Adoption of mHealth Technologies by Community Health Workers to Improve the Use of Maternal Health Services in Sub-Saharan Africa: A Systematic Review

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Abstract

Background: Limited information exists on the impact of mobile health (mHealth) use by community health workers (CHWs) on improving maternal health services in sub-Saharan Africa (SSA).

Objective: This mixed method systematic review addresses two objectives: 1) The impact of mHealth use by CHWs on antenatal care (ANC), facility-based births, and postnatal care (PNC) utilization in SSA; 2) Identifying facilitators and barriers to mHealth use by CHWs in programs designed to increase utilization of ANC, facility-based births and PNC in SSA using a socio-technical system (STS) approach.

Methods: We searched for articles in six databases (MEDLINE, CINAHL, Web of Science, Embase, Scopus, and Africa Index Medicus) up to September 2022, with additional articles identified from Google Scholar. After article selection, two independent reviewers performed screening of titles and abstracts, full-text screening, and data extraction using Covidence software. Additionally, we manually screened the reference list of included articles. Finally, we performed a narrative synthesis of the outcomes.

Results: Among the 2594 records retrieved, ten studies (a total of 22 articles) met the inclusion criteria and underwent data extraction. The studies were published from 2012 to 2022 in six countries. Among the studies reporting on ANC outcomes, 43% (three out of seven) reported that mHealth use by CHWs increased ANC utilization. Similarly, in studies reporting on facility-based births, 89% (eight out of nine) demonstrated an increase due to mHealth use by CHWs. Additionally, in PNC studies, 75% (three out of four) showed increased PNC utilization associated with mHealth use by CHWs. Many studies reported on the importance of addressing factors around the social environment of mHealth-enabled CHWs, including the perception of CHWs by the community, trust, relationships, digital literacy, training, mentorship and supervision, skills, CHW program ownership, and incentives. Very few studies reported on how program goals and culture influenced mHealth use by CHWs. Providing free equipment, accessories, and internet connectivity while addressing ongoing challenges with connectivity, power, ease of mHealth software, and equipment maintenance support allowed mHealth-enabled CHW programs to thrive.

Conclusions: mHealth use by CHWs was associated with increased ANC, facility-based births, and PNC in SSA. Identifying and addressing social and technical barriers to the use of mHealth is essential to ensure the success of mHealth programs.

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Keywords: Maternal health, Antenatal care, Postnatal care, Facility-based births, sub-Saharan Africa, mHealth, Review, Narrative Synthesis

Introduction

Sub-Saharan Africa (SSA) continues to have the highest maternal morbidity and mortality globally [1, 2]. The region contributes to only 15% of the world population [3], while accounting for 70% of all maternal deaths [4]. In 2020, SSA had a maternal mortality ratio (MMR) of 545 maternal deaths per 100,000 live births and a 1 in 40 lifetime risk of dying from maternal death [5]. These estimates are significantly higher than in any other region of the world [5].

Between 2000 and 2015, MMR decreased in many regions, including SSA [6]. Unfortunately, recent trends in MMR have not been promising; MMR has either increased or remained the same between 2016 and 2020 [7, 8]. There are projections that MMR may stay the same or increase by 2030 [9]. As such, there is a need for innovative approaches to reduce MMR.

One of the ways to accelerate the reduction in MMR is to improve coverage of maternal health services [7]. This includes improving the utilization of maternal health services within the continuum of care - i.e., four or more antenatal care (ANC) contacts, facility-based births by skilled attendants, and early postnatal care (PNC) [7]. Providing high-quality care along the maternal health continuum has been shown to reduce maternal mortality [10-14]. However, utilization of available services remains a significant challenge in SSA. For example, the utilization of ANC and PNC among women aged 15-24 years in 28 SSA countries was only 55% and 40%, respectively [15]. Studies in sub-Saharan Africa showed lower rates of facility-based births, with women in rural areas having the lowest facility births than urban areas [16, 17]. Using data from most recent surveys in SSA countries, Wan et al. and Straneo et al. found that only seven out of ten pregnant women give birth in health facilities in the region [18, 19].

The impact of community health workers (CHWs) on increasing the utilization of maternal health services has been established [20]. Working collaboratively with communities, health facilities, national Ministries of Health (MOH), and international health agencies, CHWs advocate for improved care and reduce cultural and other barriers preventing women from accessing maternal health services [21]. Additionally, CHWs provide education, identify and refer women seeking maternal health services to health facilities, and may offer case management for selected health conditions [22]. CHWs are, therefore, an essential component of reducing maternal deaths, increasing utilization of maternal health services, and eventually achieving sustainable Development Goal (SDG) 3.

To improve the efficiency of tasks and responsibilities performed by CHWs and help support improvements in clinical outcomes, mobile health (mHealth) technologies are increasingly being introduced to CHW programs [23]. mHealth is the use of mobile and wireless technologies in healthcare [24]. In general, evidence has shown that mHealth can improve outcomes in patients with chronic diseases, tuberculosis, and HIV [25]. In maternal health, mHealth has been shown to improve coverage of ANC, facility-based births, and PNC [26, 27]. However, previous reviews have not specifically examined the impact of mHealth tools when used by CHWs as the primary implementers. Specifically for CHWs, mHealth has been used to train CHWs, improve their performance and retention, support data collection, support patient adherence to medication, and provide clinical decision support [28-32]. There is no review on mHealth use by CHWs on improving the maternal health continuum of care in SSA.

Although some of these results hold the promise about using mHealth by CHWs in general, there is a lack of robust evidence on the impact of mHealth use by CHWs to improve utilization of services along the maternal health continuum of care in SSA, especially when compared to CHWs who do not use mHealth. This review aims to provide evidence synthesis on the impact of mHealth use by CHWs in SSA to improve coverage of maternal health services in comparison to CHWs not using mHealth. Additionally, it examines the factors that support or hinder the successful implementation of mHealth for improved utilization of maternal health services. These aims are captured in two objectives. Firstly, we assessed the impact of mHealth use by CHWs on the utilization of ANC, facility-based births, and PNC in SSA, comparing the outcomes with CHWs not using mHealth. Secondly, we reviewed the facilitators and barriers to mHealth use by CHWs in programs designed to increase utilization of ANC, facility-based births, and PNC.

Methods

This systematic review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist and guidelines [33]. As a mixed method systematic review, we synthesized and integrated findings from quantitative and qualitative studies to provide a more comprehensive understanding of the research question. We registered the review at PROSPERO (PROSPERO ID CRD42022346364), and the protocol was published previously [34].

Eligibility criteria

The review included studies involving eligible women of reproductive age group (15-49 years) utilizing care along the maternal health continuum of care: pregnant women utilizing ANC at any gestational age, pregnant women accessing intrapartum care at healthcare facilities, and women accessing PNC up to 42 days after giving birth regardless of the mode of giving birth. We included all studies that reported using mHealth by CHWs to improve the utilization of these three services. CHWs were included if they met the definition set by the World Health Organization (WHO): "Health workers based in communities, who are either paid or volunteers, who are not professionals, and who have fewer than two years of training but at least some training" [35]. For intervention studies included in the review, the comparator was CHW programs that were not using mHealth. We included ANC visits, facility-based births, and PNC visits as outcomes. We also collected qualitative data about facilitators and barriers to mHealth use by CHWs as described in the included studies. Further details and review criteria are outlined in the published protocol [34].

Search strategy and information sources

We searched six databases (Scopus, MEDLINE, Cumulated Index to Nursing and Allied Health Literature (CINAHL), Web of Science, Embase, and Africa Index Medicus) up to September 2022. To develop the concepts for search terms, we combined the following concepts: Women accessing maternal health services (pregnancy OR childbirth OR postnatal care) AND mHealth AND community health workers AND SSA countries. We included all known synonyms and related terms identified from the literature. We adapted the search terms to each database. Due to challenges in reproducibility, we used Google Scholar as part of reference checking [34]. For Google Scholar, we developed search terms mirroring these major concepts and searched the first 1,000 results for any new articles that met the inclusion criteria but were not captured by the other databases. A search strategy, including search terms for Google Scholar, is presented in multimedia appendix 1. We included randomized control trial designs, quasi-experimental studies, non-experimental quantitative studies, qualitative studies, and mixed methods studies that met the inclusion criteria. We excluded review and other summary-type articles, policy documents, commentaries, abstracts and conference proceedings, case reports, and protocols. Manual searches were conducted by reviewing the references of systematic reviews and all included articles. The included articles were limited to the SSA region as defined by The World Bank [36]. To reduce language bias, ensure the identification of all relevant studies regardless of publication time, and allow generalization of findings to SSA, we did not limit the review by language or year of publication.

