Author’s response to reviews

Title: Formative Research for the Design of a Scalable Mobile Health Program on Water, Sanitation, and Hygiene: CHoBI7 Mobile Health Program

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Author’s response to reviews:
Dear Editorial Board,

Thank you for your thoughtful review of our manuscript. We have addressed your concerns below in the PDF named “19MARCH19. Response to Reviewers. CHoBI7 mHealth.” We could not paste in the figure we added below.

Regards,
Christine Marie

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Reviewer reports:

Sonia Hegde (Reviewer 1): This paper describes a potentially important tool for reducing cholera and overall diarrheal disease burden in Bangladesh. Though the paper describes some of the qualitative methods and results in depth, it fails to present the necessary information in the methods and results that leads the authors to conclude it presents a theory-driven evidence-based approach. Additionally, it's unclear what was done in prior manuscripts (ref 39 and 40 and 45) and how this manuscript is different. Was the theory work done in reference 45? Please clarify. I suggest changing the conclusions in this manuscript to match the objectives presented here. My detailed comments are below.

RESPONSE: The theory-based aspects of the development of the CHoBI7 mHealth intervention are the following: (1) developing mobile messages to target psychosocial factors associated with the WASH behavioral recommendations; (2) the application of the Integrated Behavioral Model for Water, Sanitation and Hygiene (IBM-WASH) framework to identify the multi-level multidimensional factors that emerged during the qualitative research; and (3) developing behavior change techniques to target these psychosocial, technological, and contextual factors that emerged from the qualitative findings. We have added Table 2 that shows the IBM-WASH framework that was applied to intervention development.

Page 4 Line 4 I suggest changing to "Sharing mobile messages with household members and having consistent phone access.." to make it more clear.

RESPONSE: We removed this statement when we updated the abstract.

Page 5 Line 50 Are there other examples of text message reminders being used for household behavior change (aside from vaccination)?

RESPONSE: Most other examples are from high income countries and focus on chronic disease management and prevention.

Page 6 Line 10 I suggest refraining from making such statements. The idea that you are the first to do something is an unnecessary claim. Omit this sentence.

RESPONSE: We think it is important to mention that this is a new emerging area.
Page 6 Line 19 What does it mean to tailor an intervention message for the target population? Perhaps elaborate if this is a key point of the novelty of your work.

RESPONSE: Tailoring an intervention means to make an intervention specific to a target population, taking into account the psychosocial, technological, and contextual factors in a given setting. We have added the below statement.

“This approach does not take into account the psychosocial, technological, and contextual factors in a given setting that could influence behavior.”

Page 6 Line 29 Seems like an important part of the paper to support the idea of using theory-based intervention approaches. As such, will be better to explain what the difference is between theory-based interventions and health education alone. Please elaborate on this.

RESPONSE: We rephrased this section to state the following.

“There is a growing evidence base demonstrating interventions that use health theory are likely to yield greater behavior change than those based on health education alone [1-6]. Theory-based interventions are guided by behavior change theories and models that provide a framework for which interventions can be delivered, examples include the Theory of Planned Behavior, Protection Motivation Theory, the Integrated Behavioral Model for Water, Sanitation and Hygiene (IBM-WASH), the Health Belief Model, and the Risks, Attitudes, Norms, Abilities, and Self-regulation (RANAS) Model [7-11].”

Page 7 Line 46 The findings in reference 39 seems to be central to this manuscript. As such, would be good to provide more information. Same with reference 40. Also, is important to distinguish the methods and findings from these prior manuscripts to the manuscript here in question. It’s inconsistently presented throughout this manuscript.

RESPONSE: We have expanded these sections below.

