

RESEARCH

Open Access



Community health workers' usability and acceptability of an mHealth tool for post-cesarean assessments: A mixed-methods study in rural Rwanda

Eve Hiyori Estrada^{1*}, Bethany Hedt-Gauthier^{1,2}, Jonathan Nkurunziza³, Marthe Kubwimana³, Sarah Nuss^{2,4}, Callum Forbes^{2,5}, Faith Odwaro², Carol Mugabo³, Adeline Adwoa Boatın^{2,6}, Musafiri Tumusime³, Laban Bikorimana³, Naphtal Nyirimanzi³, Anne Niyigena³, Siona Prasad⁷, Robert Riviello^{1,2,8}, Fredrick Kateera³, Andrew Oryono³, Kelly Bogaert⁹, Richard Ribon Fletcher¹⁰, Nissi Byiringiro¹¹ and Vincent Kalumire Cubaka¹²

Abstract

Introduction Cesarean sections (c-sections) are one of the most common surgical procedures globally. Compared to vaginal birth there is an increased risk of postpartum complications following c-section. Returning to health facilities for postpartum monitoring can be challenging due to physical, logistic, and financial barriers, particularly for rural communities. With 94% of Kirehe District's population being rural, this district is an excellent proxy for Rwanda as a whole. Community health workers (CHWs) provide a crucial link between communities and health services, but in Rwanda they do not currently follow women after cesarean due to medical complexity. Our team developed a mobile-health (mHealth) tool to enable CHW-led community-based post-cesarean care. In this study, we assessed the usability and acceptability of the mHealth tool among CHWs in Kirehe District, Rwanda.

Methods The study took place from March–April 2023. We randomly selected 30 CHWs serving in Kirehe District, Rwanda and trained them to use the mHealth-CHW tool, including symptom-based questionnaire administration and image capture. We then administered three vignettes each replicating home visits and recorded CHWs' ability to use the tool. CHWs then completed a validated Community Health Worker mHealth Usability and Acceptability Assessment Tool survey followed by a focus group discussion. We report the overall vignette scenario scores, and the average score, percentage, and standard deviation of each category. We analyzed the proportion of CHWs who "Agreed" or "Strongly agreed" with the survey questions, conducted a thematic analysis of the focus group discussions, then convergently analyzed both quantitative and qualitative results.

Results The average evaluation scores from the vignette scenarios was 8.53 (± 0.95) out of 10 possible points. All CHWs "Agreed" or "Strongly agreed" with 80% or more of the usability statements presented, surpassing our pre-

*Correspondence:
Eve Hiyori Estrada
eve_estrada@hms.harvard.edu

Full list of author information is available at the end of the article



© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

specified threshold for success. Similarly, focus group discussion results found that the mHealth-CHW tool was a usable and acceptable tool to facilitate post-cesarean care.

Conclusions Given that the mHealth-CHW tool was quantitatively and qualitatively determined to be highly usable and acceptable, we have advanced to a community validation of the clinical features of this tool. The mHealth tool could be valuable for CHWs to provide post-cesarean follow-up in other settings.

Keywords Mobile-Health, C-section, Rural health, Postpartum care, Sub-Saharan africa, Community health

Introduction

Cesarean deliveries are one of the most common surgical procedures performed around the world, with nearly 1 in 5 live births being delivered by cesarean [1]. Although increased access to cesareans have contributed to reduced maternal mortality, particularly in sub-Saharan Africa (SSA) [1] there is a broad list of potential postoperative complications that may occur. Excluding hemorrhage, women who deliver via cesarean are overall more likely to experience postpartum complications compared to women who delivered vaginally [2]. Studies comparing risk of complications between vaginal delivery and cesarean delivery indicate increased risk of various complications for women who have had cesarean delivery, including embolism, eclampsia, postoperative bleeding, and urinary tract infection [2–4]. Among the potential complications that may be faced, surgical site infection (SSI) is the most common post-cesarean section (c-section) complication in SSA, with studies identifying rates of SSI ranging from 7.3–15.6% [5–7].

While post-cesarean monitoring is critical to ensure timely identification and management of complications, facility-based follow-up can be challenging for many women. Women in rural areas face barriers not only because they are still physically recovering from surgery but also for logistic and financial reasons. Women in SSA, where over half the population resides in rural communities [8] are less likely to access postpartum healthcare compared to their urban counterparts [9]. Distance to health facilities and the costs incurred to reach them are two notable barriers to postpartum service accessibility in the setting [9, 10]. Lack of time, distance to healthcare providers, and lack of guardians to support childcare are also barriers to accessing postpartum care [11].

Through providing care within the communities women live in, in many low- and middle-income countries community health workers (CHWs) are able to bridge gaps in care accessibility and delivery, particularly for maternal health care services [12]. In Rwanda, where there are over 45,000 active CHWs, one fourth of them are specifically responsible for the support of maternal and newborn health [13, 14]. In their current scope of work, CHWs serve all pregnant women, newborns, and women who have given birth vaginally. However, they currently do not follow women delivered via cesarean due

to the complexity of care required. Instead, these women are instructed to return to health centers for postpartum care.

Most mobile health (mHealth) applications for maternal health care delivery identified in a systematic review were found to focus on pregnant women and were developed in high-income countries [15]. However, across the world mHealth tools have become recognized for their potential to enhance healthcare service delivery, particularly for CHWs in resource constrained settings [16, 17]. These interventions can empower frontline healthworkers including CHWs to facilitate care both by improving communication and facilitating decision support during follow up [18, 19]. As such, mHealth tools present a promising avenue to overcome the gap in accessibility for postpartum care and to support CHWs to provide high quality post-cesarean care.

In Rwanda, 82.5% of major surgeries are conducted in the country's district hospitals; 60% of these surgeries are cesarean deliveries [20]. In Kirehe District, 7.8% of all babies are born via cesarean [21]. Kirehe District Hospital (KDH) serves over 460,000 district residents, providing tertiary care for patients referred from one of the sixteen health centers within the district as well as two health centers located in Mahama Refugee Camp [22, 23]. The majority (94%) of Kirehe's population is rural, making this district an excellent proxy for the 30 districts in Rwanda where most individuals live in rural setting [24]. In previous studies in Kirehe, women who have delivered via cesarean have reported that facility-based postpartum follow-up is both physically and financially challenging [25]. To address this gap, our team has developed an mHealth tool to support CHW-led, home-based follow-up after cesarean delivery. The goal of this research is to evaluate usability and acceptability of this mHealth tool among CHWs working in rural Rwanda and to explore the factors contributing to their perceptions of the tool.

Methods

Study setting

This study was conducted from March–April 2023 in Kirehe District, located in the Eastern Province of Rwanda. KDH operates under the Rwandan Ministry of Health and is supported by the Partners In Health Rwanda, known locally as Inshuti Mu Buzima (IMB).

The mHealth-CHW tool for post-cesarean care

The mHealth-CHW tool was developed in partnership with IMB, Harvard Medical School, Massachusetts Institute of Technology and Insightiv, a Rwandan technology startup leveraging artificial intelligence to address Rwanda's health systems challenges. The app, developed by Insightiv, has three primary modules: (1) Links to records for the patients to be visited that day; (2) Prompts to guide CHWs through patient clinical assessments and, if needed, referrals; and (3) Prompts to counsel women through general post-cesarean recovery. All of the app content was developed for Rwanda and east Africa using a Delphi process [26].