Data extraction

JCFK retrieved all studies from the electronic databases. CK and HRZ independently screened the title and abstract of extracted articles, independently assessed full-text articles for inclusion, and conducted manual searches. An audit log was kept throughout the process,

including documentation of reasons for exclusion. CK and HRZ performed data extraction. TvdA resolved all discrepancies. We used Covidence software for screening and data extraction [37]. We extracted information on the author(s), publication year, study designs, country and geographical scope, type and scope of work of CHWs, and mHealth characteristics, including platforms used, devices used, delivery methods, and the functions of mHealth. We also extracted the study results based on the outcomes, facilitators, and barriers to mHealth use.

Risk of bias assessment, analysis, and synthesis

All included studies underwent risk of bias assessment by CK and HRZ using the Mixed Method Assessment Tool (MMAT) [38]. Regardless of the results of the risk of bias assessment, we included the studies in data extraction, analysis, and synthesis. Due to the heterogeneity of the studies, we conducted a narrative synthesis using the three steps of Popay et al. [39]. Narrative synthesis is synthesizing using words and text, rather than statistical methods often used for qualitative studies or when meta-analysis is not possible due to heterogeneity in study designs or outcomes. First, a preliminary synthesis based on the review objectives was performed. For the impact of mHealth use by CHWs on the utilization of maternal health services, we described the direction and size of the impact on ANC attendance, facility-based births, and PNC attendance, with the results tabulated. For facilitators and barriers to mHealth use, we inductively conducted a thematic analysis to identify barriers and facilitators to mHealth use by CHWs [40]. After thematic analysis, we synthesized and reflected on the results using Davis et al.'s socio-technical system (STS) framework [41]. STS framework argues that CHWs' engagement with mHealth depends on six aspects 1) the people, 2) working practices, 3) program goals, 4) culture, 5) infrastructure, and 6) technology. The first four aspects cover the social dimension of mHealth while the last two aspects cover the technology dimension of mHealth. [42]. Applying STS by Davis et al. allowed a comprehensive and up-to-date analysis of the barriers and facilitators of both the technical and social systems of mHealth, rather than focusing on technology alone, as has been done in other digital health studies [43, 44].Further discussion on the dimensions of STS is discussed in the results section and Figure 2. Second, we explored within- and between-study relationships to describe the variability in the results before integrating and synthesizing the findings. Finally, we assessed the robustness of the synthesis by reflecting on the methodology and results in the discussion section.

Results

Summary of the studies

We retrieved 2594 records from all databases (Figure 1). After removing duplicates, 1107 records underwent title and abstract screening, leaving 64 articles. After full-text screening, 20 articles were included. We found two additional articles from reference searching, resulting in a final number of 10 studies comprising 22 articles. Reasons for exclusion included mHealth use by other health care workers other than CHWs (n=19), outcomes other than ANC, facility-based births or PNC (n=16), facility-based mHealth tools (n=3), mHealth not used to increase outcomes of interest (n= 4), the role of mHealth not clear (n=1) and not a mHealth intervention (n=1) (multimedia appendix 2).

Characteristics of the studies

The ten studies were published between 2012 and 2022 (Table 2 and Table 3; see risk of bias assessment below for article designs). Based on location, three studies were published in Tanzania [45-47], two studies each from Ethiopia [48, 49] and Uganda [50, 51] and one study

each from Rwanda [52], Mozambique [53], and Kenya [54].The mHealth program for Rwanda was implemented nationally, while the other mHealth programs were implemented either as a pilot or at a sub-national level. Half of the mHealth platforms used were mobile apps (five studies) [45-47, 49, 53], followed by SMS-based platforms (four studies) [48, 50, 52, 54] and voice calls (1 study) [51].

Risk of bias assessment

All 22 included articles were assessed for risk of bias using the MMAT tool (Table 1). Among the qualitative articles, three were assessed as low risk of bias [55-57], and one had an unclear risk of bias [58]. Among the randomized controlled trials, one had an unclear risk of bias [53], and the rest had a high risk of bias [45, 48, 51]. Among the quantitative non-randomized articles, three had a low risk of bias [46, 52, 59], and the rest had a high risk [50, 60-62]. Among the two descriptive articles, one had a low risk of bias [47], while the other had a high risk of bias [63]. Finally, one mixed method article had a low risk of bias [54], while four mixed method articles had a high risk [49, 64-66].

Table 1 Risk of bias assessment

Qualitative studies	Author/ publication year	S1. Are there clear research questions?	S2. Do the collected data allow to address the research questions?	1.1. Is the qualitative approach appropriate to answer the research question?	1.2. Are the qualitative data collection methods adequate to address the research question?	1.3. Are the findings adequately derived from the data?	1.4. Is the interpretation of results sufficiently substantiated by data?	1.5. Is there coherence between qualitative data sources, collection, analysis and interpretation?	Comments
1	Webber 2020	Yes	Yes	Yes	Can't tell	Yes	Yes	Yes	Unclear risk of bias: The reasons for choosing the sampling method are not

									described.
2	Ayiasi 2015	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low risk of bias
3	Musabyimana 2018	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low risk of bias
4	Mwendwa 2016	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low risk of bias
Quantitative randomized controlled trials	**Author/ publication year**	**S1. Are there clear research questions?**	**S2. Do the collected data allow to address the research questions?**	**2.1. Is randomization appropriately performed?**	**2.2. Are the groups comparable at baseline?**	**2.3. Are there complete outcome data?**	**2.4. Are outcome assessors blinded to the intervention provided?**	**2.5 Did the participants adhere to the assigned intervention?**	**comments**
1	Sevene 2020	Yes	Yes	Yes	Yes	Yes	Yes	Can't tell	Unclear risk of bias: The authors commented that participants may have crossed over between the intervention and control sites, but this was

									not quantified nor addressed by the study design.
2	Ayiasi 2016	Yes	Yes	Yes	No	Yes	No	No	High risk of bias: House hold and individual characteristics were not comparable. Assessors were aware of control and intervention sites
3	Hackett 2018	Yes	Yes	Yes	Yes	Yes	No	Yes	High risk of bias: No blinding.
4	Atnafu 2017	Yes	Yes	Yes	Yes	Yes	No	Can't tell	High risk of bias: No blinding, potential crossover effect,

									and the authors did not provide an explanation of this in the manuscript
Quantitative non-randomized studies	**Author/ publication year**	**S1. Are there clear research questions?**	**S2. Do the collected data allow to address the research questions?**	**3.1. Are the participants representative of the target population?**	**3.2. Are measurements appropriate regarding both the outcome and intervention (or exposure)?**	**3.3. Are there complete outcome data?**	**3.4. Are the confounders accounted for in the design and analysis?**	**3.5. During the study period, is the intervention administered (or exposure occurred) as intended?**	**Comments**
1	Webber 2022	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low risk of bias
2	Asiki 2018	Yes	Yes	No	Yes	Yes	Yes	No	High risk of bias: use of convenience sampling and some participants did not receive the

									intervention as intended.
3	Atnafu 2015a	Yes	Yes	Yes	Yes	Yes	No	Can't tell	High risk of bias: The authors did not adjust for confounders. High risk of confounding bias
4	Atnafu 2015b	Yes	Yes	No	No	Can't tell	No	Can't tell	High risk of bias: There is no sample size calculation, unclear sampling method, very high nonresponse rate and no details on choices of variables and outcomes.

