and participant reports.

Methods

The RCT of the CHoBI7 mHealth program enrolled 769 diarrhoea patients and 1857 household members from December 2016 to April 2018. The RCT compared the standard recommendation given in Bangladesh to diarrhoea patients (of any aetiology) at discharge on oral rehydration solution use for dehydration (standard message arm) to the CHoBI7 mHealth program with either a single in-person visit for health facility delivery of the program (mHealth *with no* home visits arm) or health facility delivery of the program plus two home visits (mHealth *with two* home visits arm). The two home visits were delivered during the one-week high risk period after the diarrhoea patient was discharged from the health facility. Diarrhoea patient households in the mHealth arms were sent weekly IVR, voice and text messages from the CHoBI7 mHealth program over a 12-month period. A summary text message was sent to households after voice and IVR messages, in addition to standalone text messages. Twenty six voice, 14 IVR quiz, 2 IVR (questions about the condition of intervention hardware) and 48 text messages (12 standalone text and 36 summary text messages) were sent to households during the study period. A detailed description of the CHoBI7 mHealth program is published elsewhere [17].

Implementation findings are presented using the Medical Research Council framework for process evaluation [20]. The adaption and the theory of change for delivery of the CHoBI7 mHealth program is described in detail in our recent publication George et al. 2019 [17]. The CHoBI7 mHealth program was developed through a theory-driven approach informed by the Integrated Behavioral Model for Water, Sanitation and Hygiene (IBM-WASH) and the Risks, Attitudes, Norms, Abilities and Self-regulation (RANAS) Model [21,22]. Program adaption was conducted based on mobile health workshops, semi-structured interviews and group discussions followed by a pilot study. Our goal was to deliver at least 80% of program text, voice and IVR messages to beneficiary households. Therefore, program fidelity was defined by at least 80% of program text, voice and IVR messages being answered/received by beneficiary households. Program dose was defined as the percentage of program voice, text and IVR messages answered/received and fully listened to by beneficiary households. Program reach was defined as whether household members (target audience)

reported receiving a CHoBI7 program mHealth message in the past two weeks.

VIAMO platform process evaluation indicators

The following process evaluation indicators were used to assess the CHoBI7 mHealth program based on data from the VIAMO platform: (i) the percentage of CHoBI7 text, voice and IVR messages received (for text messages) or answered (for voice and IVR) by beneficiary households (program fidelity and dose) (received by at least one phone in the household); (ii) the percentage of CHoBI7 voice and text messages fully listened to by beneficiary households (program fidelity and dose) (by at least one phone in the household); and (iii) the percentage of households replying correctly to IVR quiz responses (by at least one phone in the household). The VIAMO platform has two classifications for text messages, either 'Finished (received)' or 'Network Failed', and 'Failed' or 'Finished (answered)' for voice and IVR messages. The VIAMO platform can identify whether a text message is received and whether a voice call is answered. The percentage of CHoBI7 text messages received by beneficiary households was calculated by dividing the total number of unique text messages at each time point received by the household by the total number of unique messages sent to the household. For voice and IVR messages, the duration of the recorded message listened to (call duration) can be assessed using the VIAMO platform. If the health promotion content of the voice or IVR message was completely listened to by a household, then it was classified as 'fully listened to' (fully completed) otherwise this was classified as 'partially listen to'. The percentage of CHoBI7 voice and IVR messages fully listened to by beneficiary households were calculated by dividing the number of unique messages at each time point 'fully listened to' by the household by the total number of unique messages sent to the household. In addition, IVR quiz messages prompted beneficiaries to select one of two possible options on questions related to handwashing with soap and water treatment behaviours, and transmission of diarrhoeal diseases. If a listener selected a response, this was classified as 'replied' and then assigned to be either 'correct' or 'incorrect'.

Participant reports

Participant reports were used to assess the percentage of beneficiaries receiving and sharing an mHealth message from the CHoBI7 mHealth program in the past two weeks (program reach). Information was also collected on the percentage of beneficiaries reporting challenges with the mHealth platform during the program period. Participant reports were collected from a mHealth surveillance form administered monthly to enrolled household members 12 years of age or older. To assess whether CHoBI7 mHealth messages sent to households were being received by the primary caregiver, we calculated the percentage of primary caregivers that reported receiving a CHoBI7 mHealth message in the past two weeks at each time point.