Previous Randomized Controlled Trial of CHoBI7 Intervention

To evaluate the efficacy of the targeted 7-day CHoBI7 WASH intervention in reducing cholera among household members of cholera patients during their one week high risk period, we conducted a RCT of CHoBI7. We compared the CHoBI7 WASH intervention to the standard recommendation given in Bangladesh to diarrhea patients at discharge on oral rehydration solution (ORS) use. Delivery of the 7-day CHoBI7 intervention resulted in a 47% reduction in overall cholera infections, and a significant reduction in symptomatic cholera during the 1 week
high risk period [12]. Consistent with these findings, the odds of handwashing with soap at food and stool related events during structured observation was 14 times higher in the CHoBI7 arm compared to the standard recommendation arm, and 94% of CHoBI7 households had free chlorine concentrations in stored drinking water greater than the CDC recommended cut-off of 0.2 mg/L [13]. There were also no stored drinking water samples in the CHoBI7 intervention arm with V. cholerae. Furthermore, the 7-day CHoBI7 intervention led to significant sustained improvements in household stored drinking water quality and observed handwashing with soap practices up to 12 months post intervention, the duration of our surveillance period [14]. These findings demonstrate that the CHoBI7 intervention presents a promising standard of care for cholera patient households during their 1 week high risk period and can result in sustained WASH practices over time.

Theory Based Approach for Development of the CHoBI7 Intervention

Using a theory-based approach, the CHoBI7 intervention was informed by components of the Protection Motivation Theory, IBM-WASH Model, and the RANAS Model [7, 9, 11]. Using these theories and models we developed behavior change techniques targeting remembering, perceived susceptibility and severity, cholera awareness, disgust, response efficacy, convenience, and self-efficacy (based on previous studies [3, 15-19]), and used Likert scale statements to measure these psychosocial factors (methods are published in George et al [20]). By measuring these psychosocial factors during our recent RCT of CHoBI7, we were able to investigate the underlying mechanism of change that led to the high handwashing with soap behavior observed among intervention participants. Response efficacy (judgments about the efficacy of a preventive response that will avert the perceived threat [11]) was found to mediate the intervention's effect on handwashing with soap habit formation at the 1-week follow-up, whereas disgust, convenience, and cholera awareness were mediators of habit maintenance at the 6 to 12-month follow-up [20]. Our study was the first RCT of a WASH intervention that conducted a mediation analysis to investigate the underlying mechanism of change in a low income country.

Page 7 Line 51 For reference 40, for example, would be useful how long the intervention lasted, how long home visits lasted and if there was monitoring after 12 months?

RESPONSE: We added “7-day CHoBI7 WASH intervention”. We have also added “the duration of our surveillance period” to clarify that the surveillance period for the intervention is 12 months. We have added that home visits are “30 minutes.”
This is a bit awkwardly worded. Do you mean "intervention sustainability" instead of "maintenance"?

RESPONSE: Habit maintenance is a crucial component of the intervention we are delivering. The term “maintenance” comes from the fifth stage of the Transtheoretical Model of Behavior Change (DiClemente & Prochaska, 1982; Prochaska & DiClemente, 1983; Prochaska, DiClemente, & Norcross, 1992; Velicer, Prochaska, & Redding, 2006).

What do you mean by "response efficacy?"

RESPONSE: Response efficacy is from Protection Motivation Theory. This is defined as “Judgments about the efficacy of a preventive response that will avert the perceived threat.” We added the definition and the reference again here in this section.


What questions were asked in the group discussion and semi structured interviews. Was there a discussion guide? Would be useful to share, particular if the purpose of this endeavor is to expand the use of this already successful mobile messaging tool.

RESPONSE: We have included in the methods section the topics included in the guide. We have added the below statement.

“The semi structured interviews and group discussions were conducted with a guide covering the following topics: current sources of health related information, experiences with the current and previous mobile health programs, and recommendations for delivery of CHoBI7 WASH mHealth program.”

Make the website an actual reference with a reference number.

RESPONSE: Added as a reference.

How exactly is the pilot study in this manuscript different than the prior CH0BI7 study? Is the pilot using the same protocol developed in the prior study?
RESPONSE: This is new a study from the previous one with different methods. There was no mHealth component in our previous study. We have revised the below statement to clarify this below.

“Therefore, this current study building on our previous work evaluates the feasibility and acceptability of implementing a mHealth program as a low cost scalable approach for CHoBI7 program delivery that does not involve frequent in-person visits.”

Page 11 Line 7 What percentage of diarrhea case households did not have a mobile phone?
RESPONSE: In our current RCT over 90% of diarrhea patient households screened report phone ownership. This statement was added to the discussion section.

Page 11 Line 14 Perhaps a chart or figure to outline the timeline of interventions (of visits and calls) would be helpful...I suggest adding one to the supplement.
RESPONSE: This is added as Supplementary Table 1.