5	Hategeka 2019	Yes	Yes	Yes	Yes	Yes	Yes	Yes	low risk of bias.
6	Ruton 2018	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low risk of bias.
7	Mwendwa 2018	Yes	Yes	Yes	Yes	Yes	No	Can't tell	High risk of bias. No adjustment of confounders. As a self-reported study, it is difficult to tell if the participants received the intervention as intended.
Quantitative descriptive studies	**Author/ publication year**	**S1. Are there clear research questions?**	**S2. Do the collected data allow to address the research questions?**	**4.1. Is the sampling strategy relevant to address the research question?**	**4.2. Is the sample representative of the target population?**	**4.3. Are the measurements appropriate?**	**4.4. Is the risk of nonresponse bias low?**	**4.5. Is the statistical analysis appropriate to answer the research question?**	**Comments**
1	Fulche	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low

	r 2020								risk of bias.
2	Ngabo 2012	Yes	Yes	No	No	Can't tell	Can't tell	Can't tell	High risk of bias: The article lacks a sampling strategy and description of measurements and outcomes. High risk of confounding bias.
Mixed methods	**Author/ publication year**	**S1. Are there clear research questions?**	**S2. Do the collected data allow to address the research questions?**	**5.1. Is there an adequate rationale for using a mixed methods design to address the research question?**	**5.2. Are the different components of the study effectively integrated to answer the research question?**	**5.3. Are the outputs of the integration of qualitative and quantitative components adequately interpreted?**	**5.4. Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?**	**5.5. Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?**	
1	Webbe	Yes	Yes	Yes	Yes	No	No	No	High

	r 2019								risk of bias: Limited discussion on quantitative results in light of qualitative results
2	Boene 2021	Yes	Yes	Yes	Yes	Yes	Yes	No	High risk of bias: Some concern e.g., criteria for selection not discussed and limited discussion of qualitative methods and results.
3	Nigussie 2021	Yes	Yes	Yes	Yes	Yes	can't tell	No	High risk of bias: Limited qualitative results and no descriptions of divergences. Limite

									d information on qualitative and quantitative method.
4	Mushamiri 2015	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low risk of bias.
5	Battle 2015	Yes	Yes	Yes	Yes	Yes	Yes	No	High risk of bias: Qualitative sampling methods not adequately described.

Table 2 Quantitative studies reporting on the impact of mHealth use by CHWs.

	Author, year, and outcomes of interest	Study design	Country / Context	Intervention description	mHealth description	Main findings
	Sevene 2020 [53]	Cluster randomized control trial	Mozambique (Sub-national, rural, and urban districts)	**Intervention:** CHWs conducted home visits to pregnant women to provide education, danger signs identification, referrals, birth	**Type: Mobile app (PIERS On the Move app (POM)).** **Use:** POM was used for clinical decision support during the CHW	**ANC: No difference** In comparison to control clusters, no difference in four or more ANC visits (48·6% vs 42·5% (aOR 1·57 [99% CI 0·97-

Author, year, and outcomes of interest	Study design	Country / Context	Intervention description	mHealth description	Main findings
			preparedness, and postnatal care. CHWs also measured blood pressure and administered drugs for severe hypertensive disease. Other interventions included transport support and health talks at health facilities. **Control:** Six control clusters where CHWs conducted home visits without using mHealth. No other interventions were provided.	home visit. CHWs used the app to identify pregnant women with danger signs (using pictograms), and if danger signs were present, they would refer the client to health facilities. If no danger signs were present, CHWs measured blood pressure, and if women met predefined criteria for referral, they would be referred immediately to an appropriate health facility.	2·52]) **Facility-based births: No difference** No differences in facility births (67.3% vs.74.2% (aOR 0.8 [99% CI 0·28, 2·61]; *P* = ·71)) or births at comprehensive emergency and neonatal care facilities (CEMONC) (11.3% vs. 13.0% (aOR 0.85 [99% CI 0·27, 2·62]; *P* = ·7)
Hackett 2018 [45]	Cluster randomized control trial	Tanzania (Pilot and rural district)	**Intervention:** In 16 clusters, CHWs were trained in integrated Maternal, neonatal, and child Health(iMNCH) training. CHWs also conducted household visits to educate and refer clients to	**Type: Mobile app (CommCare-based app).** **Use:** CHWs used the app to register pregnant women, counseling of pregnant women, identification of danger signs, flagged women who needed referrals, and created reminders	**Facility-based births: Increase in utilization** 74% of pregnant women gave birth in transit or at the facility in intervention villages compared to 62% in control villages. The odds of facility delivery were two times the odds between

Author, year, and outcomes of interest	Study design	Country / Context	Intervention description	mHealth description	Main findings
			care during pregnancy and postpartum. mHealth app was used during the home visits. **Control:** CHW trained in iMNCH but using paper-based tools in 16 control clusters	for CHWs to follow up with women they referred.	the intervention and control group (OR 1.96, CI 1.21-3.19, *P*=.01)
Atnafu 2017 [48] 🔴 🟢	Cluster randomized control trial	Ethiopia (Sub-national, rural and urban districts)	**Intervention:** The intervention targeted pregnant women in two clusters: 1) Partial: Higher cadre CHWs (i.e Health Extension Workers [HEWs]) in one cluster were provided mHealth, while lower cadre volunteer CHWs were responsible for community mobilization, education, and referrals but were not provided with phones. 2) Full: In one cluster, HEWs were provided mHealth, and volunteer CHWs were provided regular phones for voice calls.	**Type: SMS-based (FrontlineSMS) and regular phone for voice calls.** **Use:** mHealth was used for SMS reminders to CHWs to follow up with pregnant women at 14, 24, 30, and 36 weeks of pregnancy to encourage women to attend all ANC visits and give birth at health facilities. Additionally, voice calls were used to arrange referrals and communication between HEWs and volunteer CHWs. Other functions of included data collection and	🔴 **ANC: Increase in utilization of ANC** High ANC attendance at baseline in both intervention and control sites. Significant increase in four or more ANC visits in intervention sites in comparison to control sites (partial intervention: 45.3% to 59.8%, *P*<.001; full intervention: 15.8% to 31.5%, *P*<.001; control sites: 24.5% to 23.3%) 🟢 **Facility-based births: Decrease in home delivery** Home births decreased in all intervention sites

Author, year, and outcomes of interest	Study design	Country / Context	Intervention description	mHealth description	Main findings
			Control: No mHealth use by CHWs. CHWs performed home visits and community mobilization.	reporting and supply chain management.	(partial intervention: 61.6% to 33.7%, full intervention: 50.7% to 35.8%, control sites: 72.8% to 58.5%)
Ayiasi 2016 [51]	Cluster randomized control trial	Uganda (Pilot, two rural districts)	**Intervention:** Existing CHWs (called Village Health Teams [VHTs]) conducted two prenatal home visits and one postnatal home visit to provide standardized educational messages for maternal and newborn care in 8 clusters. Additionally, each VHT had unlimited calls with healthcare workers for clinical consultation. **Control:** VHTs in eight health clusters provided usual community mobilization.	**Type: Voice calls Use:** Mobile phones were used for clinical consultation between CHWs and providers and to arrange for referrals from the communities to health facilities..	**ANC: No significant differences in rates of ANC visits.** 85% of women made three or more ANC visits in interventional clusters compared to 71% in control clusters (aOR 1.82(0.65–5.09), *P*=.26). **Facility-based births: Higher in intervention than control sites** Three times higher (90%) in intervention sites than in control sites (28%). Intervention increases the odds of facility delivery by 18 (OR 17.94, 95% CI 6.3-51.4, *P*<.001).