Statistical analysis

Logistic and linear regression analyses were performed with study arm as the predictor and the process evaluation indicator as the outcome to determine whether there were significant differences in indicators between study arms. All analyses described above were performed using STATA software version 13.

Results

Seventeen hundred seventy seven participants from 517 households were enrolled in the CHoBI7 mHealth program (264 households in the mHealth *with no* home visits arm and 253 households in the mHealth *with two* home visits arm) (Table 1). The mean age for program participants was 18 years, and 54% (966/1777) were female. Ninety four percent (487/517) of households had at least one person who could read and write. Forty four percent (230/517) of households reported refrigerator ownership, and 28% (146/517) reported having a concrete roof. Twenty three percent of households (121/517) were lost to follow-up at the 12-month time point.

Program households received 91% (5425/5987) of standalone text messages and 92% (16451/17831) of summary text messages. Sixty percent of households (311/517) received all standalone text messages sent, and 85% (440/517) of households received over 80% of standalone text messages sent. Forty nine percent (254/517) of households received all summary text messages sent, and 88% (454/517) of households received over 80% of weekly summary text messages sent. Eighty three percent (9448/11345) of voice messages sent were fully listened to. Six percent of households (29/517) answered all voice messages sent, and 88% (456/517) of households answered over 80% of voice messages sent. Eighty six percent (6618/7669) of IVR messages sent to program households were fully listened to. Fifty nine percent of households (358/517) answered all IVR messages sent, and 93% (482/517) of households answered over 80% of IVR messages sent.

Table 1 Baseline population characteristics by study arm

	mHealth with no home visits arm	mHealth with two home visits arm
Study households	264	253
All study participants	886	891
Household members of index diarrhoea patients	622	638
Number of primary caregivers	264	253
Number of individuals 12 years of age or older	496	513
Mean study participants per household		
Mean ± SD (Min–Max)	3.4 ± 0.85 (2–7)	3.5 ± 0.93 (2–6)
Mean study participants per household (≥ 12 years)		
Mean ± SD (Min–Max)	1.89 ± 0.65 (1–5)	2.03 ± 0.66 (1–5)
Baseline household member age		
Mean ± SD (Min–Max) (years)	18 ± 15 (0.08–80)	18 ± 15 (0.08–75)
0–5 years	34%	32%
5–12 years	10%	10%
12–18 years	1%	2%
18 years or greater	55%	56%
Gender		
% female	55%	54%
Household roof type		
Concrete	28%	28%
Tin	71%	72%
Other	<1%	0%
Household wall type		
Concrete	71%	71%
Mud	3%	4%
Tin	26%	25%
Other	0%	<1%
Household floor type		
Concrete	97%	96%
Other	3%	4%
Electricity	93%	92%
Refrigerator ownership	45%	44%
At least one household member can read and write	95%	94%

SD, standard deviation.

There was no significant difference by study arm in the proportion of program messages received for standalone or summary text messages or a significant difference by study arm for IVR messages being fully listened to. The percentage of voice messages fully listened to was significantly higher in the mHealth with two home visits arm compared to the mHealth with no home visits arm ($P = 0.01$, 82% *vs.* 84%) (Table 2).

Program households replied to 68% (4004/5906) of unique IVR quiz messages sent, and 81% (3258/4004) of these quiz responses were correct (Table 3). At Week 3, when asked whether hands should be washed with soap after or before eating, 91% (311/340) of households responded 'before eating'. At Month 11.75, 83% (219/264) of participants responded correctly that contaminated water and hands spread germs. The only difference by study arm in the proportion of households that responded correctly to quiz questions was for the Month 4 program message, where more respondents in the mHealth with two home visits arm knew that hands and water could spread germs than the mHealth with no home visits arm ($P = 0.04$, 87% *vs.* 78%).