Page 11 Line 58 Please elaborate on what you mean by convenience based sampling - does this mean only available government stakeholder members were asked to participate?
RESPONSE: We added the below statement to the methods section.

“Government stakeholders were selected if they were involved in mHealth or WASH activities at the Bangladesh Ministry of Health and Family Welfare. All government stakeholders were responsible for the implementation of government programs related to health in Bangladesh. Participants from diarrhea patient households were selected based on willingness to participate and availability of time.”

Page 12 Line 34 What are the key research questions for the analysis that were asked? Are they the same questions asked in the patient group discussion? This is a major part of your methods.
RESPONSE. We state the research questions in the “formative research aims.” I have moved these down to the methods section for clarity.
“The formative research aims were the following: (1) identify government stakeholders perceptions and preferences for scaling the CHoBI7 mHealth program in Bangladesh; (2) identify beneficiary perceptions and preferences for delivering this program (e.g. mobile message type, message content, and message timing and frequency); and (3) determine the feasibility of implementing this program (e.g. mobile phone access and message sharing).”

Page 12 Line 46 Again, please specify what convenience sampling means. Do you mean cases and individuals from case households who were at the hospital were asked to participate? It's unclear.

RESPONSE: We clarified this in our earlier response.

Page 12 Line 51 Here you describe the purpose of the group discussion with patients and patient family members. Would be nice to do this for the semi structured interviews with government stakeholders as previously stated. Why were those interviews done? What questions were asked?

RESPONSE: We added this information.

“There were 12 government stakeholder interviews to identify government stakeholder perceptions and preferences for scaling the CHoBI7 mHealth program in Bangladesh; and 28 intervention arm pilot participant interviews to identify beneficiary perceptions and preferences for delivering this program and to determine the feasibility of implementing this program.”

Page 13 Line 16 What themes did you examine in your thematic analysis? Please be more specific. Seems important to highlight the specific themes especially if the hope is for this to be expanded and repeated in other cities or countries.

RESPONSE: These themes are discussed in the result section. We organized these in the following topics. This statement was added to the methods section.

“The themes that emerged where put in the following categories: current mobile health activities, use of mobile phone messages for CHoBI7 program delivery, mobile message type preference for CHoBI7 program, sender of CHoBI7 mHealth program, message delivery and content, access to CHoBI7 mHealth messages, timing and frequency for CHoBI7 mHealth message delivery.”
Page 16 Line 48 Seems a major point in Bangladesh WASH studies to have in-person visits in order to achieve sustained behavior change - across different studies. However, this point is not expanded on much in the discussion. Would be useful to expand on this more in the discussion.

RESPONSE: We agree that this is an important topic to explore. Our upcoming paper on the findings of the randomized controlled trial of the CHoBI7 mHealth program will go into this topic in more depth. The objective of our current work is to evaluate the acceptability and feasibility of delivery of a WASH mHealth program. The findings from our current RCT will determine if this approach is effective in achieving sustained WASH behavior change without the need for frequent in-person visits.

Page 17 Line 24 Seems that another point that is not discussed much in the discussion is reaching persons who can't read and write. It's suggested that both voice and text messages are useful for this reason, but there is also no mention of how much of the population is illiterate (in urban vs rural Bangladesh) and how much of an impact this fact has on the program.

RESPONSE: I agree this is important we added a paragraph on this in the discussion. The most recent data we found did not include the urban vs. rural breakdown.

“An important contextual factor for delivery of text messages is the literacy rate in the target population. In Bangladesh, the literacy rate for females over 15 years of age is 70%, and 76% for males [54]. Furthermore, in our current work we found that greater 92% of households in slum areas of Dhaka have at least one person in the home that can read and write (Personal Communication: Christine Marie George). Given this high household literacy rate text messages presents a feasible approach for intervention delivery in our study setting.”

Page 24 Line 45 There is also little mention of the role of gender in the program roll out when it seems incorporating literature on gender dynamics in the household alongside results from the group discussions is critical. Seems this should also be discussed at greater length in the discussion as it is pertinent to the primary objective of creating a feasible, effective program.