Author, year, and outcomes of interest	Study design	Country / Context	Intervention description	mHealth description	Main findings
Webber 2022 [46, 64] 	Interrupted time series	Tanzania (Sub-national, rural)	**Intervention:** CHWs were trained to educate pregnant women on the importance of ANC, giving birth at facilities and danger signs using a mHealth app. Other interventions implemented included birth kit distribution at 34-36 weeks gestation and transport support. **Control:** CHWs who were not using mHealth	**Type: Mobile app (based on community health toolkit).** **Use:** The mobile health app supported CHWs in providing education on the importance of attending ANC, giving birth at facilities, and identifying danger signs.	**Early results** **Facility-based births: Suggested an increase in facility-based births** Rates of facility deliveries increased (Bunda town from 87% to 93%, Bunda rural from 70% to 84% and Tarime from 48% to 67%) between 2015 and 2016. **Final Evaluation** **ANC: No difference** No difference in four or more ANC visits after introducing mHealth (Immediate change: OR = 1.19 95% CI 0.93 to 1.51, *P* = .171 per month. Gradual effect: OR = 1.02, 95% CI 0.99 to 1.05, *P*= .24 per month). **Facility-based births: increase in utilization** 85.1% increase in facility deliveries

	Author, year, and outcomes of interest	Study design	Country / Context	Intervention description	mHealth description	Main findings
						post intervention as compared to 71.8% at baseline with an immediate increase in the odds of facility-based births (OR=1.51, 95% CI 1.14 to 2.01, *P*=.004) and a small gradual effect (OR = 1.03 per month, 95% CI 1.00 to 1.07, *P* = .06). **PNC: No difference** No significant immediate change and a decline in the trend of PNC after introducing mHealth (Immediate change: OR = 1.07, 95% CI 0.61 to 1.89, *P* = .81, gradual effect OR = 0.92, 95% CI 0.86 to 0.98,*P* = .01)
	Hategeka 2019 [52, 59]	Interrupted time series desig	Rwanda (National program, rural	**Intervention:** CHWs with mHealth supported pregnant women	**Type: SMS-based Use:** CHWs used an open-source rapidSMS platform to	**Using DHS data (2014-2015) in 29/30 districts.**

Author, year, and outcomes of interest	Study design	Country / Context	Intervention description	mHealth description	Main findings
	n	and urban districts)	with education, follow-up, and linkage to care in the maternal health continuum of care. The intervention was stratified. a) Facilities in 20 districts were receiving the usual support. b) Facilities in 10 districts that received health system strengthening by two NGOs (including ongoing training to CHWs and equipment provision to health facilities) **Control:** CHWs not using mHealth	facilitate communication between the health system and CHWs, facilitate clinical appointments by using reminders, support the clinical decisions by providing information on what to do by CHWs during an emergency and facilitate referrals in emergencies by linking CHWs with the ambulance drivers. Other functions of the rapidSMS system included registries/vital events tracking, data collection and reporting and electronic health records.	**ANC: No difference** No change in any ANC visits [Immediate change: -1.00, 95% CI: -2.30 to 0.29 and gradual effect: -0.04, 95% CI: -0.14 to 0.06]. No change in four or more ANC visits [Immediate change: -1.69, 95% CI:-9.94 to 6.55 and gradual effect: -0.40, 95% CI: -1.09 to 0.27] No change in first trimester ANC visits [immediate change: -3.80, 95% CI: -13.66 to 6.05 and gradual effect: -0.62, 95% CI: -1.43 to 0.19] **Facility-based births: No difference** No change in facility-based births [Immediate change: -1.79, 95% CI: -6.16 to 2.58 and gradual effect: -0.13, 95% CI: -0.49 to 0.22]. **Using routine health facility date in all 30**

Author, year, and outcomes of interest	Study design	Country / Context	Intervention description	mHealth description	Main findings
					districts **ANC: No difference** No change in all 30 districts (*P*= .51 and .70 for supported districts and .38 and .50 for non-supported districts). **Facility-based births: A gradual increase in facility-based births** In supported sites, there was no immediate change in facility births but a change in gradual effect (estimate 0.015 facility births per 1000 population, 95%CI: 0.007–0.023, *P* < .001).No change in non-supported sites. PNC: Immediate increase in PNC visits Change in supported facilities (0.11 visits/1000 population immediate

Author, year, and outcomes of interest	Study design	Country / Context	Intervention description	mHealth description	Main findings
					increase of PNC visits, 95% CI: 0.033-0.179, *P* =.007) and no change in trend. No change in the rate of PNC visits in non-supported districts (*P*=.13)
Asiki 2018 [50]	Nested cohort study	Uganda (Pilot, rural)	**Intervention:** In 13 clusters, CHWs registered pregnancies and made monthly visits to pregnant women to relay text messages and track outcomes. **Control** 13 villages where CHWs followed pregnancies monthly using paper-based forms	**Type: SMS-based** **Use:** mHealth supported CHWs to register pregnancies. Additionally, each month, SMS reminders were sent to CHWs on which pregnant women they should visit to relay targeted messages on timely and safe ANC and facility-based births.	**Facility-based births: Decreases in-home delivery** Intervention home delivery was 9.2%, and control home delivery was 22.4%. After controlling for confounders, the intervention arm had lower odds of home delivery (AOR 0.38, 0.15-0.97).
Mushamiri 2015 [54]	Mixed method study, the quantitative component used a non-randomized control	Kenya (Sub-national, rural)	**Intervention** CHWs providing a community-based package of care and following up with pregnant women using mHealth. **Control** CHWs who were providing community-based package of care and were not	**Type: SMS-based platform** **Use:** SMS reminders were sent to CHWs to remind pregnant women three days before the ANC once they are registered in mHealth. Reminders were repeated two times if the women failed to	**ANC: mHealth increased utilization of ANC** In comparison to women not followed by CHWs using mHealth, women had three times the odds of making more ANC visits, even after adjusting for HIV (aOR = 2.58, 95% CI [1.10-6.01])

Author, year, and outcomes of interest	Study design	Country / Context	Intervention description	mHealth description	Main findings
	group study.		using mHealth.	attend ANC. Reminders were sent up to 18 months after delivery.	
Nigussie 2021 [49]	Mixed methods	Ethiopia (rural and urban, subnational)	CHWs registered, referred, followed up, and tracked pregnant women along the maternal health continuum of care. CHWs and their supervisors used mHealth to support their tasks.	**Type: Mobile app** Once clients are registered in the app, the system sends notifications and reminders to CHWs app to visit pregnant women and remind them to go to a health facility for ANC and PNC. These reminders are also sent through SMS to CHWs and clients. Additionally, the program supported with free caller user group, facilitating referrals from the community to the facility.	**ANC: suggest increases in utilization** Pregnancy registration in the first and second trimesters increased between Q3 2017 and Q2 2018 (e.g. first-trimester registration increased from around 0% to about 10%), with a corresponding decline in registration in the third and fourth trimesters. **Facility-based births: Suggests increase in utilization** Facility-based births: Increased from around 100 per quarter to over 900 in Q2 2018 **Postnatal care: Suggests increase in utilization.**

Author, year, and outcomes of interest	Study design	Country / Context	Intervention description	mHealth description	Main findings
					Increased from around 100 per quarter to over 700 in Q2 2018.
Fulcher 2020 [47, 65]	Descriptive process evaluation	Tanzania (Rural and urban, sub-national)	CHWs registered and enrolled pregnant women conducted three ANC home visits and three PNC visits using mHealth. Other supporting interventions included community savings, transport support, and stakeholder engagement.	**Type: Mobile app (Mangologic app)** **Use:** The app helped CHWs to know when to conduct home visits, identify women with danger signs and referring them to care, follow up with women within three days after referral and helped coordinate referrals with health facilities. The app was also used for data collection.	**Early Findings** **Facility-based births: Suggests increase in utilization** Among 13,231 deliveries, 75% gave birth at hospitals in comparison to a baseline of 35%. **PNC: Suggests increase in utilization** 88% PNC attendance in intervention sites in comparison to a baseline of 36% from DHS **Final evaluation** **Facility-based births: Suggests increase in utilization** Health facility births increased from 60%, 70%, 80% and 80% between years one and four. **PNC: Suggests increase in utilization** Women who attended PNC

Author, year, and outcomes of interest	Study design	Country / Context	Intervention description	mHealth description	Main findings
					visits increased from 60%, 60%, 70%, and 80% in years 1, 2, 3 and 4, respectively.

Antenatal care Facility-based birth Postnatal care

Impact of mHealth use by CHWs on maternal health services

The ten studies (13 articles) reported at least one outcome of interest (Table 2). We present the findings based on the outcome of interest.

ANC

Seven studies (eight articles) [46, 48, 49, 51-54, 59] reported at least one ANC outcome. Based on outcomes, only two studies reported on ANC visit in the first trimester [49, 52]. None of the studies reported on eight or more ANC contacts. Three out of the seven (43%) studies [48, 49, 54] showed an association between mHealth use by CHWs and increased ANC utilization. Based on platform, the studies that showed an association used SMS-based platforms (two studies) [48, 54] and mobile app (one study) [49].

The observational study, which had a high risk of bias, suggested increased ANC utilization after mHealth use by CHWs. Using a mobile app, this study conducted in Ethiopia by Nigussie [49] showed an increase in ANC contact in the first trimester by about 10%.