For the mHealth *with no* home visits arm, 73% (132/182) of program households (household-level) reported receiving a mobile message from the CHoBI7 mHealth program in the past two weeks at the 6-month time point, and 78% (150/192) at the 12-month time point (Figure 1). For the mHealth *with two* home visits arm, 77% (151/197) of program households reported receiving a mobile message from the CHoBI7 mHealth program in the past two weeks at the 6-month time point, and 78% (157/201) at the 12-month time point. Seventy one percent (350/492) of program participants (participant-level) at the 6-month time point reported receiving a message from the CHoBI7 mHealth program in the past two weeks, and 69% (414/604) at the 12-month time point (Figure 2). This did not significantly differ by study arm. Seventy percent (249/357) of caregivers reported receiving a message from the CHoBI7 mHealth program in the past two weeks at the 6-month time point, and 67% (240/357) at the 12-month time point. This also did not significantly differ by study arm.

Eighty six percent of participants (768/896) reported sharing CHoBI7 mHealth program mobile messages with another individual during the 12 month program period. Seventy seven percent (694/896) of participants reported sharing CHoBI7 mHealth program messages with spouses, 55% (494/896) with neighbours, 49% (443/896) with their children, 24% (215/896) with parents, 21% (190/896) with siblings, 18% (158/896) with in-laws, 18% (161/896) with friends, and 13% (117/896) with co-workers over the 12-month program period. There were no significant differences between study arms for sharing a message with others (Table 4). Eighty one percent (733/896) of participants reported that someone in their household shared a CHoBI7 program mobile message with them during the 12 month program period. Seventy four percent of participants (663/896) reported that a spouse shared a CHoBI7 mHealth message with them during the program period, 35% (318/896)

Table 2 Summary of CHoBI7 mHealth program mobile messages sent to households

		mHealth with no Home visits arm		mHealth with two home visits arm		Overall results for both arms		
Message type	Indicator	*n*	%	*n*	%	*n*	%	p-value
Standalone text	Sent	3087	--	2900	--	5987	--	
	Failed	307	10%	255	9%	562	9%	0.38
	Received	2780	90%	2645	91%	5425	91%	0.71
Summary text	Sent	8986	--	8845	--	17831	--	
	Failed	693	8%	687	8%	1380	8%	0.83
	Received	8293	92%	8158	92%	16451	92%	0.17
Voice	Sent	5684	--	5661	--	11345	--	
	Failed	466	8%	440	8%	906	8%	0.92
	Partially Completed	541	10%	450	8%	991	9%	0.06
	Fully Completed	4677	82%	4771	84%	9448	83%	0.01
Interactive voice response	Sent	3928	--	3741	--	7669	--	
	Failed	418	11%	335	9%	753	10%	0.19
	Partially Completed	166	4%	132	4%	298	4%	0.32
	Fully Completed	3344	85%	3274	88%	6618	86%	0.32

n is based on the number of unique mobile messages sent to a household. 'Fully Completed' is the same as 'Fully Listen to' in the manuscript text. One hundred twenty one households were lost to follow-up at the 12 month time point.

reported a child in their household, 12% (105/896) reported parents, 7% (60/896) reported siblings, and 7% (65/896) reported in-laws (Table 5). There were no significant differences in having a message shared between study arms.

Forty nine percent (438/896) of participants reported at least once during the study period that they were too busy to receive program messages, 38% (337/896) reported that they were not able to read a text message, 37% (327/896) reported that mobile messages were not being shared by the phone's owner, 34%(307/896) reported that their phone was damaged, and 17% (148/896) had no one available to read text messages to them. There were no significant differences between study arms for reported challenges (Table 6).

Discussion

The process evaluation of the CHoBI7 mHealth program demonstrated high fidelity, dose and reach of mobile message delivery in both mHealth study arms. Over 80% of voice and IVR quiz messages were fully listened to, and 90% of text messages were received by program households. The majority of households responded to IVR quiz questions, and 81% of their responses were correct. Furthermore, the majority of households (78%) reported receiving an mHealth message from our program in the past two weeks at our 12-month follow-up. We also observed frequent message sharing within households and with those outside of program households. These findings demonstrate that the CHoBI7 mHealth program presents an effective approach to deliver voice, IVR and text messages to households in slum areas of Dhaka, Bangladesh. These results complement our recent RCT of the CHoBI7 mHealth program that demonstrated this program was effective in significantly increasing handwashing with soap and stored drinking water quality, and reducing diarrhoea and stunting in young children [19].