The clinical assessment module has two parts. First, there is a symptom and complication screening questionnaire, whereby women are asked to self-report presence of any of the following symptoms: pain in chest, or racing or fluttering heartbeat; difficulty breathing or shortness of breath; painful breasts (burning or extreme tenderness) and fever; worsening or extreme abdominal pain; worsening or extreme pain at wound site or incision; thick discharge (yellow, white, bloody) from the wound, or redness, hardness, or separation of incision; calf pain, or red or swollen leg that is painful or warm to touch; excessive vaginal bleeding, or blood clots the size of an egg or bigger; foul smelling or yellow-green vaginal discharge; burning or pain with urination; four days or more since passing stool or more than one day since passing gas; fever with or without shivering; seizures; constant headache, or headache with change in vision, nausea, vomiting, abdominal pain, feeling faint, or convulsions; persistent nausea or vomiting; dizziness; feeling low in spirits or emotional; having difficulty caring for themselves or their baby; having thoughts of harming themselves or their baby; experiencing violence or feeling unsafe at home. The symptoms are linked to complications women may face post-c-section, for instance, swelling may indicate a deep vein thrombosis. The second component of the mHealth tool is a mobile library that facilitates standardized capture of a high-quality image of the cesarean incision and processing of the images using a machine learning algorithm, trained on women residing in rural Rwanda to predict presence of an SSI [27, 28]. All app content is viewable in both Kinyarwanda, the local language in Rwanda, and English. The app is able to function offline in order to be usable in communities without cellular coverage. At the end of the visit, the app then prompts the CHW to provide guidance to return to a health facility for care, if need be, according to the woman's symptoms and the incision classification.

Overview of activities

At a selected health center, study activities took place over the course of two days. On the first day, study team

members led an introduction to the mHealth-CHW tool, introducing the various functions and navigation of the app. The CHWs were then given time to complete a series of practice assessments; these assessments consisted of tasks that allowed CHWs to practice navigating the tool, such as login, viewing patient records, and initiating a visit. There was also the opportunity to navigate the apps using vignettes for further practice. Formal assessments were completed on the second day, during which CHWs undertook usability assessments with three vignettes each. CHWs were then surveyed quantitatively on the usability and acceptability of the tool, and participated in a focus group discussion for a qualitative assessment of usability and acceptability. We provide more details of these formal assessments below.

CHW sample size and selection

To capture the geographic variation in CHW perspectives of post-c-section follow-up, we randomly selected three of the 16 health centers in Kirehe District. From these health centers, we randomly sampled five CHWs located within two kilometers of the health center and five CHWs located further than two kilometers from the health center; we stratified by health center proximity because we hypothesized that this could affect exposure to smartphones and digital literacy. In total we recruited 30 CHWs – 15 CHWs residing within two kilometers from their health center and 15 CHWs who resided further than two kilometers from their health center. Our sample size allowed us to complete rapid assessments and compare performance to our usability and acceptability thresholds, described in more detail below. If we failed to achieve these thresholds, we would continue to update the mHealth tool and evaluate iteratively until these thresholds were achieved.

CHW usability and acceptability assessments

Design and administration of vignettes

In order to test the usability of the mHealth-CHW tool our team developed vignettes emulating CHWs follow-up of patients at their homes. Vignettes were made to represent three different scenarios: follow-up of patients with normal recovery (no complications), follow-up of patients experiencing complications, and follow-up with a forced user/app errors (e.g., needing to change patient responses). Five vignettes were made for each scenario, resulting in fifteen total vignettes. Three Obstetrician/Gynecologists (AB, AO, KB) were asked to review vignettes and provide feedback upon initial development and again after feedback was implemented. The vignettes were then pretested with three CHWs for additional feedback through semi-structured interviews and face validation of the vignettes. The final vignettes are

available in both Kinyarwanda and English (see Additional file 1 and Additional file 2, respectively).

For the vignette administration, CHWs were randomly assigned three vignettes representing one of each of the follow-up scenario. The CHW would then conduct a sample post-cesarean home visit using the tool with the patient actor (a study team member). A facilitator observed the interaction and completed the facilitator evaluation guide based on completion of core steps.

Assessments

Completion of core steps

Study data collectors used an evaluation guide to score the CHW use of the mHealth tool in each vignette scenarios across three scoring areas: (1) CHWs' general fulfillment of visit steps (e.g., introducing themselves at the start of the interaction); (2) if each question was asked as indicated by the app; and (3) if the correct answer was entered according to the patient response.

The community health worker mHealth usability and acceptability assessment tool

Following the completion of vignettes, CHWs completed quantitative and qualitative assessments of the tool's usability and acceptability. We created a new tool for this study's quantitative assessment. Our team adapted two existing tools – the mHealth App Usability Questionnaire and the Practitioner Opinion (Acceptability) Scale – which are used to assess mHealth usability and acceptability, respectively [29, 30]. We also included several additional items for usability regarding our tools core functions. The resulting questions were adapted to be comprehensible at a sixth-grade reading level and underwent a cross-language translation process, which consisted of translation into Kinyarwanda, back translation, and harmonization between a study team member and independent translator. All items then underwent content evaluation to assess relevancy and clarity of the tool by eight content experts and then face evaluation assessing the clarity and comprehensibility by ten CHWs. Items were dropped if the content-validity index was less than 0.78 or if face validation content-validity index was less than 0.60. The development and validation of the full tool, referred to as the Community Health Worker mHealth Usability and Acceptability Assessment Tool (CHW-MUAAT), is further described elsewhere [31]. Each item in the tool were captured on a Likert-scale from 1 to 5, with 1 being “Strongly disagree” and 5 being “Strongly agree”. For the tool to be considered usable and acceptable we predetermined thresholds that 80% of CHWs should “Agree” or “Strongly Agree” with 80% of the statements presented. The final tool contains 22 items, with 18 usability statements and four acceptability statements (see Additional file 3); The Cronbach's alpha value for the

final items was 0.86 for the 12 MUAQ usability questions, 0.73 for the four POAS acceptability questions and 0.87 for questions added by the study team [31].

Focus group discussions

Following completion of the CHW-MUAAT, CHWs participated in focus group discussions. Groups included the five CHWs at a health center from the same distance strata (within or further than two kilometers away); in total, six focus group discussions were conducted.

Our team developed a series of questions asking about the CHWs' experiences following postpartum women, their perception of the mHealth-CHW tool, and any suggestions they might have for the intervention (see Additional file 4). CHWs in the focus group took turns reading questions from the focus group discussion guide aloud for the discussion. We used a low moderator involvement approach whereby the moderator ensured questions were sufficiently addressed through probing brief responses but did not engage in discussion. Study team members MK and JN served as moderators for these focus group discussions.

Within focus groups, the study team member concluded the groups once no new topics were emerging in the discussion. Focus group research literature states that saturation can be achieved at three focus groups per stratum [32]; the team members leading the focus groups discussion did not observe new themes emerging in the last groups as compared to the first and thus the focus groups were concluded after the six.