RESPONSE: We agree this is important. We discuss in the discussion section the challenges female household members faced in accessing our mobile messages, their recommendations for resolving this challenge, and the modifications we made to the intervention content to address these challenges. We added to the discussion section a description of what components were added to the intervention, and mentioned the importance of considering gender equity during the development of WASH mHealth messages. We received the below paragraph.
“Gender norms around mobile phone access and message sharing emerged as important contextual and technological factors. Some female household members did not have consistent access to mobile phones, and reported that male household members were not always sharing CHoBI7 mHealth messages. Female participants emphasized the importance of them receiving these messages since they were often the ones responsible for taking care of young children, and wanted to keep their child healthy. This is an important challenge to address particularly if no home visits are conducted to reinforce mHealth messages, and given our setting where female household members have lower rates of phone ownership. In Bangladesh, it is estimated that 82% male adults are mobile owners compared to only 55% of adult females [50]. This gender inequity in phone ownership is likely driven by the patriarchal family structure which is common in Bangladesh [51]. The challenge of phone access is consistent with findings from the Aponjon mHealth program [52]. This program in Bangladesh delivers text messages to women during pregnancy on antenatal care. Aponjon subscribers reported that calls were sometimes missed because someone else in the household had the phone. Through CHoBI7 formative research we were able to identify potential solutions to address the challenge of message sharing and access through delivering messages at a time when most household members were present, sending messages to the phones of both female and male household members (when possible), and through discussing message sharing in the health facility and in mobile message content. The effectiveness of these approaches will be evaluated in our current RCT of the CHoBI7 intervention. This is important given that previous studies have emphasized the importance of usability and accessibility for the effectiveness and sustainability of mHealth interventions [53]. These findings highlight the importance of considering gender dynamics during message development, and the need for intervention approaches that ensure gender equity in access to message content.”

Page 26 Line 30 The beginning of the Intervention Development section discusses the targeted five key behaviors/psychosocial factors of the mHealth message, but doesn't clearly state that the formative work of relating the WASH behaviors to the psychosocial factors was done in a prior publication. That seems imperative to mention/reference. Furthermore, Table 2 shows how the messaging relates to the IBM-WASH framework but nowhere in this manuscript is it described or discussed though it seems to be a major part of what you're claiming to be a strength of the paper. Was the work for Table 2 done just for this manuscript or is it also from another reference? Please clarify. If it is for this manuscript - then it seems beneficial to talk about the theory-based approach more in detail as that is a central part of the conclusion. Again, please clarify how the objectives and results are different in this manuscript than prior manuscripts

RESPONSE: The theory-based aspects of the development of the CHoBI7 mHealth intervention are the following: (1) developing mobile messages to target psychosocial factors associated with the WASH behavioral recommendations; (2) the application of the Integrated Behavioral Model for Water, Sanitation and Hygiene (IBM-WASH) framework to identify the multi-level
multidimensional factors that emerged during the qualitative research; and (3) developing behavior change techniques to target these psychosocial, technological, and contextual factors that emerged from the qualitative findings. We have added Table 2 that shows the IBM-WASH framework that was applied to intervention development.

We have also revised the below two paragraphs to explain our approach for intervention development.

“Intervention Development

The CHoBI7 mHealth intervention program development targeted five key behaviors: (1) preparing soapy water using water and detergent powder; (2) handwashing with soap at food and stool related events; (3) treating household drinking water using chlorine tablets during the one week high risk period after the diarrhea patient in the household was admitted to the health facility; (4) safe drinking water storage in a water vessel with cover; and (5) heating of household drinking water until it reaches a rolling boil after the one week high risk period. The CHoBI7 mHealth program was developed through a theory-based approach which was informed by the IBM-WASH Model and Protection Motivation Theory [25, 29]. Intervention development was guided by the IBM-WASH Model to target the habitual, individual, interpersonal/household, community, and structural/societal-level factors that are drivers of our target WASH behaviors [25]. For example, higher-level contextual and technological factors, such as national policies on WASH and delivery of mHealth messages to the public were considered through the engagement of government stakeholders in intervention development; and habitual level factors such as frequency of exposure to mobile messages were explored by engaging pilot participants in interviews and discussion groups. This multi-level approach allowed us to develop behavior change techniques to regulate factors identified during formative research that facilitated or impeded the targeted behaviors.

