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Implementation research logic model in the design and execution of eHealth innovations for maternal and newborn healthcare in Ethiopia

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Abstract

Background The use of eHealth innovations is becoming increasingly important in improving health outcomes, especially for maternal and newborn health. However, planning and executing these innovations can be challenging due to their complex nature. To provide guidance and clarity on implementation approaches, researchers need to use implementation research (IR) tools. We conducted IR to recognize the challenges in implementing eHealth innovations in the context of maternal and newborn healthcare using the implementation research logic model (IRLM). Therefore, this paper aims to describe the practical application of IRLM to design, execute and evaluate eHealth innovations that improve maternal and newborn care in public facilities in Ethiopia.

Methods We employed rapid review, formative assessment and process evaluation of an eHealth innovation in selected healthcare facilities serving maternal and newborn care. The eHealth innovation we developed and deployed was named 'ADHERE' (**A**ntenatal Care, Chil**D**birt**H** Car**E** and Postnatal Ca**RE**), representing the continuum of maternal care. The rapid review was conducted as an initial step using the Consolidated Framework for Implementation Research (CFIR). We employed a mix of data collection methods: interview/discussion, eHealth system or document review and direct observation. Furthermore, we executed various stakeholder engagement activities: two co-creation workshops and on-site iterative discussions. We applied the Framework for Reporting Adaptations and Modifications to Evidence-based Implementation Strategies (FRAME-IS) to capture ongoing implementation learnings.

Results We developed IRLM of the eHealth innovation implementation for three contexts: urban, peri-urban and remote public healthcare facilities. The model depicted the mechanism of interaction between implementation determinants and implementation strategies to produce the intended implementation outcomes. The IRLM helped to identify more than 35 implementation barriers or facilitators for eHealth interventions and to develop over 17 mitigation strategies for the study contexts. The initial IRLM was refined through ongoing implementation learnings and the mitigation strategies that were executed.

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Conclusions The IRLM is a comprehensive and effective guiding tool for the development, implementation and evaluation of innovations in various low- and middle-income contexts. Researchers and implementing partners should adapt and use it.

Keywords Implementation science, Implementation research logic model, Maternal healthcare, Newborn healthcare, Implementation strategies, eHealth, eHealth innovation, Ethiopia

Background

Over the last two decades, the implementation of high-impact interventions such as skilled care during antenatal, labour and delivery and postnatal periods contributed to the gains in maternal and child health in low- and middle-income countries (LMICs), including Ethiopia [1–3]. However, maternal and neonatal mortalities are still high [4–6]. eHealth innovations have the potential to further improve access and quality of high-impact interventions.

In 2014, the global community remarked on the importance of leveraging information and communication technologies (ICTs) in national health information systems and health infrastructure. ICTs including eHealth applications are central to support health services delivery [7, 8]. In the era of Sustainable Development Goals, the World Health Organization and others urged countries to promote electronic data capture and processing; adopt eHealth programs; and develop eHealth policies and strategies for reproductive, maternal, newborn and child health [7]. Ethiopia also started to have an eHealth strategy in 2014 [9]. The Ethiopian eHealth strategy identified five priority areas for eHealth implementation: (1) health information systems, (2) telemedicine, (3) mHealth, (4) eLearning and (5) community information systems [10]. Evidence was also stressed to have a strategy to develop an eHealth solution that ensures smooth handover, scalability, local capacity development [11] and entails acceptability [12, 13].

Implementation and evaluation of digital health interventions (DHIs) are challenging as they are complex in nature [14–16] and entail complex interactions between the user, technology and healthcare team [14, 15]. Thus, the use of theoretical frameworks is crucial in providing researchers with guidance and clarity on implementation or evaluation approaches [14]. The selection of an appropriate theoretical framework is also equally important [17]. Besides, implementation science offers the required body of knowledge and tools to streamline the effective implementation and monitoring of eHealth innovations [15]. For example, Cremers et al. 2021 developed an eHealth implementation guideline to increase the effectiveness in selection and implementation of eHealth interventions in practice [18].

Furthermore, co-creation in healthcare, especially for eHealth solutions, is identified as a fundamental principle for developing person-centred technologies that accelerate innovation adaptation. Co-creation involves co-design by users and producers [19]. An eHealth research should be more contextual; report more on setting factors; employ more responsive and pragmatic designs; and report results more transparently on issues important to potential adopting patients, clinicians and organizational decision-makers [20].