Analysis

Because quantitative and qualitative data were collected on the same day, we used a convergent mixed method design for our analysis. We conducted the quantitative and qualitative analysis separately and then compared against each other to fully understand the usability and acceptability of the mHealth-CHW tool.

Quantitative analysis

We described the overall vignette scenario scoring from the facilitator evaluation as numbers and percentages out of all vignettes administered ($n=90$). The scoring is broken down by performance, ranging from evaluation scores of 70 to 100%. We separately analyzed each item within the scores (i.e., fulfillment of visit steps, asking questions as indicated, and recording answers as indicated) as the average score, percentage, and standard deviation of each category. Vignette assessments were entered directly into and analyzed in Google sheets.

We analyzed the proportion of CHWs who “Agreed” or “Strongly agreed” with each CHW-MUAAT question and presented them as numbers and percentages out of all CHWs. We pre-specified that 80% or more of CHWs

Table 1 Demographic information of CHWs (*n* = 30)

Demographic characteristic	<i>n</i>	%
Age		
26–35 years	3	10.0
36–45 years	16	53.3
46 + Years	11	36.7
Marital Status		
Married	29	96.7
Divorced/widowed	1	3.3
Education		
Completed primary school	25	83.3
Completed secondary school	5	16.7
Other livelihood		
No other formal activities/cultivator	15	50.0
Own business generating monthly income	15	50.0
Distance from Health Center		
Within 2 km	15	50.0
Greater than 2 km	15	50.0
Own a smartphone as a personal device		
Yes	2	6.7
No	28	93.3
Number of years as CHW		
1–2 years	4	13.3
3–5 years	1	3.3
6+ years	25	83.3

should have agreed with the statements with 14 out of 18 usability statements and 3 out of 4 acceptability statements for the mHealth tool to be deemed usable and acceptable. Data were collected using REDCap and analyzed using Stata version 16.

Qualitative analysis

We used thematic analysis to evaluate the results of the focus group discussions. The team first did inductive parallel coding, with two team members developing codes in Kinyarwanda using the original transcripts and one team member developing codes using transcripts translated to English. The team members then compared codes and had discussions to resolve any disagreements in coding. The two codebooks were then reconciled to develop the master codebook. This process of parallel coding ensured no themes were lost in translation of the focus group discussions and that meanings were being preserved in the process. All qualitative analysis was done in MAXQDA Analytics Pro 2020.

Results

Description of CHWs

Most recruited CHWs were married (*n* = 29, 96.7%), did not use a personal smartphone (*n* = 28, 93.3%), and had served as CHWs for six or more years (*n* = 25, 83.3%) (Table 1). All had completed at least primary school, and half of them (*n* = 15) were cultivators or had no formal profession.

Table 2 Vignette step completion and facilitator assessment

Facilitator evaluation of CHW usability testing		
Number of scenarios performed with score of	Number of CHW scenarios (<i>N</i> = 90)	Percent
100%	54	60.0
> 90%	58	64.4
> 80%	80	88.9
> 70%	85	94.4
Number of CHWs who scored 100% in	Number of CHWs (<i>N</i> = 30)	Percentage
3/3 scenarios	11	36.7
2/3 scenarios	8	26.7
1/3 scenarios	5	16.7
0/3 scenarios	6	20.0
Number of CHWs with at least one scenario scoring 100%	24	80.0
Component break-down of CHW usability testing scores	Average score	Standard deviation
Facilitator evaluation score (Out of 10)	8.53	0.95
Questions asked as prompted by tool (Out of 19)	18.46	1.02
Patient responses input into application correctly (<i>N</i> = 19)	18.72	0.63

Completion of critical vignette steps

Each of the 30 CHWs participated in three scenarios of role-play with a validated vignette for a total of 90 scenarios performed for the study. Study facilitators scored the interaction based on a 10-question evaluation of the CHW. Of these 90 scenarios, 54 (60%) performed scored a facilitator evaluation score of 100% (Table 2). Of the 30 CHWs, 24 (80%) CHWs had at least one scenario with a facilitator score of 100%; 11 (36.7%) of them had scores of 100% for all three scenarios they performed. The average facilitator evaluation score was 8.53 (± 0.95) out of 10 possible points. Of the 19 questions that CHWs were prompted to ask by the mHealth tool, CHWs asked an average of 18.46 (± 1.02) questions correctly, and input an average of 18.72 (± 0.63) of the responses provided during the scenarios correctly.

CHW-MUAAT results

Across the 18 usability statements, between 27–30 CHWs (90–100%) “Agreed” or “Strongly agreed” with the statements (Table 3). The lowest rating for any given question was “Neutral”. The lowest scoring usability statements were “It is easy for me to learn to use the app”, “Whenever I make a mistake on the app, it is easy and quick to correct it”, and “I can use the app even when the Internet connection is poor or not available”, with 28 (93.3%) stating “Agreed” or “Strongly agreed”. All of the 30 CHWs (100%) “Agreed” or “Strongly agreed” with the 80% or more of the 18 usability statements presented.

Table 3 CHW responses to usability and acceptability survey (the community health worker mHealth usability and acceptability assessment tool (CHW-MUAAT))

	Statement	Number of CHWs who 'Agreed' or 'Strongly agreed' with the statement (N = 30)	Percent
Usability	The app is easy for me to use.	30	100.0
	It is easy for me to learn to use the app.	28	93.3
	Whenever I make a mistake on the app, it is easy and quick to correct it.	28	93.3
	I like the interface of the app.	30	100.0
	The information in the app is well organized, so I can easily find the information I need.	30	100.0
	The time it takes to use this app works well for me.	29	96.7
	Overall, I am satisfied with this app.	30	100.0
	The app improves my ability to deliver healthcare services.	30	100.0
	The app helps me manage my patient's health effectively.	30	100.0
	This app has all the functions and capabilities I expected it to have.	30	100.0
	I can use the app even when the Internet connection was poor or not available.	28	93.3
	This app would be useful for my home visits to women after cesarean section.	30	100.0
	It is easy for me to log into the app with my username and password.	29	96.7
	It is easy for me to find the correct patient using the patient name ID.	30	100.0
	It is easy for me to take or retake a picture of the wound using the app.	30	100.0
	It is easy for me to read the recommendations given by the app.	30	100.0
	It is easy for me to communicate with women when using the app.	30	100.0
	I feel comfortable using the app during home visit for follow up of women who delivered by cesarean section.	30	100.0
	Number of CHWs who "Agreed" or "Strongly agreed" with > 80% of usability statements (n = 20)	30	100.0
Acceptability	It is easy for me to understand how to use the app.	29	96.7
	The app is a good fit for the way I conduct visits to women after cesarean section.	30	100.0
	The app will save me time during home visits to women who delivered by cesarean section.	30	100.0
	I think using this mHealth app will be more helpful than hurtful.	30	100.0
	Number of CHWs who "Agreed" or "Strongly agreed" with > 80% of acceptability statements (n = 4)	29	96.7

For the four acceptability questions, 29 (96.7%) of them "Agreed" or "Strongly agreed" with 80% or more of the statements. The lowest rating for any given question was "Neutral". The lowest scoring acceptability statement was "It is easy for me to understand how to use the app", with 29 (96.7%) stating "Agreed" or "Strongly agreed". With these scores, we surpassed our threshold of 80% of CHWs positively scoring 80% or more of the usability and acceptability statements.