mHealth messages were developed to target the following psychosocial factors: response efficacy of the behavioral recommendations, remembering of handwashing with soap, water treatment, and safe water storage, convenience (e.g. promoting the use of enabling hardware), awareness of diarrhea transmission and prevention, nurture towards children in the household, self-efficacy of behavioral recommendations, feelings of disgust towards feces, perceived severity and susceptibility, and gender norms and roles (e.g. acceptability of the female household members receiving mHealth messages) [25, 29]. Table 1 includes examples of the mHealth Behavior Change Techniques included in the CHoBI7 mHealth program to target these psychosocial factors and IBM-WASH dimensions. These psychosocial factors were identified through: (1) the formative research findings presented in this publication (gender norms/roles, nurture, and remembering); (2) psychosocial factors associated with habit formation and maintenance in our previous RCT of the CHoBI7 intervention (response efficacy, disgust,
convenience, and diarrhea disease awareness) [44]; and (3) factors found in previous studies to be associated with WASH behavior change (self-efficacy and descriptive norms [25] and perceived severity and susceptibility [29, 30]).”

Page 27 Line 50 Are participants able to text/call Dr. Chobi back with questions? Is there a hotline? Please clarify.

RESPONSE: There was no call or text back option available, or hotline. This statement was added to the methods section.

“There was no call or text back option available, or hotline.”

Page 28 Line 33 You state that phone messages were sent to husbands to inform them that their wife's phone would also be messaged - would be nice if you could also cite other literature on how to reach mothers/women in households.

RESPONSE: We would like to clarify that the recommendation to send CHoBI7 mHealth messages to both male and female household members is given by a health promoter during health facility delivery of the program (not by phone). We have pasted this paragraph below.

“In an effort to increase access to mHealth messages among female caregivers, we added a module delivered by a promoter in the health facility during the patient’s stay in the hospital for illness on mHealth message delivery and access. During this module the promoter starts by asking diarrhea patients and their family members which phones in the household should receive CHoBI7 mHealth messages. The health promoter then recommends mobile messages be sent to the phone of the primary child caregiver in the home, when possible, explaining the importance of caregivers receiving these messages for the health of their children (targeting nurture). Promoters also explain that a female health provider will be contacting them, never a male. This module was included to try to alleviate concerns from husbands about voice and text messages being sent to their wife’s phone, and based on recommendations to send phone messages to the female household members (targeting gender norms).”

Page 29 Line 20 You continually state that you are presenting a novel theory driven evidence based approach - but it seems that work was actually done in another manuscript and the purpose of this manuscript was to design program implementation based on qualitative data. There is no
theory discussed in this manuscript except for Table 2, which is not discussed at all in detail in this paper. I suggest editing this sentence to say what was actually done in this manuscript - even to say "using a previously developed theory driven approach..."

RESPONSE: We have added the below two paragraphs to explain in more detail how health theory was incorporated into the delivery of this intervention.

“Intervention Development

The CHoBI7 mHealth intervention program development targeted five key behaviors: (1) preparing soapy water using water and detergent powder; (2) handwashing with soap at food and stool related events; (3) treating household drinking water using chlorine tablets during the one week high risk period after the diarrhea patient in the household was admitted to the health facility; (4) safe drinking water storage in a water vessel with cover; and (5) heating of household drinking water until it reaches a rolling boil after the one week high risk period. The CHoBI7 mHealth program was developed through a theory-based approach which was informed by the IBM-WASH Model and Protection Motivation Theory [25, 29]. Intervention development was guided by the IBM-WASH Model to target the habitual, individual, interpersonal/household, community, and structural/societal-level factors that are drivers of our target WASH behaviors [25]. For example, higher-level contextual and technological factors, such as national policies on WASH and delivery of mHealth messages to the public were considered through the engagement of government stakeholders in intervention development; and habitual level factors such as frequency of exposure to mobile messages were explored by engaging pilot participants in interviews and discussion groups. This multi-level approach allowed us to develop behavior change techniques to regulate factors identified during formative research that facilitated or impeded the targeted behaviors.