A major success of the CHoBI7 mHealth program was the ability to successfully deliver mHealth messages with high reach to the primary caregivers in the household. Phone access for the primary caregiver in the home emerged as an important challenge during our formative research [17]. This is consistent with findings from the Aponjon mHealth program [23]. This mHealth program delivers text messages to women during pregnancy on antenatal care in Bangladesh. Female Aponjon subscribers reported that sometimes program calls were missed because someone else in the household had the phone, and that program messages were often not shared with them. Through tailoring our CHoBI7 mobile messages to encourage message sharing with all household members and through emphasising the importance of primary caregivers receiving our mobile messages during health facility visits, we were able to overcome this challenge. It is estimated that 82% of adult males are mobile phone

Table 3 Summary of CHoBI7 mHealth program interactive voice response quiz questions

IVR Quiz question	mHealth with *no* home visits arm				mHealth with two home visits arm				*P*-value[†]
	Households sent messages (*N*)	Received % (*n*)	Replied % (*n*)	Correct % (*n*)	Households sent messages (*N*)	Received % (*n*)	Replied % (*n*)	Correct % (*n*)	
IVR Quiz Day 3: How long after adding the chlorine tablet should you wait to drink this water? Correct Answer: 30 min Wrong Answer : 15 min	258	73% (189)	71% (135)	80% (108)	247	81% (201)	73% (147)	84% (123)	0.42
IVR Quiz Week 3: Should you wash your hands with soapy water after or before eating? Correct Answer: Before Wrong Answer : After	255	91% (231)	73% (169)	91% (153)	242	95% (231)	73% (171)	92% (158)	0.54
IVR Quiz Week 5: How many key times are there for hand washing with soapy water? Correct Answer: Four times Wrong Answer : Three times	258	93% (240)	63% (150)	72% (108)	244	95% (231)	68% (158)	72% (113)	0.93
IVR Quiz Week 7: After heating your water until a rolling boil, how will you store this water? Correct Answer: Keep the water covered with a lid Wrong Answer: Keep the water open without any cover	260	90% (234)	67% (156)	76% (118)	242	96% (232)	66% (154)	82% (127)	0.14
IVR Quiz Month 3.75: How many times do you need to wash your hands with soapy water and use safe drinking water in a day? Correct Answer: Every time in every day Wrong Answer: At least once in a day	216	94% (202)	60% (122)	88% (107)	212	91% (192)	71% (137)	91% (125)	0.36
IVR Quiz Month 4: How can diarrhea germs spread? Correct Answer: Germs spread by hands and through water Wrong Answer: Germs spread by air	260	92% (239)	74% (178)	78% (139)	245	91% (222)	74% (165)	87% (143)	0.04
IVR Quiz Month 5: How often do I need to clean my buckets? Correct Answer: Every week Wrong Answer : Every day	253	92% (232)	61% (141)	48% (67)	241	92% (221)	58% (128)	48% (62)	0.88

Table 3 (*Continued*)