Qualitative results

Across the six focus group discussions, the median time of the interviews was 52.5 min (range: 28 min to 1 h and seven minutes).

We identified the following themes regarding usability and acceptability of the mHealth-CHW tool from the focus group discussions: (1) Factors contributing to usability and acceptability of the mHealth-CHW tool; (2) Potential concerns affecting usability and acceptability of the mHealth-CHW tool; and (3) Recommendations to increase usability and acceptability of the mHealth-CHW tool.

Factors contributing to usability and acceptability of the mHealth-CHW tool

The usability of the tool was attributable to CHWs' positive experience using the app, along with the general benefit of using a smartphone in the field. CHWs noted that the content was clear and understandable to them because it was in Kinyarwanda, and their overall impression of the tool was that it is well-designed and is an effective resource (Focus group discussion, Quote 1 (FGD, Q1)). The fact that the app could be used without cellular connection was also identified as a feature contributing to usability in the field; if the tool were not designed to be used offline CHWs would need to purchase data each time they went to visit women (FGD, Q2). Additionally, the mHealth-CHW tool was said to be an improvement from the current practice of carrying registers because all information needed to carry out home visits would be available in one smartphone app. This would lighten their workload physically and mentally (FGD, Q3).

FGD, Q1: *"In fact, this application is well-designed, it is clear enough, it guides us on what to do. It is good*

to use it. We liked it. Therefore, we have warmly welcomed it.” – CHW #1, Group 2 A.

FGD, Q2: “Regarding what I liked about this application; first, it is different from other applications we knew. How? Usually, for other applications, in order to use their service, you need to have internet, you need to first buy megabytes. Contrary, for our application we don’t need that. We just log into the application. Then, this is something we should appreciate.” – CHW #3, Group 3 A.

FGD, Q3: “I am happy with the application. We will use it because we have been trained on how to use it. Before the introduction of this technology, we used to carry books and a pen and taught people. With this technology, we will press on the button of the cell phone and know which direction to take. We will follow that direction and arrive at a woman’s home. When we get there, we will do what we have to do and take pictures. This technology will make our work easier.” – CHW #5, Group 3B.

CHWs highlighted numerous factors contributing to the acceptability of the mHealth-CHW tool. Generally, follow-up using the tool was seen as an additional opportunity support women’s health regardless of their delivery method (FGD, Q4). The experience training to follow up with women after c-section using the tool contributed greatly to acceptability, with many CHWs stating that the increased knowledge and skills would benefit both them and the communities they serve (FGD, Q5). The setup of the mHealth-CHW tool would ensure that all steps for follow up are carried out at each home visit, making visits consistent and efficient (FGD, Q6). By allowing them to screen for complications and identify when women should be referred to a health facility, the tool was viewed as something that would help reduce maternal morbidity and mortality by ensuring timely care seeking (FGD, Q7). This also addresses financial and logistic challenges related to seeking follow-up care since, for this intervention, women would only need to return to the health center if the tool identifies an issue requiring them to seek help.

FGD, Q4: “I personally am very happy of the fact that CHW-led home-based follow-up of women after c-section is integrated in my activities. Usually, we were visiting those who had vaginal delivery. For those who had c-section, they would come from the hospital, stay at home alone, and the c-section wound might be deteriorated and have pus discharge for instance. Now that this responsibility is included in our duties, I am very delighted as I will be visiting them right after their hospital discharge, before five days. I will ask them about their health status, challenges they

will be facing, and advise them. Brief, I am happy of the fact this responsibility is now included in our duties.” – CHW #5, Group 1A.

FGD, Q5: “There is no single reason that would lead me not be willing to follow up women who had c-section in their homes through the use of the application, as it will increase their knowledge thanks to the knowledge I will have acquired with regard to the follow-up of post-partum women. I will increase my knowledge in both the follow-up of women who had vaginal delivery and c-section delivery.” – CHW #5, Group 2 A.

FGD, Q6: “We used to go to visit women having a list of things we would do memorized in our mind, and when we got there, we could find that a woman had some other things to ask you. We could answer them according to their questions, and skip what we had planned as we had forgotten them, while they were essential. I appreciate this application as it is an additional support I will be using as a reminder as I will have it with me. I will be asking them what I know and using the application at the same time. The application will remind me, and show me what to tell women, and they will be asking me questions in accordance with what I will have told them. And I will be improving my skills in using the application. It is good to have known the application, it will help women.” – CHW #3, Group 1B.

FGD, Q7: ... it will reduce the problems they were facing. For instance, after c-section, they could have a problem, such as feeling abdominal pain, and they could think that it was due to c-section, whereas there was another problem, we could hear that they had infection. In fact, they did not know anything about it. ... Later on, they may go to health center when the c-section wound has already been decomposed. However, thanks to this application, we will be able to identify the problems women who had c-section have, and then take them to health center so that they take care of them before the situation gets worse to the extent that they are referred to hospital, as when they stay in hospital for long, their family becomes poor since they spend too much money. When we get to know about their problem in time, we will help them at a low level as the situation will not have gotten worse.” – CHW #3, Group 3 A.

A major point making the tool acceptable was that using it would address key challenges to women’s recovery. Many CHWs identified that lack of knowledge regarding proper self-care behaviors after c-section may slow women’s recovery or cause other complications (FGD, Q8). Because the tool houses instructions for safe recovery, it would help CHWs tackle this issue by providing

information on adequate wound care, proper diet, and other behaviors women should adopt to help them recover (FGD, Q9). The fact that information would come from the mHealth-CHW tool would also help establish credibility of the instructions, making the guidance acceptable to both the CHW and the patient being visited (FGD, Q10). Similarly, CHWs thought they could use the tool as a reference to facilitate discussions with family members and potentially the community to encourage their support for the recovering woman (FGD, Q11).

FGD, Q8: *"They might also have limited knowledge about that sickness. They might not know the behavior they need to adopt for their quick recovery. Therefore, they might need support or someone to help them. Not having someone to help them might lead to the deterioration of their health status."* – CHW #3, Group 2 A.

FGD, Q9: *"This application will mitigate these challenges we have identified, as Community Health Workers will be visiting them, get to know their problems, and then use the application to show them how they will take care of themselves and behave themselves."* – CHW #6, Group 2B.

FGD, Q10: *"As far as I am concerned, I think technology will be instrumental in [home visits]. We will visit these women and examine their wounds. Technology has made life easier. If a Community Health Worker reads out information from the application, both the patient and carer will take it as reliable information from a healthcare institution and will therefore see the need to seek medical attention."* – CHW #3, Group 3B.

FGD, Q11: *"Most of the time, those women's husbands do not understand why it is necessary for their wives to go back to the hospital, especially those living in rural areas. They are only worried about expenses. If a Community Health Worker reaches out to a family with such a problem and talk to family members, preferably in the presence of the husband, they reach an agreement. I believe that technology would yield a sustainable solution."* – CHW #4, Group 3B.