mHealth messages were developed to target the following psychosocial factors: response efficacy of the behavioral recommendations, remembering of handwashing with soap, water treatment, and safe water storage, convenience (e.g. promoting the use of enabling hardware), awareness of diarrhea transmission and prevention, nurture towards children in the household, self-efficacy of behavioral recommendations, feelings of disgust towards feces, perceived severity and susceptibility, and gender norms and roles (e.g. acceptability of the female household members receiving mHealth messages) [25, 29]. Table 1 includes examples of the mHealth Behavior Change Techniques included in the CHoBI7 mHealth program to target these psychosocial factors and IBM-WASH dimensions. These psychosocial factors were identified through: (1) the formative research findings presented in this publication (gender norms/roles,
nurture, and remembering); (2) psychosocial factors associated with habit formation and maintenance in our previous RCT of the CHoBI7 intervention (response efficacy, disgust, convenience, and diarrhea disease awareness) [44]; and (3) factors found in previous studies to be associated with WASH behavior change (self-efficacy and descriptive norms [25] and perceived severity and susceptibility [29, 30]).”

Page 29 Line 40 I suggest omitting this sentence - better to refrain from making such claims.

RESPONSE: We would like to highlight that this is a novel area of research.

Page 30 Line 53 The fact that many female household member did not have consistent access to mobile phones seems quite critical even though both male and females in households are being sent voice and text messages. If many females don't even have access to phones, it defeats the purpose. What percentage of women do not have mobile phones? (urban vs. rural) This seems important for the ministry to know in order to assess how to roll out the program. Is contacting men vs women more effective in households?

RESPONSE: In Bangladesh, it is estimated that 82% male adults are mobile owners compared to only 55% of adult females [23]. This was added to the discussion section with a further discussion on this issue. The most current data did not provide a breakdown by rural vs. urban.

“Gender norms around mobile phone access and message sharing emerged as important contextual and technological factors. Some female household members did not have consistent access to mobile phones, and reported that male household members were not always sharing CHoBI7 mHealth messages. Female participants emphasized the importance of them receiving these messages since they were often the ones responsible for taking care of young children, and wanted to keep their child healthy. This is an important challenge to address particularly if no home visits are conducted to reinforce mHealth messages, and given our setting where female household members have lower rates of phone ownership. In Bangladesh, it is estimated that 82% male adults are mobile owners compared to only 55% of adult females [50]. This gender inequity in phone ownership is likely driven by the patriarchal family structure which is common in Bangladesh [51]. The challenge of phone access is consistent with findings from the Aponjon mHealth program [52]. This program in Bangladesh delivers text messages to women during pregnancy on antenatal care. Aponjon subscribers reported that calls were sometimes missed because someone else in the household had the phone. Through CHoBI7 formative research we were able to identify potential solutions to address the challenge of message sharing and access through delivering messages at a time when most household members were present, sending
messages to the phones of both female and male household members (when possible), and through discussing message sharing in the health facility and in mobile message content. The effectiveness of these approaches will be evaluated in our current RCT of the CHoBI7 intervention. This is important given that previous studies have emphasized the importance of usability and accessibility for the effectiveness and sustainability of mHealth interventions [53]. These findings highlight the importance of considering gender dynamics during message development, and the need for intervention approaches that ensure gender equity in access to message content.”

Page 31 Line 53 Was a formal cost-effectiveness analysis done comparing different interventions?
RESPONSE: No. This will be done at the end of the current randomized controlled trial.

Page 32 Line 31 So changes were made to the mHealth messages based on the pilot study - but in this manuscript it is very unclear what exactly the before and after were. Seems it was more how the delivery of messages happened rather than changes to the messages themselves as I think the five main factors still stayed the same correct? Again, I think it would help to clarify what was done previously and what new methods and results are being presented in this manuscript.
RESPONSE: We have added Figure 1 which summarized the formative research activities and the revisions made to the intervention based on qualitative research findings.

We have also added Supplementary Table 3 which summarizes the intervention components that were informed by the formative research. We did not change the 5 key behavior targeted.

Additionally, in this paragraph on strengths you mention that the use of health theory is a strength - it is indeed a strength and sadly seldom used. However, again, this manuscript fails to go into detail of the theories that were used and how they were used to develop the interventions. Please clarify.
RESPONSE: The theory-based aspects of the development of the CHoBI7 mHealth intervention are the following: (1) developing mobile messages to target psychosocial factors associated with the WASH behavioral recommendations; (2) the application of the Integrated Behavioral Model for Water, Sanitation and Hygiene (IBM-WASH) framework to identify the multi-level multidimensional factors that emerged during the qualitative research; and (3) developing
behavior change techniques to target these psychosocial, technological, and contextual factors that emerged from the qualitative findings. We have added Table 2 that shows the IBM-WASH framework that was applied to intervention development. We elaborated on this further in our earlier responses.