IVR Quiz question	mHealth with *no* home visits arm				mHealth with two home visits arm				
	Households sent messages (*N*)	Received % (*n*)	Replied % (*n*)	Correct % (*n*)	Households sent messages (*N*)	Received % (*n*)	Replied % (*n*)	Correct % (*n*)	*P*-value[†]
IVR Quiz Month 6 : How many days is the high risk period for becoming sick after someone in your home has severe diarrhea? Correct Answer: 7 days Wrong Answer : 14 days	258	88% (228)	70% (160)	80% (128)	240	90% (217)	74% (161)	74% (119)	0.20
IVR Quiz Month 6.75: When do you have to wash your hands with soap, Before or after cutting cucumbers? Correct Answer: Before cutting cucumbers Wrong Answer: After cutting cucumbers	246	89% (216)	63% (136)	90% (123)	220	91% (200)	67% (134)	93% (124)	0.54
IVR Quiz Month 7.75: What do you need to do after washing both hands with soapy water? Correct Answer: You should use a clean cloth Wrong Answer: You should dry your hands on your clothing	255	87% (222)	68% (151)	85% (120)	244	90% (219)	63% (139)	88% (122)	0.46
IVR Quiz Month 8.75: How do you dispense water from your blue bucket for drinking? Correct Answer: By using the tap on the blue bucket Wrong Answer: By dipping a mug or glass in the blue bucket	255	84% (215)	66% (142)	85% (120)	248	88% (218)	71% (154)	90% (138)	0.19
IVR Quiz Month 10.75: How should Aklima boil her water to keep her family safe from severe diarrhea? Correct Answer: She should heat her water until it reaches a rolling boil Wrong Answer: She should heat her water until it becomes hot	254	85% (216)	67% (145)	83% (121)	248	85% (212)	70% (148)	84% (125)	0.81
IVR Quiz Month 11.75: How are the germs that cause severe diarrhea spread? Correct Answer: Germs are spread by contaminated water and hands Wrong Answer: Germs are spread from bad air	251	84% (211)	65% (138)	85% (117)	232	85% (198)	64% (126)	81% (102)	0.41

N and *n* values are based on the number of households.
[†]*P*-value for percent of correct IVR quiz responses compared by study arm.

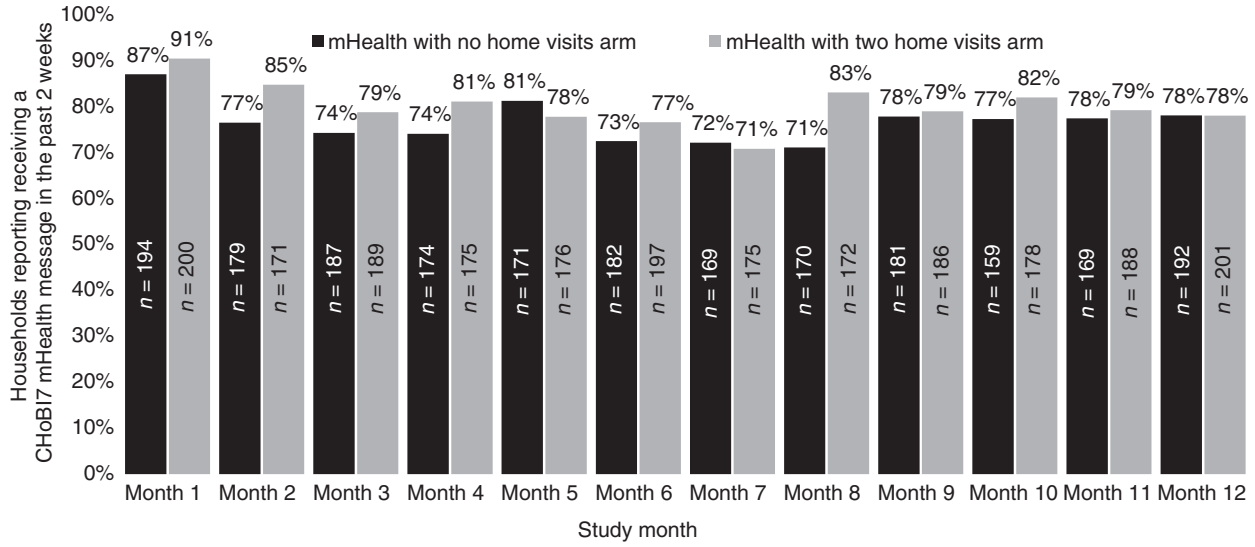

Figure 1 Households reporting receiving a CHoBI7 mHealth message in the past 2 weeks over the study period.