Potential concerns affecting usability and acceptability of the mHealth-CHW tool

Potential concerns affecting acceptability to using this tool in the field were identified. Some women may be reluctant to answer screening questions or have their wound image taken due to misperception around these steps, thus building trusting relationships with the women being visited was emphasized for acceptance (FGD, Q12). Maintaining privacy of the image and information being captured was also a point of concern (FGD, Q13). CHWs iterated that women should be approached

in a respectful and non-judgmental manner during the home visits, otherwise they may feel scared or discouraged (FGD, Q14). Other concerns were generally about conducting home visits, including the need to train more CHWs to follow-up with women, time and cost of reaching women living in more remote areas, and loss of income from spending time volunteering as a CHW (FGD, Q15).

FGD, Q12: *"Regarding CHW-led home-based follow-up of women after c-section, with regard to taking a picture of the c-section [wound], I think we need to think about this challenge ... We may ask them to let us look at the picture of the c-section wound or take a picture of the wound, depending on their understanding, they may think that the wound would be deteriorated if we looked at it. However, depending on how open they felt to you, they may agree, but they may also refuse in some instances. I think we need to predict such possibility. It will depend on their level of understanding. However, I think, depending on the relationship we will build with them, and the changes we will make, they will accept us without any problems."* – CHW #2, Group 1 A.

FGD, Q13: *"The challenges I think we might face, it might happen that when taking a picture of the c-section, you don't take it appropriately. It might happen that you put the phone somewhere without having saved the pictures, without having saved them confidentially. In case someone happens to get in contact with it, they might get the information they were not supposed to access. They might start saying, 'I saw this and that.' If the patient gets to know that her information was leaked, they will get embarrassed of course. We cannot ignore that challenge."* – CHW #3, Group 1 A.

FGD, Q14: *"Your conduct during the visit to women who had C-section, the way you receive her, and the way she receives you, will count a lot. For instance, when you act like you are a high ranked official, that woman will be scared when she sees you. In that case, whatever you tell her, she will hear it being traumatized. When visiting women who had c-section, Community Health Workers should not go there as authorities, they should be humble. They should greet them, introduce themselves, see how they are received, and then start the conversation when the woman is at ease. Otherwise, when you go there behaving as an authority, you may scare the woman, and she might have changes in the wound."* – CHW #5, Group 3 A.

FGD, Q15: *"In addition to our work as Community Health Workers, we also need to eat and sustain our families. If I spend most of the time doing my work as*

a Community Health Worker, I may fail to develop myself and my family. If the government values what we do, they should think about the way they could support us so that we may not face challenges that can prevent us from fulfilling our duties as Community Health Workers. That is how I think they can solve this problem.” – CHW #2, Group 3B.

Recommendations to increase usability and acceptability of the mHealth-CHW tool

CHWs provided several recommendations to improve the intervention. They recommended having a place to show information from any health facility visits, namely those that occurred as referrals from home visits, as a part of the continuum of care (FGD, Q16). Although most CHWs said that the app is structured well one CHW expressed concern about the number of questions women are asked during the visit (FGD, Q17). During the screening, a question prompting CHWs to ask about and record issues not covered by the questionnaire was requested. They also recommended expanding the population the tool could be used to follow up with to include pregnant women and newborn children (FGD, Q18). A platform or other space collecting feedback about the mHealth-CHW tool and home visits should also be made available to CHWs, especially as experiences may vary on the field (FGD, Q19). Finally, CHWs should receive continuous training and have phones with the mHealth-CHW tool be available for them to practice conducting home visits (FGD, Q20).

FGD, Q16: *“I think that, after visiting a woman, giving her some assistance, helping her to get to the healthcare institution, and after her complete recovery and return home, there should be some kind of follow-up. What will be the link between her previous medical condition and the second time I visit her after recovery? I did not see any possibility to record this kind of information and send it via the application. In my opinion, this option of reporting the recovery process should be added in the application. We need to know what happened after the treatment.” – CHW #4, Group 3B.*

FGD, Q17: *“I think that we ask women too many questions. Nineteen to twenty questions! We may keep on asking her questions and end up losing her. We may ask her all these questions while she is experiencing serious health problems such as an infected c-section wound with a lot of pus. My concern is that she may take this question-answer session as a waste of time and decide to go away. There are too many questions. That is my opinion.” – CHW #2, Group 3B.*

FGD, Q18: *“They should include visiting pregnant women and visiting new born in the application, so that we can use it when visiting pregnant women and when visiting newborn, in the same way we will be using it for women who had c-section.” – CHW #5, Group 2B.*

FGD, Q19: *“When we start working and practice what we have learnt, we will note any challenge that will arise. If there is a platform where we can share ideas, we will use it to report any challenges we will have encountered, changes or improvements to be made. We cannot suggest anything at the moment because we have not gone to the field to know what works and what doesn’t.” – CHW #1, Group 3B.*

FGD, Q20: *“What I think can be added is frequent refresher training opportunities and follow-up. We should be allowed to practice what we have learnt from the training as soon as possible because we may forget it.” – CHW #2, Group 3B.*

Convergent analysis

Both the quantitative and qualitative results support that the app was highly usable and acceptable to CHWs. For quantitative assessments, the predetermined thresholds for both usability and acceptability were met (Table 3), which was consistent with the strong perceptions of usability and acceptability of the mHealth-CHW tool reported in the focus group discussions. The lowest scoring usability statements (rated “Neutral”) were “It is easy for me to learn to use the app”, “Whenever I make a mistake on the app, it is easy and quick to correct it”, and “I can use the app even when the Internet connection is poor or not available”. These points were not brought up in the focus group discussion as barriers to usability. The “Neutral” ratings to the CHW-MUAAT statements contrasted with CHW statements which described the tool as easy to use (FGD, Q1) and appreciated the ability for offline usability (FGD, Q2). The positive feedback from the focus group discussions also differ from the lowest rated acceptability statement (rated “Neutral”), “It is easy for me to understand how to use the app”.

In the focus group discussions, CHWs stated that strong relationships between the CHWs and patients were needed for the mHealth-CHW intervention to be successful. In these discussions, they noted that for homebased follow-up to be acceptable, it would be important to build trust between patients and CHWs through respectful conduct and maintaining patient privacy (FGD, Q12-14). The need for strong relations was not directly assessed by the CHW-MUAAT; however, despite these concerns, all 30 CHWs “Agreed” or “Strongly agreed” that using the tool would be more helpful than hurtful (Table 3).

Discussion

Our team has designed an innovative mHealth tool to enable CHWs to conduct home visits and follow up with women who have undergone cesarean deliveries in rural Rwanda. In this study we assessed CHWs' performance when using the mHealth-CHW tool in vignette scenarios, then asked CHWs to quantitatively and qualitatively assess the usability and acceptability of the tool. Overall, CHWs performed well in the vignette scenarios as scored by facilitators, and on average asked and input almost all visit questions correctly in the app. CHWs expressed that they perceived the mHealth-CHW tool to be highly usable and acceptable in both the quantitative and qualitative evaluation.