Three RCTs, one with an unclear risk of bias [53] and two with a high risk of bias [48, 51], reported on ANC outcomes. Atnafu et al. [48] used an SMS-based platform to remind CHWs to follow up pregnant women at 14, 24, 30, and 36 weeks of pregnancy in Ethiopia. The study found a significant increase in the proportion of women with four or more ANC visits in the intervention sites in comparison to control sites (cluster with higher cadre CHWs using SMS platform while lower cadre CHWs were not provided with phones: 45.3% to 59.8%, P<.001; cluster with higher cadre CHWs using SMS platform while lower cadre CHWs were using mHealth for voice calls: 15.8% to 31.5%, P<.001; control sites (no mHealth): 24.5% to 23.3%). The RCT conducted by Sevene et al. [53] in Mozambique was a clinical decision support mHealth app primarily used to support CHWs to screen for hypertension and make referrals to health facilities for care when they enroll pregnant women during initial home visits or scheduled community follow-ups of pregnant women. As a secondary outcome, the proportion of women with four or more ANC visits was not statistically different between intervention and control sites. Finally, a study conducted by Ayiasi et al. [51] in Uganda, where CHWs used voice

calls for consultations with healthcare workers during home visits, showed no significant difference in the number of women who attended three or more ANC visits between intervention and control sites.

Four quasi-experimental studies reported on ANC outcomes. In an SMS-based mHealth platform in Kenya, Mushamiri et al. [54] reports positive findings between pregnant women receiving appointment reminders by CHWs using mHealth compared to women receiving CHW care without mHealth. In this study, women receiving care from CHWs using mHealth and starting ANC in the second trimester had three times the odds of attending ANC Visits (aOR = 2.58, 95% CI [1.10-6.01]) than women receiving care from CHWs not using mHealth. An SMS-based study (reported by two quasi-experimental articles) [52, 59] used an interrupted time series design to evaluate a nationally implemented rapidSMS platform in Rwanda. RapidSMS platform was an interactive two-way communication between CHWs and health care workers that facilitated clinical appointments of pregnant women by using reminders, supported the clinical decisions by providing information on what to do by CHWs during an emergency, and facilitated referrals during emergencies. After scaling rapid-SMS countrywide, ten districts received health system strengthening support from two non-governmental organizations (NGOs) (Ongoing training to CHWs and equipment provision to health facilities). In contrast, the rest of the district received the usual support from the Rwanda MOH. Using 2014-2015 Demographic and Health Survey data in 29 out of 30 districts of Rwanda, Hategeka et al. [52] found no change in any ANC visits, ANC in the first trimester, or four or more ANC visits. Using routinely collected health facility data in 461 health facilities, Ruton et al. [59] found no change in ANC visits in all 30 districts of Rwanda. Finally, a quasi-experimental study using a time-series design by Webber et al. [46] used a mHealth app in Tanzania to educate women on the importance of attending maternal health services. Findings showed no significant differences in four or more ANC visits after introducing mHealth.

Facility-based births

Nine studies (a total of 12 reports) reported on facility-based births: 89% (eight out of nine studies) found an association between mHealth use by CHWs and an increase in facility-based births or a reduction in home births. Among the studies that found a positive association, three studies [48, 49, 54] used an SMS-based platform, four studies [45-47, 49] used a mobile app, and one study used voice calls [51].

A low-risk-of-bias process evaluation study implemented in Tanzania by Fulcher et al. [47], utilized a mobile app by CHWs to increase demand for facility services by pregnant women, showing an increase in facility-based births from year 1 to year 4 of implementation (from 60% to 90%). Nigussie [49] also found increased facility-based births after implementing mHealth by CHWs.

In a high-risk-of-bias RCT conducted in Tanzania, Hackett et al. [45], compared the impact of the mHealth app between intervention clusters where CHWs were using the app and control clusters where CHWs were not using mHealth. The odds of facility-based births in intervention clusters were double those in the control clusters (OR 1.96, CI 1.21-3.19). RCTs conducted by

Atnafu et al. [48] and Ayiasi et al. [51] also reported a reduction in home births (home births decreased in all intervention sites [cluster with higher cadre CHWs using SMS platform while lower cadre CHWs were not provided with mHealth: 61.6% to 33.7%, cluster with higher cadre CHWs using SMS platform while lower cadre CHWs were with mHealth for voice calls: 50.7% to 35.8%, control sites: 72.8% to 58.5%]) and an increase in facility-based births (Intervention increased the odds of facility birth by 18 (OR 17.94, 95% CI 6.3-51.4, *P*<.001)), respectively. However, Sevene et al. [53] found no change in facility-based births between intervention and control clusters.

Two quasi-experimental studies where CHWs used mobile apps found a positive impact of mHealth on improving facility-based births and reducing home birth rates. Webber et al. [46], a low-risk of bias study from Tanzania found mHealth increased the odds of facility births (Immediate increase: OR=1.51, 95% CI 1.14 to 2.01, *P*=.004; gradual effect: OR = 1.03 per month, 95% CI 1.00 to 1.07, *P* = .06). Asiki et al. [50], a high-risk of bias study from Uganda compared the impact of an SMS-based platform between CHWs using SMS reminders to follow up on pregnancy outcomes with CHWs not using mHealth in Uganda. After controlling for confounders, mHealth reduced the odds of home births (aOR 0.38, 95% CI 0.15-0.97). Two quasi-experimental reports based on the rapidSMS study in Rwanda showed mixed results. Hetegeka et al. [52] found no change in facility-based births. Ruton et al. [59] found no change in 20 districts that were not supported by the two NGOs, while there was a change in 10 supported districts (Gradual effect in 10 supported sites- 0.015 facility births per 1000 population per month, 95% CI: 0.007–0.023, *P* < .001)) signifying the extra role played by embedding mHealth into broader health system strengthening initiatives.

PNC

We found two observational studies [47, 49] and two quasi-experimental studies[40, 53] reporting on mHealth use by CHWs on PNC visits [46, 59]. Among the three studies that showed a positive association, mobile app [47, 49] and SMS [59] were used.

Fulcher et al. [47] found that the mHealth app used by CHWs increased any PNC visits from 60% to 80% within four years of implementing the program. Nigussie also showed an increase in any PNC visits by mHealth use by CHWs [49]. In Rwanda, Ruton et al [59] reported a 100% increase in PNC within a year of starting mHealth in 10 districts that received extra NGO support (0.11 visits/1000 population immediate increase in PNC visits, 95% CI: 0.033-0.179). However, the rate of PNC visits remained the same in 20 districts not receiving health system strengthening. Finally, a study from Tanzania by Webber et al. [46] showed no impact of the mobile health app on PNC.

Facilitators and barriers to mHealth use

Eight studies (a total of 14 articles) reported on facilitators and barriers to mHealth uptake (Table 3 and Figure 2). We will discuss facilitators and barriers simultaneously and in alignment with the STS framework by Davis et al [41]: Goals, People, Culture, Processes, Infrastructure, and Technology. The definitions of the dimensions are described in each section.

Table 3 Studies reporting on barriers and facilitators to mHealth use by CHWs

	Study	Articles (author, year)	Designs	mHealth description	The study aims/findings
1	Sevene 2020	Boene 2021 [66]	Mixed methods	Mobile app	**Facilitators:** Training on mHealth, refresher training, mentorship and supervision, smartphones improved their status as healthcare workers, trust by communities, and good working relationships with clients. **Barriers:** Poor battery life, poor attachment with accessories, lack of power to charge phones, and poor network connectivity
2	Atnafu 2017	Atnafu 2015a [60]; Atnafu 2015b [61]	Both are Cross-section studies	SMS-based	**Facilitators:** Good working relations with supervisors, availability of free phone and free airtime. **Barriers:** Poor network connectivity, lack of power to charge phones, inadequate number of phones or other equipment, loss or damage of phone and other equipment, and inadequate airtime.
3	Ayiasi 2016	Ayiasi 2015 [55]	Qualitative	Voice calls	**Facilitators:** Smartphones improved their status as health care workers, trust by communities, good working relations with supervisors, and positive supervisor feedback. **Barriers:** Staff absences, lack of power to charge phones, poor network connectivity, poor attitude of health care workers, and poor relationships with clients.
4	Webber 2022	Webber 2019 [64]; Webber 2020 [58]	Mixed methods; qualitative	Mobile app	**Facilitators:** Free phone, airtime, and solar chargers. **Barriers:** Poor network connectivity, lack of power to charge phones, inadequate airtime, poor app navigation. and poor app workflows.
5	Hategeka 2019	Ngabo 2012 [63]; Musabyimana	Descriptive, qualitative; qualita	SMS-based	**Facilitators**: MOH ownership, incentives, strong existing CHW program, additional health system strengthening activities, appropriate stakeholder engagement, high education level of CHWs, training,