Page 33 Line 4 Does mobile phone ownership decrease as you move farther away from urban areas? What does that distribution look like? Seems important for stakeholders to know for program implementation.

RESPONSE: We do not have data on this.

Page 33 Conclusion - Seems this method of intervention delivery could also be useful for surveillance, particularly if household members are able to text back if other household members get sick. Could expand on the potential utility of mHealth in Bangladesh as the purpose of this manuscript started with the Ministry asking for formative work on feasibility of program delivery and utility. Discussion of the potential for a mobile app would also be interesting.

RESPONSE: We agree mHealth presents a promising surveillance tool. We intentionally did not use mHealth for surveillance and have left this out of the manuscript because of concerns that the two type of messages (health promotion and surveillance) would be confused by participants.

Overall, I think this paper needs great clarity on what its objective is and how it is different than prior papers. After defining that, it needs to focus on presenting results specific to this objective and conclusions specific to this objective and not results or conclusions from prior work. Because as is, there is no theory discussed in the body of this manuscript. If I am mistaken and Table 2 was in fact developed for this manuscript, then it needs to be described in the methods and results section in more detail. Either way, this paper is not clearly presented. However, I do feel the results are indeed important to share - that a mHealth WASH intervention is effective.

RESPONSE: These concerns are addressed in our responses above.
James B Tidwell, PhD (Reviewer 2): This paper addresses important topics, both in understanding handwashing behavior change and the use of mHealth interventions, and fills a void in the literature, namely the use of intentional, theoretically-driven methods of formative research and the reporting of those findings. There are several strengths of the manuscript, including the adaptation of a program previously demonstrated to be effective whose evaluation yielded theoretical insights into how such an mHealth intervention might work; the broad engagement of stakeholders in designing the program for large-scale uptake; and the extensive feedback solicited from end users.

There are a couple of changes which in my opinion would make the manuscript much stronger. Specifically:

1) There is a discussion of conducting theory-driven formative research, but it seems from my reading that the main use of theory was in identifying behavioral determinants from the prior program to use in the current one through the evaluation of the prior program. The other mention of theory I found was the description of drawing from multiple theoretical frameworks without discussion of how that is done (i.e., simply taking determinants from different frameworks is far from a neutral approach to theory). I think that there is a great opportunity to strengthen the conclusions if theory is referenced/used in any or all of the following ways: (1) The process by which FR was done (e.g., stakeholder engagement, iterative testing, etc., and how that impacted the design process), (2) The theory used to adapt a non-mHealth intervention to an mHealth intervention (this is not my area, but I think that this would be fascinating to consider and demonstrate for others, especially given what seems to me to be the common assumption that a non-mHealth intervention simply translated into text messages or an app is somehow an effective way to develop an mHealth intervention), or (3) The behavior change framework(s) used (either the original source theory, or amalgamation of theories, with a resulting theoretical framework)-as much as possible given that some of this may be post-data collection theoretical exploration (though re-examining interviews from a new theoretical lens may be to some extent possible), but this would also be useful in the planned RCT evaluation to better understand program effects.

RESPONSE: Thank you for your review of our manuscript. The theory-based aspects of the development of the CHoBI7 mHealth intervention are the following: (1) developing mobile messages to target psychosocial factors associated with the WASH behavioral recommendations; (2) the application of the Integrated Behavioral Model for Water, Sanitation and Hygiene (IBM-WASH) framework to identify the multi-level multidimensional factors that emerged during the qualitative research; and (3) developing behavior change techniques to target these psychosocial, technological, and contextual factors that emerged from the qualitative findings. We have added Table 2 that shows the IBM-WASH framework that was applied to intervention development.
We have also revised the two paragraphs below on how health theory informed intervention development.