We found that all 30 CHWs positively agreed with 80% or more of the usability statements presented and all but one positively agreed with 80% or more of the acceptability statements, surpassing our thresholds for the study. The high usability and acceptability found through the CHW-MUAAT was also seen in the focus group discussion, where CHWs expressed that the tool was easy to use and would fulfill the needs of a home-visit. End-user perception of usability and acceptability of a tool are crucial to the success of mHealth applications. A systematic review on the success of mHealth in sub-Saharan Africa identified that acceptance by end users is a key factor in the success of the interventions [33]. Perceived utility, meeting staff demands and needs, and providing adequate training were some factors contributing to acceptance [33]. These factors were also positively identified in our quantitative and qualitative investigation of the intervention's perceived usability and acceptability. While our study results indicated that the tool was usable and acceptable, being mindful of these factors will be vital to the success of the intervention moving forward.

Major points contributing to usability and acceptance of the tool could be connected to how its functions would address challenges to post-c-section recovery the had CHWs identified. Notably, CHWs identified that lack of knowledge about recovering from c-section could lead to poor wound healing or misunderstanding between women and their family members; lack of knowledge around self-care practices after c-section has also been observed in other studies [34–37]. By having guidelines for post-c-section recovery into the mHealth-CHW tool, CHWs can readily provide consistent and reliable recommendations to women who may otherwise not have access to this critical information. This can help ensure that women understand the behaviors and practices that promote healing and recovery, as well as those that may hamper it. Our team developed and integrated context specific instructions to ensure that any cultural practices which may affect recovery are addressed [26].

Continued training for post-cesarean specific follow-up and refresher training for the mHealth tool were identified as part of the support necessary intervention. A separate review identified that acceptance and familiarity with use of phones contribute to positive perception of mHealth projects [38]. In our study, many of our CHWs said that they did not use a personal smartphone, and some CHWs identified that this experience was the first time they had used a smartphone at all. However, difficulty using the smartphone and tool in general was not identified as a barrier to mHealth facilitated follow-up in the quantitative nor the qualitative assessment. This is likely due to the support provided by our team in training CHWs to use the mHealth-CHW tool – team members involved in the training not only introduced the application, but also supported CHWs in learning how to operate the smartphones for the study. The success of this initial training and the request for continued trainings further demonstrate that investing appropriate time and resources for the primary users in mHealth is key to success in interventions of this nature.

In the focus group discussions CHWs identified that ensuring women feel comfortable with the home visits will be vital to acceptance of mHealth tool-facilitated follow-up in the community. Similar studies have found that building rapport and taking a friendly, respectful approach to visits helps with the acceptance of home follow-up, and helps both the patient and HCP feel at ease with the interaction [39–41]. Trainings for home follow-up should take time to discuss the attitude and approach that can be taken to promote a positive relationship between the patient and HCP. It should be emphasized that patients may not completely feel comfortable with home-based healthcare visits initially, and that it is important to take time to ensure they have established a fair and trusting relationship when carrying out these activities. Having a trusting relationship with their HCP can also improve patients' perceived privacy and enable honest communication of any health concerns they may have [42].

Ultimately, CHWs showed a strong willingness to integrate follow-up of women who have cesarean deliveries in their responsibilities and expressed through both the CHW-MUAAT and focus group discussions that the mHealth-CHW tool was a usable and acceptable facilitator for this. This enthusiasm for incorporating mHealth into their work aligns with findings from other studies, which demonstrated that CHWs are welcoming to the use of digital health tools, provided they receive adequate training and programmatic support [43–47]. In the scope of maternal child health, many mHealth interventions are focused on health during pregnancy, antenatal care visits, and postnatal care for the child [15, 48]. Given the positive feedback from the CHWs and the potential

of mHealth interventions to enhance delivery of health services, tools to support the woman through the maternal health continuum of care, notably in the postpartum period, should be considered and explored in other contexts.

The introduction of a mHealth tool to support CHW-led home-based follow-up for women who delivered via cesarean Rwanda aligns well with the country's evolving technological landscape and community health strategy. While smartphones are required for this mHealth tool and smartphone ownership is still relatively low compared in the country [49] the government aims to equip all CHWs with smartphones as part of the national digitalization process. Further, CHWs already use basic cell-phones as part of the RapidSMS program to monitor home visits and send follow-up care reminders [50]. The RapidSMS system currently does not include the detailed instruction and symptom-based follow-up guidance to allow CHWs to support women who have had c-section. Our work expands the capabilities of mHealth-supported CHW follow-up in Rwanda and the tool evaluated in this paper could be expanded to include postpartum support for women who deliver vaginally.

This study has limitations for consideration. This evaluation was conducted with a small number of CHWs and thus must be interpreted with caution. Because we randomly chose health centers and stratified by proximity to health centers, we are confident in the representation of these CHWs relative to other CHWs in Kirehe District and other rural sites. Usability and acceptability in a simulated setting compared with use in real-life scenarios may also yield different results, therefore testing in the field will also need to be done to fully establish usability. Some of the contents of the tool, such as the recovery instructions are designed specifically for home CHW-led follow-up in Rwanda; however, the tool's prompts could be adapted for other settings with, we anticipate, little impact on the CHWs' usability and acceptability. Others seeking to utilize a similar intervention should review and adapt the design and content of the mHealth tool with the guidance of country-specific experts and CHWs.

Conclusion

In both the quantitative and qualitative evaluations, we found the mHealth-CHW tool to be highly usable and acceptable among CHWs. CHWs endorsed the tool as a facilitator for supporting women recovering after c-section in rural Rwanda and expressed willingness to integrate follow-up as part of their responsibilities. Because we exceeded our predetermined thresholds for usability and acceptability, our team will proceed with validation of the mHealth-CHW tool home follow-up findings against HCP assessments at a study clinic.

This intervention to support post c-section recovery should be pursued in other contexts, particularly where CHWs are responsible for postpartum follow-up and where there is a substantial rural population. The method of delivering care here should also be considered for other aspects of CHW-led care, such as home visits for child health and patients with non-communicable diseases.

Abbreviations

SSA	Sub-Saharan Africa
SSI	surgical site infection
C-sections	cesarean-sections
CHWs	community health workers
mHealth	mobile health
KDH	Kirehe District Hospital
HCPs	healthcare providers

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12884-025-08155-1>.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

Acknowledgements

We acknowledge the support of Partners in Health/Inshuti Mu Buzima, Kirehe District Hospital, site leaders of Mulindi, Nasho, and Mushikiri Health Centers, and the CHWs who participated in this study.

Author contributions

Funding acquisition: BHG, VC; Conceptualization and methodology: EHE, BHG, JN, MK, SN, CF, AB, LB, NN, AN, FK, AN, SP, RR, FK, RF, NB, VC; Vignette design: EHE, JN, SN, CF, FO, AB, AO, KB; CHW-MUAAT design: JN, SN. Data collection: JN, MK, MT, NB; Data cleaning and analysis: EHE, BHG, JN, MK, SN, VC; Manuscript preparation of original draft: EHE, BHG, JN, SN. All authors reviewed and approved the final manuscript.

Funding

This research was funded by the National Institutes of Health, award number R21HD103052. SN was supported by the Fogarty International under Award Number D43 TW010543. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Authors' contributions.

Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study received ethical approval from both the Rwanda National Ethics Committee (No.109/RNEC/2022) and the Harvard Longwood Campus Institutional Review Board (IRB22-1025). This study was performed in accordance with the World Medical Association Declaration of Helsinki. The study team obtained written informed consent from all study participants at the time of enrollment.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

¹Department of Global Health and Social Medicine, Harvard Medical School, Boston, USA

²Program in Global Surgery and Social Change, Harvard Medical School, Boston, MA, USA

³Partners In Health/Inshuti Mu Buzima, Kigali, Rwanda

⁴Department of Otorhinolaryngology-Head and Neck Surgery, Massachusetts Eye and Ear Infirmary, Boston, USA

⁵Center for Equity in Global Surgery, University of Global Health Equity, Kigali, Rwanda

⁶Department of Obstetrics and Gynecology, Massachusetts General Hospital, Boston, USA

⁷Harvard Medical School, Boston, MA, USA

⁸Center for Surgery and Public Health, Brigham and Women's Hospital, Boston, MA, USA

⁹Denver Health, University of Colorado, Denver, CO, USA

¹⁰Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA, USA

¹¹Insightiv LTD, Kigali, Rwanda

¹²Department of Community Health and Social Medicine, University of Global Health Equity, Kigali, Rwanda

Received: 10 February 2025 / Accepted: 1 September 2025

Published online: 23 December 2025

References

- Betran AP, Ye J, Moller AB, Souza JP, Zhang J. Trends and projections of caesarean section rates: global and regional estimates. *BMJ Glob Health*. 2021;6(6):e005671.
- Van Otterloo L, Connelly C, Gould J, Abreo A, Main E. Mothers at risk: factors affecting maternal postpartum length of stay. *J Perinat Neonatal Nurs*. 2018;32(4):303–14.
- Bishop D, Dyer RA, Maswime S, Rodseth RN, van Dyk D, Kluyt HL, et al. Maternal and neonatal outcomes after caesarean delivery in the African surgical outcomes study: a 7-day prospective observational cohort study. *Lancet Glob Health*. 2019;7(4):e513–22.
- Harrison MS, Goldenberg RL. Caesarean section in sub-Saharan Africa. *Matern Health Neonatol Perinatol*. 2016;2:6.
- Chu K, Maine R, Trelles M. Caesarean section surgical site infections in sub-Saharan Africa: a multi-country study from medecins Sans frontieres. *World J Surg*. 2015;39(2):350–5.
- Sway A, Nthumba P, Solomkin J, Tarchini G, Gibbs R, Ren Y, et al. Burden of surgical site infection following Caesarean section in sub-Saharan Africa: a narrative review. *Int J Womens Health*. 2019;11:309–18.
- Mekonnen AG, Mittiku YM. Surgical site infection and its association with rupture of membrane following Caesarean section in Africa: a systematic review and meta-analysis of published studies. *Matern Health Neonatol Perinatol*. 2021;7(1):2.
- Rural population (% of total population). - Sub-Saharan Africa | Data [Internet]. World Bank Group. Available from: <https://data.worldbank.org/indicator/SPRUR.TOTL.ZS?locations=ZG>. Accessed 18 Nov 2024.
- Tessema ZT, Yazachew L, Tesema GA, Teshale AB. Determinants of postnatal care utilization in sub-Saharan Africa: a meta and multilevel analysis of data from 36 sub-Saharan countries. *Ital J Pediatr*. 2020;46(1):175.
- Nkurunziza T, Riviello R, Kateera F, Niiwacu E, Nkurunziza J, Gruendl M, et al. Enablers and barriers to post-discharge follow-up among women who have undergone a caesarean section: experiences from a prospective cohort in rural Rwanda. *BMC Health Serv Res*. 2022;22(1):733.
- Tesfahun F, Worku W, Mazengiya F, Kifle M. Knowledge, perception and utilization of postnatal care of mothers in Gondar Zuria district, Ethiopia: a cross-sectional study. *Matern Child Health J*. 2014;18(10):2341–51.
- Ahmed S, Chase LE, Wagnild J, Akhter N, Sturridge S, Clarke A, et al. Community health workers and health equity in low- and middle-income countries: systematic review and recommendations for policy and practice. *Int J Equity Health*. 2022;21(1):49.
- Ministry of Health Rwanda. Maternal newborn and child health strategic plan 2018–2024. Rwanda: Ministry of Health Rwanda; 2018 Jul [cited 2024 Jun 6]. Available from: https://www.moh.gov.rw/fileadmin/user_upload/Moh/Publications/Strategic_Plan/Rwanda_MNCH_StrategicPlan_June_costed_v2Draft.pdf
- Ministry of Health Rwanda. Fourth health sector strategic plan July 2018 – June 2024. Rwanda: Ministry of Health Rwanda; 2017 [cited 2024 Jun 6]. Available from: <https://www.minecofin.gov.rw/index.php?eID=dumpFile&t=f&f=15856&token=7aabf4f0ec53ed2685b9bd0a1f9df78a60651a35>
- Ameyaw EK, Amoah PA, Ezeika O. Effectiveness of mHealth apps for maternal health care delivery: systematic review of systematic reviews. *J Med Internet Res*. 2024;26:e49510.
- Abreu FDL, Bissco MAS, Silva AP, Boschi SRMS, Scardovelli TA, Santos MF, et al. The use and impact of mHealth by community health workers in developing and least developed countries: a systematic review. *Res Biomed Eng*. 2021;2021(37):563–82.
- Greuel M, Sy F, Bärnighausen T, Adam M, Vandormael A, Gates J, et al. Community health worker use of smart devices for health promotion: scoping review. *JMIR Mhealth Uhealth*. 2023;11:e42023.
- Agarwal S, Perry HB, Long LA, Labrique AB. Evidence on feasibility and effective use of mHealth strategies by frontline health workers in developing countries: systematic review. *Trop Med Int Health*. 2015;20(8):1003–14.
- Osei E, Mashamba-Thompson TP. Mobile health applications for disease screening and treatment support in low- and middle-income countries: a narrative review. *Heliyon*. 2021;7(3):e06639.
- Petroze RT, Nzayisenga A, Rusanganwa V, Ntakiyiruta G, Calland JF. Comprehensive national analysis of emergency and essential surgical capacity in Rwanda. *Br J Surg*. 2012;99(3):436–43.
- National Institute of Statistics Rwanda, Ministry of Health Rwanda, ICF International. Rwanda demographic and health survey 2014–2015. Rockville, Maryland, USA: Republic of Rwanda; 2016 Mar [cited 2024 Jun 6]. Available from: <https://dhsprogram.com/pubs/pdf/FR316/FR316.pdf>
- Kirehe District Hospital. About us. Rwanda: Kirehe District Hospital; 2016 Jan [cited 2024 Jun 6]. Available from: <https://www.kirehehospital.gov.rw/1/about-us/kirehe-district-hospital>
- National Institute of Statistics Rwanda, Ministry of Health Rwanda, ICF International. Fifth Population and Housing Census, Rwanda 2022. Republic of Rwanda; 2022 [cited 2024 Jun 6]. Available from: <https://statistics.gov.rw/file/13775/download?token=zpRqCk04>
- National Institute of Statistics Rwanda. The Fifth Rwanda Population and Housing Census, District Profile: Kirehe. 2023. Republic of Rwanda; 2023 [cited 2024 Jun 6]. Available from: <https://www.statistics.gov.rw/sites/default/files/2025-05/KIREHE.pdf>
- Powell BL, Nkurunziza T, Kateera F, Dusabe L, Kubwimana M, Koch R, et al. Synthesizing postpartum care pathways, facilitators, and barriers for women after Caesarean section: a qualitative analysis from rural Rwanda. *J Glob Health Rep*. 2021;5:e2021043.
- Kateera F, Hedt-Gauthier B, Luo A, Niyigana A, Galvin G, Hakizimana S, et al. Safe recovery after caesarean in rural Africa: technical consensus guidelines for post-discharge care. *Int J Gynaecol Obstet*. 2023;160(1):12–21.
- Alayande BT, Prasad S, Abimpaye M, Bakorimana L, Niyigana A, Nkurunziza J, et al. Image-based surgical site infection algorithms to support home-based post-caesarean monitoring: lessons from Rwanda. *PLOS Glob Public Health*. 2023;3(2):e0001584.
- Fletcher RR, Schneider G, Hedt-Gauthier B, Nkurunziza T, Alayande B, Riviello R, et al. Use of convolutional neural Nets and transfer learning for prediction of surgical site infection from color images. *Annu Int Conf IEEE Eng Med Biol Soc*. 2021;2021:5047–50.
- Zhou L, Bao J, Setiawan IMA, Saptono A, Parmanto B. The mHealth app usability questionnaire (MAUQ): development and validation study. *JMIR Mhealth Uhealth*. 2019;7(4):e11500.
- O'Connor AM, Cranney A. User manual – Acceptability. Ottawa: Ottawa Hospital Research Institute; 2002 [cited 2022 Nov]. Available from: https://decisionaid.ohri.ca/docs/develop/User_Manuals/UM_Acceptability.pdf
- Nkurunziza J, Nuss S, Estrada EH, Kubwimana M, Boatina AA, Bikorimana L et al. Adapting and validating tools to assess the usability and acceptability of mHealth tools among community health workers in rural Rwanda: development of the community health worker mHealth usability and acceptability assessment tool (CHW-MUAAT). *JMIR mHealth and uHealth*. Forthcoming 2025.
- Hennink MM, Kaiser BN, Weber MB. What influences saturation?? Estimating sample sizes in focus group research. *Qual Health Res*. 2019;29(10):1483–96.