	Study	Articles (author, year)	Designs	mHealth description	The study aims/findings
		2018 [57]; Mwendwa 2016 [56]; [62]	tive; cross-section		positive feedback, positive program outcomes, trust by communities, good working relations with supervisors, and good network connectivity. **Barriers:** High initial cost of development, illiteracy, poor network connectivity, lack of power to charge phones, inadequate airtime, high workload due to both paper and smartphone-based data entry, poor organization of training, app in a foreign language, inadequate supervision, inadequate number of phones or other equipment, poor relationships with clients, loss or damage of phone and other equipment, and no stipend or salary to CHWs.
6	Nigussie 2021	Nigussie 2021 [49]	Mixed methods	Mobile app	**Facilitators**: Appropriate stakeholder engagement and MOH ownership, additional health system strengthening activities. **Barriers:** High workload due to both paper and smartphone-based data entry, phone sharing culture, fear of losing phones to theft, delay in reporting challenges of mHealth, lack of skills in monitoring service delivery, loss and damage of phone and other equipment, poor network connectivity, inadequate airtime, loss and damage of phone and other equipment, delay in repairing or replacing equipment, and burden of carrying multiple mobile devices.
7	Fulcher 2020	Fulcher 2020 [47]	Descriptive process evaluation	Mobile app	**Barriers:** Poor network connectivity, high loss to follow up of clients, high attrition of CHWs, and software crashing.
8	Mushamiri 2015	Mushamiri 2015 [54]	Mixed methods	**Type: SMS-based**	**Facilitator:** Free caller user group, and good network connectivity **Barriers:** Contract termination with a network provider, and late health-seeking

	Study	Articles (author, year)	Designs	mHealth description	The study aims/findings
					behavior

People

STS describes this dimension as the users and stakeholders of a system and their characteristics. The included articles explored facilitators and barriers around CHWs as the main stakeholders, their surrounding environment (e.g., communities and supervisors), and their characteristics (e.g., attitudes, behavior, skills).

One of the unintended benefits but a powerful facilitator of mHealth use was the effect of the mHealth devices on the status of CHWs. mHealth improved the social status of CHWs as they were perceived as being recognized by the formal health system [55, 66]. Perceived higher social status improved community trust, another facilitator identified in multiple studies [55, 56, 66]. Other facilitators identified included higher education level of CHWs [56, 62], strong existing CHW program [63], MOH ownership of CHW programs [49, 63], and positive feedback from supervisors [55, 56, 62].

The social dynamics within and outside the CHW program also positively or negatively impacted mHealth use. Good working relationships and positive feedback between CHWs, their supervisors, healthcare workers, and communities facilitated mHealth use [55, 56, 61, 66]. In contrast, poor relationships among CHWs and communities and healthcare workers were singled out as barriers to mHealth use [49, 55, 57]. Other barriers identified in the studies included a lack of skills in monitoring service delivery by CHW supervisors [49], high staff absences and turnover [47, 55], CHW illiteracy [56], poor attitude by facility-based staff [55], and high loss to follow-up of clients [47].

Processes

Processes describe how practices and procedures are organized to support the system's uptake. The included articles described the influence of systems, practices, and procedures designed to support CHWs in effectively using mHealth. Additional existing health system strengthening activities facilitated positive outcomes in some mHealth-enabled CHW programs [49]. For example, additional training, provision of extra equipment and supplies, and supervision in Rwanda's rapidSMS program facilitated mHealth use by CHWs [59]. Additionally, engaging multiple and appropriate stakeholders, including telecommunication companies, facilitated the use of mHealth [49, 63]. In a study in Kenya, suspending a contract with a mobile communication provider for a few weeks was one of the most significant barriers to SMS-based mHealth rollout [54].

Several other processes were reported in many studies. Adequate training and refresher training on mHealth [62, 66], strong mentorship and supervision of CHWs [66], and improving education of CHWs facilitated mHealth use [56]. In contrast, a high CHW workload [49], poor reporting systems [49, 56], lack of training or poor training organization [56], and inadequate supervision [56] were reported as barriers to mHealth use. Provision of incentives/provision of salaries to CHWs was also mentioned, with regular incentives/salary as a facilitator [63] and lack of incentives/salary or low incentives/salary as a barrier to mHealth use [57].

Goals

This dimension explores how program performance and outcomes influence the uptake of a system. Very few studies reported on the impact of goals on mHealth uptake by CHWs, and only one facilitator and one barrier were identified. Positive program outcomes (e.g. perceived reduction in mortality by CHWs) in a rapidSMS program in Rwanda reinforced the use of mHealth [56, 57, 62]. One study in Kenya reported late presentation to ANC as a barrier [54]. This factor had a detrimental impact on the mHealth-driven goals of ANC visits within the scope of this study.

Culture

In STS, this dimension describes the influence of users' and stakeholders' beliefs, norms, and values in a system. Among the included studies, there needed to be more literature on how culture affected the use of mHealth. None of the studies reported on cultural factors that might facilitate mHealth adoption. Two studies conducted in Ethiopia [49, 61] reported sharing of a mHealth installed phone with other family members, which was part of the norm, as a barrier to mHealth use as the phone could not be used by CHWs when needed. In one of the studies, over a third of CHWs reported sharing the phone with other family members [61]. Additionally, two studies based on rapidSMS in Rwanda reported app language in a foreign language (i.e. English) as a cultural barrier [56, 62].

Infrastructure

This domain comprises the assets of a system. Among included studies, mHealth equipment and internet connectivity were frequently mentioned to influence the uptake of mHealth. Free phones [58, 61], free airtime, or reimbursement of airtime costs [58, 61] were facilitators of mHealth use. The provision of solar power for charging devices was also reported [58]. Lastly, reliable internet connectivity was mentioned as a facilitator of mHealth use [54, 63].
Most of the studies focused on barriers associated with devices and related equipment. The most commonly reported challenges with devices and associated equipment included loss and damage of phones and other equipment [49, 61, 63], delays in repairing or replacing equipment [49], the burden of carrying multiple mobile devices [49], fear of losing phones to theft [49], inadequate number of phones or other equipment [57, 61], poor quality of phones and battery life [66], and poor attachment of phones with their accessories [66]. In many settings, especially rural settings, lack of electricity was commonly reported as a barrier [55, 56, 58, 60, 61, 63, 64, 66]. Finally, poor mobile network connectivity [47, 49, 55, 56, 58, 60, 61, 64, 66] and inadequate airtime [49, 56, 60, 64] were also mentioned as barriers to mHealth use.

Technology

This domain comprised the influence of mHealth software on the uptake of mHealth use. Free closed user group calls were a facilitator in a voice-based mHealth platform; no other facilitators were identified [54]. However, several technology-related barriers were reported, including poor app workflows [58, 64] and frequent app software crashes [47]. One study reported the high cost of the technology used in mHealth as a barrier [63].

Discussion

This review is the first to synthesize evidence on the use of mHealth by CHWs to improve maternal health utilization in SSA. While most studies (nine out of ten) supported mHealth use

by CHWs to increase utilization of facility-based births, the results are mixed for ANC and PNC. For ANC and PNC, only about half of the studies showed that mHealth use by CHWs increases the utilization of these services. Based on the intervention descriptions, mHealth use by CHWs may have increased utilization by creating demand for these services. As shown previously, the demand created by mHealth is possible through multiple pathways. mHealth use by CHWs may have increased knowledge of good maternal health practices, leading to behavior change towards health facility use for care [47]. This is particularly important for studies that use mHealth apps. Secondly, primarily through SMS-based platforms, reminders may have encouraged women's attendance at health services [67]. It is also possible that mHealth may have increased demand by increasing satisfaction and trust in CHWs and the health system and may also have improved adherence to practices used by CHWs to increase demand for health services [68].