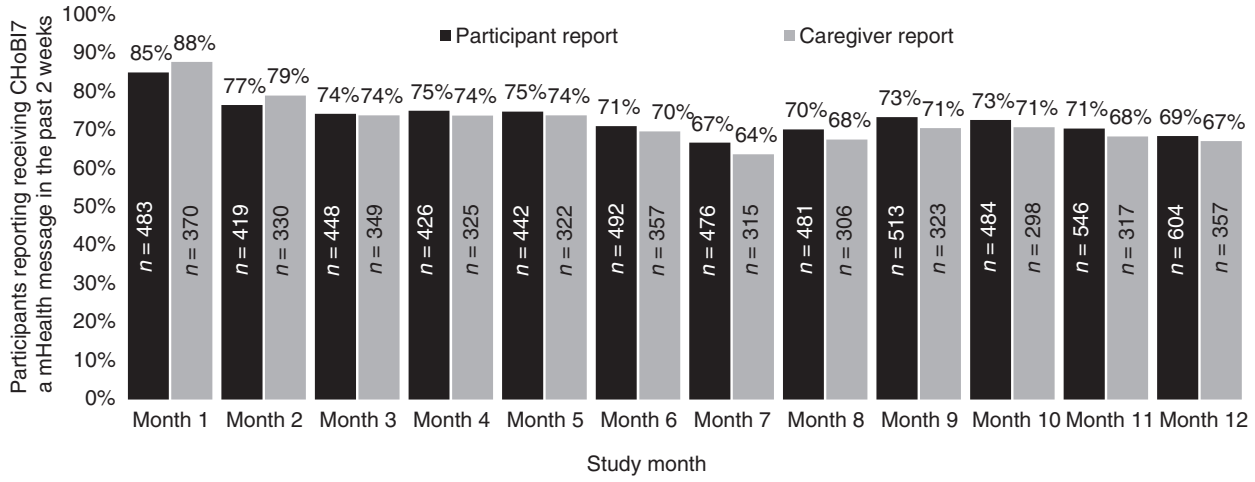

Figure 2 Participants and caregivers reporting receiving a CHoBI7 mHealth messages in the past 2 weeks over the study period.

owners *vs.* only 55% of adult females in Bangladesh [24]. Therefore, it is important that future mHealth programs targeting child health ensure that mobile messages are reaching female caregivers in the household.

Another successful aspect of the CHoBI7 mHealth program was the high number of beneficiaries that fully listened to IVR quiz messages and responded correctly. Furthermore, this did not significantly differ by mHealth arm. This finding suggests that home visits are not needed to ensure households correctly answer program quiz questions. The IVR quiz messages present a novel approach to assess awareness on key program behaviours and to tailor program messages accordingly. For example, we learned through our IVR quiz messages during the pilot study that households were unclear on the four key times for handwashing with soap. This led us to further emphasise these key times during our RCT. We also learned during the pilot that beneficiaries often took quizzes together as a family in the evenings [17]. This finding suggested that IVR quizzes could serve as an approach to engage several household members at once in mobile message content. This is the first study to our

Table 4 Participants reporting sharing a CHoBI7 mHealth message with others over the study period (Months 1–12) (N = 896)

Shared with	mHealth with *no* home visits arm % (n)	mHealth with two home visits arm % (n)	P-value*
Any sharing	85% (367)	87% (401)	0.43
Spouse	76% (328)	79% (366)	0.24
Neighbour	54% (232)	57% (262)	0.37
Children	51% (220)	48% (223)	0.43
Parents	23% (100)	25% (115)	0.54
Sibling	20% (88)	22% (102)	0.54
In-Law	19% (81)	17% (77)	0.42
Friends	19% (83)	17% (78)	0.37
Co-Worker	12% (54)	14% (63)	0.61

*P-value is a comparison of proportions by study arm.

Table 5 Participants reporting someone shared a CHoBI7 mHealth message with them over the study period (Months 1–12) (N = 896)

Someone shared	mHealth with *no* home visits arm % (n)	mHealth with two home visits arm % (n)	P-value*
Any sharing	79% (344)	84% (389)	0.08
Spouse	73% (317)	75% (346)	0.60
Children	36% (156)	35% (162)	0.75
Parents	11% (46)	13% (59)	0.33
Sibling	6% (25)	8% (35)	0.29
In-Law	7% (30)	8% (35)	0.72

*P-value is a comparison of proportions by study arm.

knowledge to use IVR quizzes to engage beneficiaries in a WASH program. Two-way text messaging has been associated with improved medication adherence practices compared to one-way texting; however, the literature on the impact of voice IVR messages is limited [25]. Our finding that 86% of IVR messages were fully listened to by beneficiaries is consistent with a previous study in Senegal that used IVR educational questions as part of a mobile learning program on management of contraceptive side effects and misconceptions among mid-wives and nurses. This study found that 80% of these IVR messages were received by beneficiaries [26]. Future studies should evaluate the effectiveness of IVR quiz messages in encouraging other WASH behaviours.