“Intervention Development

The CHoBI7 mHealth intervention program development targeted five key behaviors: (1) preparing soapy water using water and detergent powder; (2) handwashing with soap at food and stool related events; (3) treating household drinking water using chlorine tablets during the one week high risk period after the diarrhea patient in the household was admitted to the health facility; (4) safe drinking water storage in a water vessel with cover; and (5) heating of household drinking water until it reaches a rolling boil after the one week high risk period. The CHoBI7 mHealth program was developed through a theory-based approach which was informed by the IBM-WASH Model and Protection Motivation Theory [25, 29]. Intervention development was guided by the IBM-WASH Model to target the habitual, individual, interpersonal/household, community, and structural/societal-level factors that are drivers of our target WASH behaviors [25]. For example, higher-level contextual and technological factors, such as national policies on WASH and delivery of mHealth messages to the public were considered through the engagement of government stakeholders in intervention development; and habitual level factors such as frequency of exposure to mobile messages were explored by engaging pilot participants in interviews and discussion groups. This multi-level approach allowed us to develop behavior change techniques to regulate factors identified during formative research that facilitated or impeded the targeted behaviors.

mHealth messages were developed to target the following psychosocial factors: response efficacy of the behavioral recommendations, remembering of handwashing with soap, water treatment, and safe water storage, convenience (e.g. promoting the use of enabling hardware), awareness of diarrhea transmission and prevention, nurture towards children in the household, self-efficacy of behavioral recommendations, feelings of disgust towards feces, perceived severity and susceptibility, and gender norms and roles (e.g. acceptability of the female household members receiving mHealth messages) [25, 29]. Table 1 includes examples of the mHealth Behavior Change Techniques included in the CHoBI7 mHealth program to target these psychosocial factors and IBM-WASH dimensions. These psychosocial factors were identified through: (1) the formative research findings presented in this publication (gender norms/roles, nurture, and remembering); (2) psychosocial factors associated with habit formation and maintenance in our previous RCT of the CHoBI7 intervention (response efficacy, disgust, convenience, and diarrhea disease awareness) [44]; and (3) factors found in previous studies to be associated with WASH behavior change (self-efficacy and descriptive norms [25] and perceived severity and susceptibility [29, 30]).”
We have also added Figure 1 which summarized the formative research activities and the revisions made to the intervention based on qualitative research findings.

We have also added Supplementary Table 3 which summarizes the intervention components that were informed by the formative research.

2) A constant challenge with small sample, qualitative FR to directly feed into a behavioral intervention is how to elicit preferences that are meaningful and that might lead to the greatest behavioral impacts (e.g., it is unsurprising that the government officials recommended the source of the messages be a government official!). It would be helpful to provide more critical reflection on the stated preferences of individuals, perhaps couched in relevant literature (e.g., are voice vs. text messages actually more effective? how often should messages be sent?) to the degree possible.

RESPONSE: Thanks for your insights. We have summarized how formative research activities have informed intervention development in Figure 1. We have also added this in more detail in Supplementary Table 3, and have described stakeholder feedback on voice vs. text messages in more detail in the discussion section (see below). The literature is actually very limited on whether voice vs. text messages are more effective because most mHealth intervention pick one or the other. We could not find information on this for low and middle income countries. We have added a sentence on this in the discussion section.

“Both text and voice messages were considered to be important by beneficiaries and government stakeholders. Voice messages were seen as beneficial because they could be understood by those that could not read and write. While text messages were viewed as being valuable because they could be saved and viewed later and shared messages with others. Text messages were also stated to serve as important reminders to perform the promoted WASH behaviors. This finding lead to the delivery of voice messages followed by a summary text message in the CHoBI7 mHealth program. Most mHealth programs rely on either text or voice message, and rarely employ both, therefore this is an important finding that should be explored in future work [13]. Future studies should investigate preferences around voice and text messages for delivery of WASH interventions in other settings.”

There are a couple of other small issues I noticed (this is far from comprehensive- these are just the ones that jumped out at me):

P28, L51 "shorten" -> "shortened"

P29, L4 "charge" -> "charged"

Lots of noun phrases used as adjectives that need hyphenation (e.g., "theory-driven approach")
These edits were added.

There are also a few references that could be quickly updated—specifically, updated diarrheal disease burdens, portions attributable to handwashing, and figures on handwashing rates after contact with excreta globally.


These references were added.


22. Bangladesh. UNESCO.