This review adds evidence on the impact of mHealth on maternal health utilization. Previous reviews have focused on the impact of mHealth on maternal health outcomes and have yet to distinguish the primary users of mHealth. A previous systematic review conducted by Gayesa et al. in low and lower-middle-income countries found that mHealth increased the odds of facility-based births and PNC [26]. Similarly, Wagnew et al. [69] reported that SMS-based mHealth increased the utilization of four or more ANC visits and facility-based births in low and middle-income countries. Rahman et al. and Sandool [27] also report positive effects of mHealth on ANC coverage and facility-based births in low and middle-income countries [70]. However, our study is unique as it presents the effect of mHealth use specifically by CHWs, a target group not explored in the other studies. Additionally, this is the first review to focus on SSA specifically.

We found mixed results on the impact of mHealth use by CHWs on ANC visits. Three of the seven studies that reported on ANC showed that mHealth use by CHWs may increase the utilization of ANC. While two SMS-based mHealth studies in Kenya and Ethiopia [48, 54] and one mobile app in Ethiopia [49] found increases in the overall number of ANC visits or four or more ANC visits, all other studies found no effect. We also found that many studies reported four or more ANC visits as an outcome. Reporting on four or more ANC visits may be attributed to the previous recommendation by WHO, where a minimum of four ANC visits were deemed adequate [71, 72]. Only two studies reported on ANC visits in the first trimester, and none of the studies reported on eight or more ANC contacts as recommended by recent WHO guidelines [73]. Since in many settings, especially in SSA, women start ANC late [74, 75], which may affect the number of ANC visits, we suggest designing mHealth programs to specifically focus on encouraging the early attendance of ANC (Table 4). Designing mHealth to support women to start ANC earlier may have two advantages. Firstly, mHealth may help identify pregnancies early through decision support and referrals to health facilities. Secondly, mHealth may support the provision of high-quality, community-based ANC care by CHWs [76]. This will ensure that mHealth supports recommended ANC contacts and the quality and outcomes of these community contacts.

We found very few studies reporting on PNC compared to studies reporting on ANC and facility-based outcomes. Among the four studies, one SMS-based study [59] and two mobile app

studies [47, 49] found increases in PNC visits after implementing mHealth programs. We suggest more studies designed to specifically show the effect of mHealth on postnatal visits, as providing care during the postnatal period reduces maternal and neonatal deaths and complications [7] (Table 4).

Findings from this review also have implications on scale-up and mHealth platforms of choice in SSA. Among the ten included studies, only one study in Rwanda has been implemented nationally [52], with the rest implemented as pilots or at the sub-national level. Additionally, the majority of the studies used either SMS or mHealth app. Since the results of this review show the benefits of mHealth by CHWs on maternal health outcomes, we suggest a national scale-up in pilot or sub-national programs, or new programs may consider the scale-up of mHealth from the beginning. As a choice of platform, this review has shown that SMS-based or mHealth apps may be used as platforms of choice (Table 4).

This review has also identified facilitators and barriers to mHealth use by CHWs across the six domains of STS. Most studies reported facilitators and barriers on people, processes, infrastructure, and technology among the six dimensions. One of the common findings was around the perceived improvement of CHW status when they started using mHealth, as well as improved trust. This finding is echoed across other studies [77, 78] and may be an essential reason for introducing mHealth in limited resource settings. A recent review on the use of mHealth by CHWs, specifically smart devices, also found similar finding that mHealth improves the CHW status [79]. As echoed by Perry et al. [31], improving the status of CHWs and increasing their recognition by the formal health system is a crucial enabler for successful CHW programs, and mHealth may provide the pathway toward this. Additionally, paying attention to the social environment of CHWs, including relationships, plays a vital role in the success of mHealth programs [80].

The findings from processes, infrastructure, and technology domains reinforce the importance of strengthening CHW programs and health service infrastructure before the introduction of mHealth or as part of its implementation. Critical components like MOH ownership, stakeholder engagement, standardized and robust systems like training, and provision of incentives/salary to CHWs need to be considered to ensure the success of mHealth in many settings. Other studies have also emphasized the need to build systems and appropriate governance to address barriers around mHealth equipment and evolving mHealth technologies [81, 82]. We therefore recommend the design and implementation of mHealth programs in SSA to include health system strengthening activities to maximize the impact of mHealth tools (table 4).

We need further studies across the two domains of the STS framework: culture and goals. Firstly, very few studies reported on the influence of culture and mHealth use by CHWs in SSA. Incorporating various aspects of culture, like local language, into mHealth improves its acceptability, usability and effectiveness [83, 84]. Unfortunately, limited studies report on the impact of culture on mHealth [84, 85], and we found similar results in this review [56, 61, 62]. More studies should be designed to explore culture and mHealth. Secondly, further research is needed on the impact of clearly defined goals as enablers and barriers to mHealth (Table 4).

This review has some limitations that should be considered when interpreting the findings. First, it focused on mHealth interventions by CHWs for women of reproductive age utilizing ANC, facility delivery, and PNC within 42 days in SSA. While this limits generalizability to other populations, settings, and maternal health outcomes, it allowed for a targeted examination of mHealth impact on key services across the continuum of care in a region with high maternal mortality.

Second, the review included studies that implemented mHealth alongside other health system

strengthening activities, making it difficult to isolate the effect of mHealth alone. However, this reflects the real-world implementation of mHealth as a tool to enhance CHW service delivery within broader health systems, rather than as a standalone solution.

Third, the review may have missed some relevant studies by excluding grey literature and not assessing publication bias. However, a comprehensive search of six databases and reference checking was conducted, and all studies meeting inclusion criteria from these sources were included.

Finally, studies were excluded if they lacked sufficient information on the mHealth intervention, which could introduce selection bias. However, this was necessary to ensure the review could meaningfully synthesize and interpret how mHealth was used to impact outcomes.

This study has implications for program implementation, policy, and research. Although these recommendations focuses on mHealth implementation in SSA, we hope some lessons can be applied to other settings. We present a summary of recommendations in Table 4.

Table 4 Implications of this review

Maternal health continuum of care outcomes	1. ANC: Design mHealth programs measuring the impact of mHealth on attendance of ANC in the first trimester and eight or more ANC contacts. 2. PNC: Design more studies to measure the impact of mHealth on PNC
Coverage of mHealth	1. National scale-up of mHealth programs in settings where mHealth has been shown to work but is being implemented as a pilot or at the sub-national level. 2. Where national scale-up of mHealth is desired, consider adding health system strengthening activities in addition to mHealth intervention. 3. Scale up of mHealth platforms that have been shown to work in other settings/countries in SSA.
Choice of mHealth platform	Consider SMS-based platforms and mobile health apps
STS domain requiring further data	Design studies to measure the influence of culture and goals on mHealth use

Conclusions

The study found evidence that mHealth use by CHWs increases the utilization of facility-based births. Although the results are mixed, about half of the studies that reported on ANC and PNC showed mHealth use by CHWs increased utilization of these outcomes. We found limited studies measuring the impact of mHealth on increasing ANC in the first trimester and eight or more ANC visits. Based on STS, most studies explored barriers and facilitators across people, processes, and procedures, building and infrastructure, and technology domains of STS. There needs to be more studies on STS's culture and goals domains as it concerns the impact and uptake of mHealth for improving maternal health outcomes.