33. Ag Ahmed MA, Gagnon MP, Hamelin-Brabant L, Mbemba GIC, Alami H. A mixed methods systematic review of success factors of mhealth and telehealth for maternal health in sub-Saharan Africa. *Mhealth*. 2017;3:22.
34. Atuhaire S. Knowledge and practices of post Cesarean section mothers towards self-care after delivery at Mbarara regional referral hospital. *SJHR Afr*. 2021;2(3):13.
35. Musabeyezu J, Santos J, Niyigena A, Uwimana A, Hedt-Gauthier B, Boatini AA. Discharge instructions given to women following delivery by cesarean section in Sub-Saharan Africa: a scoping review. *PLOS Glob Public Health*. 2022;2(4):e0000318.
36. Mashe V, Mavondo GA, Mavondo J, Kachepe P, Chamisa JA. Knowledge and attitudes on selfcare practices following child birth by caesarean section at Marondera hospital in Zimbabwe. *Cognizance J Multidiscip Stud*. 2022;2(8):1–39.
37. Yaqoub RM, Khouj MA, Alsaif AA, Eissa GA, Alhemdi JA, Albasri S. Awareness and knowledge of caesarean section complications among women in Jeddah, Saudi Arabia. *Cureus*. 2022;14(12):e32152.
38. Aranda-Jan CB, Mohutsiwa-Dibe N, Loukanova S. Systematic review on what works, what does not work and why of implementation of mobile health (mHealth) projects in Africa. *BMC Public Health*. 2014;14:188.
39. Singh D, Cumming R, Negin J. Acceptability and trust of community health workers offering maternal and newborn health education in rural Uganda. *Health Educ Res*. 2015;30(6):947–58.
40. Stoutenberg M, Crouch SH, McNulty LK, Kolkenbeck-Ruh A, Torres G, Gradidge PJJ et al. Acceptability and feasibility of home-based hypertension and physical activity screening by community health workers in an under-resourced community in South Africa. *J Public Health (Berl)*. 2024;32:1011–22.
41. Crocker ME, Stout JW. A qualitative study of perspectives on the acceptability and feasibility of virtual home visits for asthma. *BMC Public Health*. 2023;23(1):2546.
42. Iott BE, Campos-Castillo C, Anthony DL. Trust and privacy: how patient trust in providers is related to privacy behaviors and attitudes. *AMIA Annu Symp Proc*. 2020;2019:487–93.
43. Schoen J, Mallett JW, Grossman-Kahn R, Brentani A, Kaselitz E, Heisler M. Perspectives and experiences of community health workers in Brazilian primary care centers using m-health tools in home visits with community members. *Hum Resour Health*. 2017;15(1):71.
44. Zaidi S, Kazi AM, Riaz A, Ali A, Najmi R, Jabeen R, et al. Operability, usefulness, and task-technology fit of an mHealth app for delivering primary health care services by community health workers in underserved areas of Pakistan and Afghanistan: qualitative study. *J Med Internet Res*. 2020;22(9):e18414.
45. Charanthimath U, Katageri G, Kinshella MW, Mallapur A, Goudar S, Ramadurg U, et al. Community health worker evaluation of implementing an mHealth application to support maternal health care in rural India. *Front Glob Womens Health*. 2021;2:645690.
46. Kachimanga C, Mulwafu M, Ndambo MK, Harare J, Murkherjee J, Kulinkina AV, et al. Experiences of community health workers on adopting mHealth in rural Malawi: a qualitative study. *Digit Health*. 2024;10:20552076241253994.
47. Kansiime WK, Atusingwize E, Ndejjo R, Balinda E, Ntanda M, Mugambe RK, et al. Barriers and benefits of mHealth for community health workers in integrated community case management of childhood diseases in Banda parish, Kampala, Uganda: a cross-sectional study. *BMC Prim Care*. 2024;25:173.
48. Kachimanga C, Zaniku HR, Divala TH, Ket JCF, Mukherjee JS, Palazuelos D, et al. Evaluating the adoption of mHealth technologies by community health workers to improve the use of maternal health services in sub-Saharan Africa: systematic review. *JMIR Mhealth Uhealth*. 2024;12:e55819.
49. National Institute of Statistics Rwanda. Seventh Integrated Household Living Conditions Survey (EICV7, 2023–2024). Republic of Rwanda; 2025 [cited 2025 Jul 26]. https://www.statistics.gov.rw/sites/default/files/documents/2025-04/EICV_7_booklet%20for%20dissemination.pdf
50. Ngabo F, Nguimfack J, Nwaigwe F, Mugeni C, Muhoza D, Wilson DR, et al. Designing and implementing an innovative SMS-based alert system (RapidSMS-MCH) to monitor pregnancy and reduce maternal and child deaths in Rwanda. *Pan Afr Med J*. 2012;13:31.

Publisher's note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.