Through our process evaluation, we identified key challenges to CHoBI7 mHealth program implementation. A common challenge was not being able to read text messages. However, it is important to note that only 17% of beneficiaries reported that no one in the household could

Table 6 Reported challenges with CHoBI7 mHealth program over the study period (Months 1–12) (N=896)

Challenge	mHealth with no home visits arm %(n)	mHealth with two home visits arm %(n)	P-value*
Participants were too busy to receive mobile messages	50% (216)	48% (222)	0.56
Not being able to read text messages	37% (162)	38% (175)	0.91
Mobile messages not being shared by phone owner	38% (163)	35% (164)	0.49
Damage to household phone	35% (153)	33% (154)	0.51
No one available in the household to read text messages for them	18% (78)	15% (70)	0.24
Poor cell phone reception made voice calls hard to hear	14% (61)	10% (46)	0.06
Accidentally deleted text messages before reading it	3% (13)	3% (13)	0.86
Full inbox blocked incoming messages	3% (14)	2% (10)	0.32
Accidentally hung up on voice calls before message finished	5% (21)	3% (14)	0.16
Distracting/noisy background made it hard to hear the voice calls	6% (25)	6% (29)	0.76

*P-value is a comparison of proportions by study arm.

read a text message for them. In addition, over 94% of program households report at least one person in the household that could read and write. Therefore, most beneficiaries were able to receive the content of text messages, even if they could not read the messages themselves. The literacy rate in Bangladesh for females over 15 years of age is 70% and 76% for males [27]. This finding highlights the importance of including voice messages in mHealth programs. Most mHealth programs in LMICs employ either text or voice messages; rarely, are both used [28]. Another challenge was beneficiaries being too busy to receive program messages at 49%. We tried to overcome this challenge by sending messages in the

evening when most household members were home [17]. Our approach is consistent with an mHealth program in Senegal that found that users accessed the program the most in the evening [29]. Future studies may consider evaluating the effectiveness of sending text and voice messages based on the time window requested for each individual household.

Mobile message sharing was high among beneficiaries with the majority reporting sharing CHoBI7 mHealth messages with spouses, neighbours, children, parents, siblings, in-laws, friends or co-workers. This finding is consistent with our formative research which found that participants valued the content of program messages and thought that it was important to share the content of these messages with others to help to improve their health [17]. Additional work is needed to identify the spillover effects of the CHoBI7 mHealth program to other households.

This study has some limitations. First, the study was conducted only in Dhaka and therefore cannot be generalised to rural areas in Bangladesh. Second, we focused our study on diarrhoea patient households, so these findings cannot be generalised to other populations. Third, we focused on households that reported phone ownership. Future studies should include those households that have shared access to phones.

This study has several strengths. First, the monthly mHealth surveillance allowed us to determine whether participants were receiving program mHealth messages and the challenges they were encountering. Second, the use of the process evaluation indicators developed from the VIAMO platform allowed us to determine whether program mobile messages were being received, answered and fully listened to, and whether quiz IVR messages were answered correctly. Third, the 12-month duration of the study allowed us to observe trends in fidelity indicators over time.

Conclusion

The CHoBI7 mHealth program was implemented with high fidelity, dose and reach. Through process evaluation, we identified robust indicators that can be used to track the progress of mHealth programs. This included the percentage of voice and IVR messages fully listened to and the percentage of voice, text and IVR messages received and answered as a measure of program dose and fidelity, and the number of household members that received and shared a program message as a measure of program reach. This study presents an approach for process evaluation that can be implemented to evaluate future mHealth programs globally.

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