Multimedia Appendix 1: Search strategy

Multimedia Appendix 2: Excluded studies and reasons for exclusion

Author contributions

Conceptualization and study design: CK, THD, TvdA, IOA

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Conflicts of Interest

None declared

Abbreviations

SSA: Sub-Saharan Africa
ANC: Antenatal care
PNC: Postnatal care
mHealth: Mobile health
CHWs: Community health workers
STS: Social-technical system
RCT: Randomized controlled trials
SDG: Sustainable Development Goals
MMR: Maternal mortality ratio
MMAT: Mixed method assessment tool
SMS: Short Message Service
NGO: non-Governmental organization
OR/ aOR: Odds ratio/ adjusted odds ratio
CI: Confidence interval
WHO: World Health Organization
MOH: Ministry of Health

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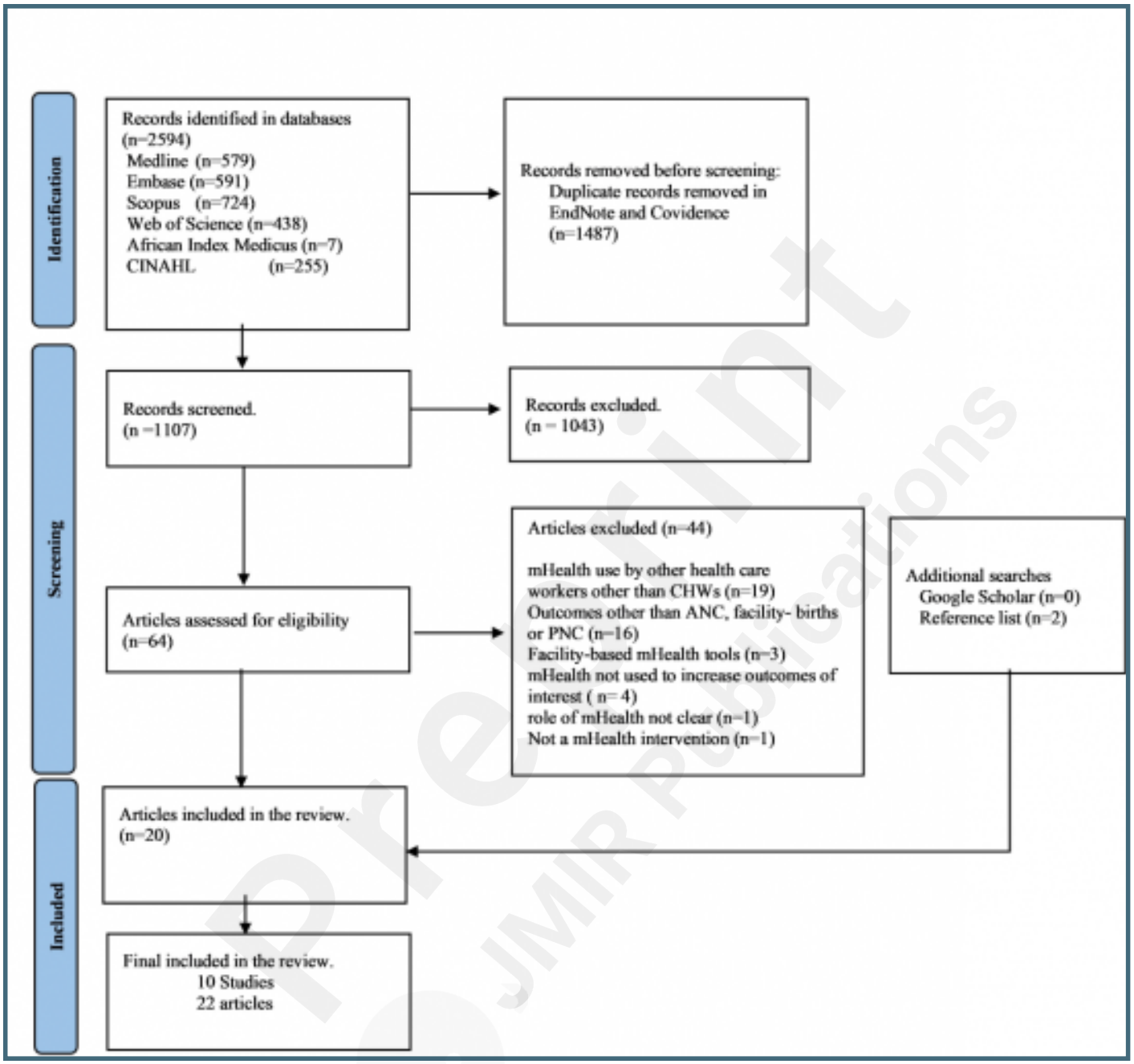
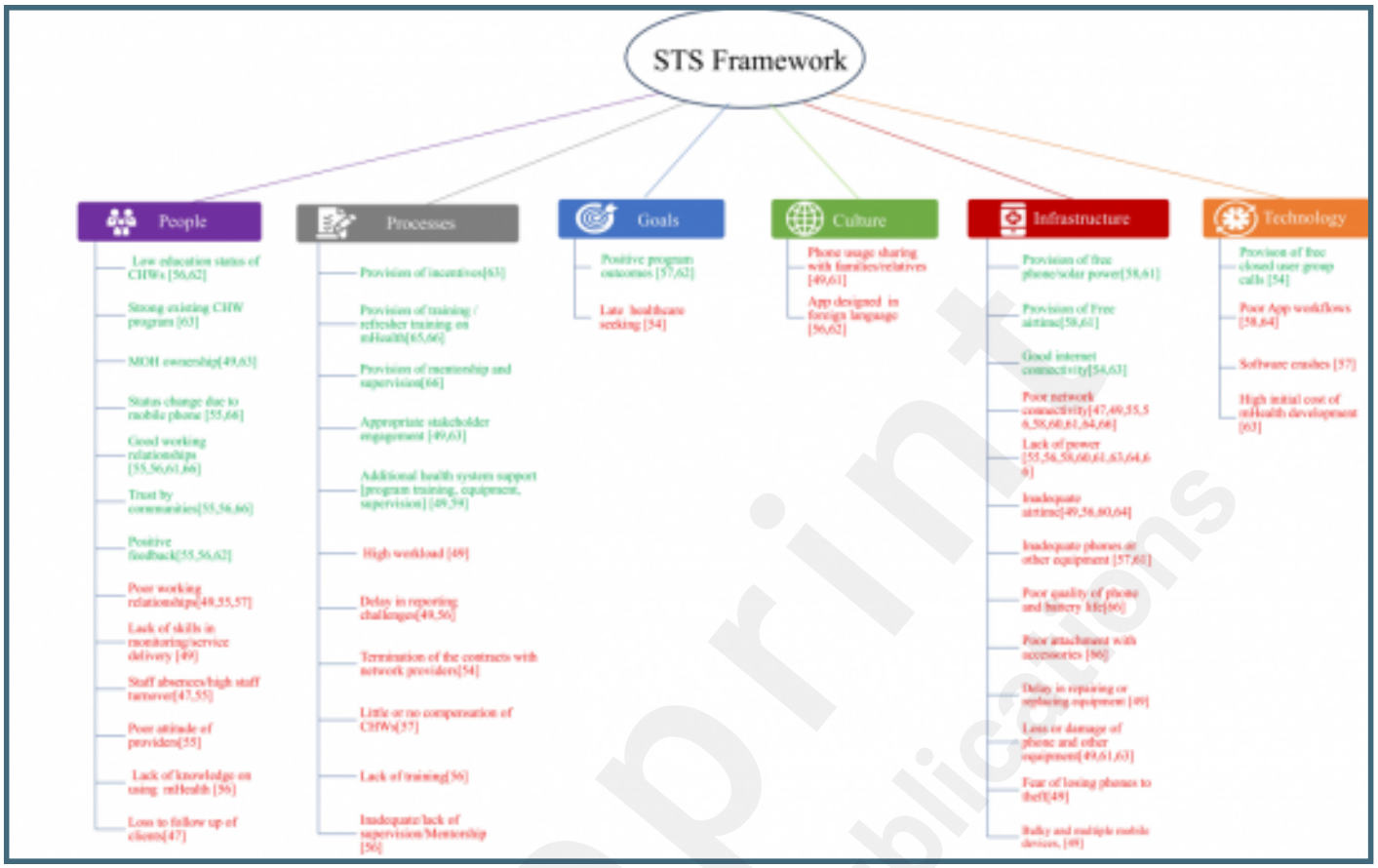
Supplementary Files

Figures

PRISMA flow diagram.



Facilitators and barriers mapped according to the socio-technical system (STS) framework.



Multimedia Appendixes

Search strategy.
URL: http://asset.jmir.pub/assets/334fafeaf27bbf9542e42a6f155bdc90.docx

Excluded studies and reasons for exclusion.
URL: http://asset.jmir.pub/assets/fbd6e1fea4eb0ff46fc2bea130e60cf9.docx

CONSORT (or other) checklists

PRISMA checklist.
URL: http://asset.jmir.pub/assets/bc7fc3eb39a68ead14dbb5c8a2faf72a.pdf