The consolidated framework for implementation research (CFIR) in eHealth innovation was reported to foster clarity regarding implementation effort and comparability with other implementation studies [15]. The implementation research logic model (IRLM) is a new and more comprehensive implementation research (IR) model [21] that could help us to address earlier mentioned research agendas in eHealth. The IRLM provide a structure to address the relationships between determinants of implementation, implementation strategies, the mechanisms of action resulting from the strategies and the implementation and clinical outcomes affected. The IRLM core components are guided with the most prominent frameworks including the CFIR. The model also allows for the thorough specification of all introduced and existing strategies, as well as their changes, including adaptations, additions and discontinuations, during the project [12, 21–24]. Tiruneh et al. reported that the model was effective in guiding IR to improve a community-based healthcare service in Ethiopia. They suggested that IRLM offered a clear process and path to prioritize implementation challenges and choose strategies informed by mechanisms of action [25]. Therefore, this paper aims to describe the practical application of IRLM in the design, execution and evaluation of eHealth innovations in public healthcare facilities serving mothers and their children in Ethiopia. The findings will guide researchers, programmers and implementing partners for successful planning, execution, reporting and evaluation of eHealth innovations in resource-limited settings.

Methods

Study setting

The study was conducted in eleven public health facilities (six in the intervention arm and five in the control arm) in Amhara region, Ethiopia. The healthcare facilities were selected from Bahir Dar City (capital of Amhara

region) and the Bahir Dar Zuria, North Mecha and Yilmana Densa districts. We selected the healthcare facilities according to healthcare level, client load, healthcare facility residential location and distance from the capital of Amhara region. The eHealth innovation was deployed in six healthcare facilities. Thus, the main focus of this paper is to discuss the practical application of IRLM in these facilities. The studied healthcare facilities were providing MCH care including antenatal care (ANC), labour and delivery care and postnatal care (PNC). We grouped the healthcare facilities into urban, peri-urban and rural facilities based on their location. Urban healthcare facilities were those facilities located in Bahir Dar city and in two district towns (Adet and Merawi towns). Peri-urban healthcare facilities were those facilities located in Bahir Dar Zuria district while rural or remote healthcare facilities were facilities located in remote villages of the study area.

eHealth innovation development and characteristics

The eHealth tool we developed and implemented was named ADHERE to signify adherence to the recommended high-impact maternal and newborn healthcare packages. The development process of ADHERE was described in detail in Kebebaw et al. [26] and Alemneh et al. [27]. In brief, it was started in 2020 with a collaboration between ICT and maternal and child health experts at Bahir Dar University. The tool passed through heuristic-based usability evaluation and end-user-based usability evaluation. The ADHERE system was implemented at the point-of-care (POP) in MCH units. The system is also designated as eMCH tool because it is designed to transform a paper-based standard ANC, delivery care and PNC into electronic-based care. The system had a built-in eDecision support system (eDSS), ePartograph and safe childbirth checklist that could assist HCPs' clinical decisions. The ePartograph allows for automated recording instead of manual partograph drawing, which is time consuming, burdensome and subject to human error. The usability problems detected in each step were corrected before the deployment of the tool.

Study process

We employed rapid review, formative assessment and process evaluation to adapt the IRLM for ADHERE. The IRLM comprised four core elements: (1) implementation determinants, (2) implementation strategies, (3) mechanisms of action and (4) outcomes [21, 28]. The implementation determinants were organized according to the CFIR, which categorized the factors into five themes: (1) intervention characteristics, (2) inner settings, (3) outer settings, (4) individual characteristics and (5) implementation process [22]. The implementation strategies were developed on the basis of the expert recommendations for implementing change (ERIC) taxonomy [24]. The mechanisms of actions were refined as conceptualized in Lewis et al. [29]. We also proposed implementation outcomes as recommended in Proctor et al. 2011 [12].

The ADHERE project implementation was organized in three phases: preparation, intervention and post-intervention. This paper relays only on the preparation and intervention phases of the project. In the preparation phase, we conducted a rapid review and formative assessment to identify determinants, select implementation strategies and link them with mechanisms of action to influence the proposed implementation outcomes. In the intervention phase, we systematically and prospectively captured implementation facilitators, emerging challenges and modifications in implementation strategies to overcome the emerging challenges.

(a) Rapid review

As the initial step of this IR, we conducted a rapid review guided by the CFIR framework. The rapid review aimed to identify barriers and facilitators to implementing eHealth interventions in Ethiopia. We developed and used a search strategy for both peer-reviewed and grey literature databases. We searched MEDLINE via PubMed, Google Scholar and Google to develop this narrative synthesis. The search terms used were: eHealth, telemedicine, eHealth app(s), eHealth application(s), electronic health record(s), electronic medical record(s), clinical decision support system(s), computerized decision support system(s), decision support system(s), decision aid(s), digital health, health facility(ies), healthcare facility(ies), health care facility(ies), health institution(s), healthcare institution(s), hospital(s), health centre(s) and Ethiopia.

The review included quantitative, qualitative and mixed methods studies and studies of various designs including cross-sectional, case–control, cohort and interventional designs. Additionally, we included documents published in English and studies conducted in Ethiopia. The overall search and review steps were outlined following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Scoping Reviews (PRISMA-ScR) guideline [30, 31]. The details are given in PRISMA flow diagram (Fig. 1).

(b) Formative assessment

The formative assessment was conducted in the preparation phase of the project. We used both qualitative and quantitative approaches. The study employed a descriptive qualitative design and a cross-sectional quantitative survey. We employed mixed methods of semi-structured interview, document review and direct observation

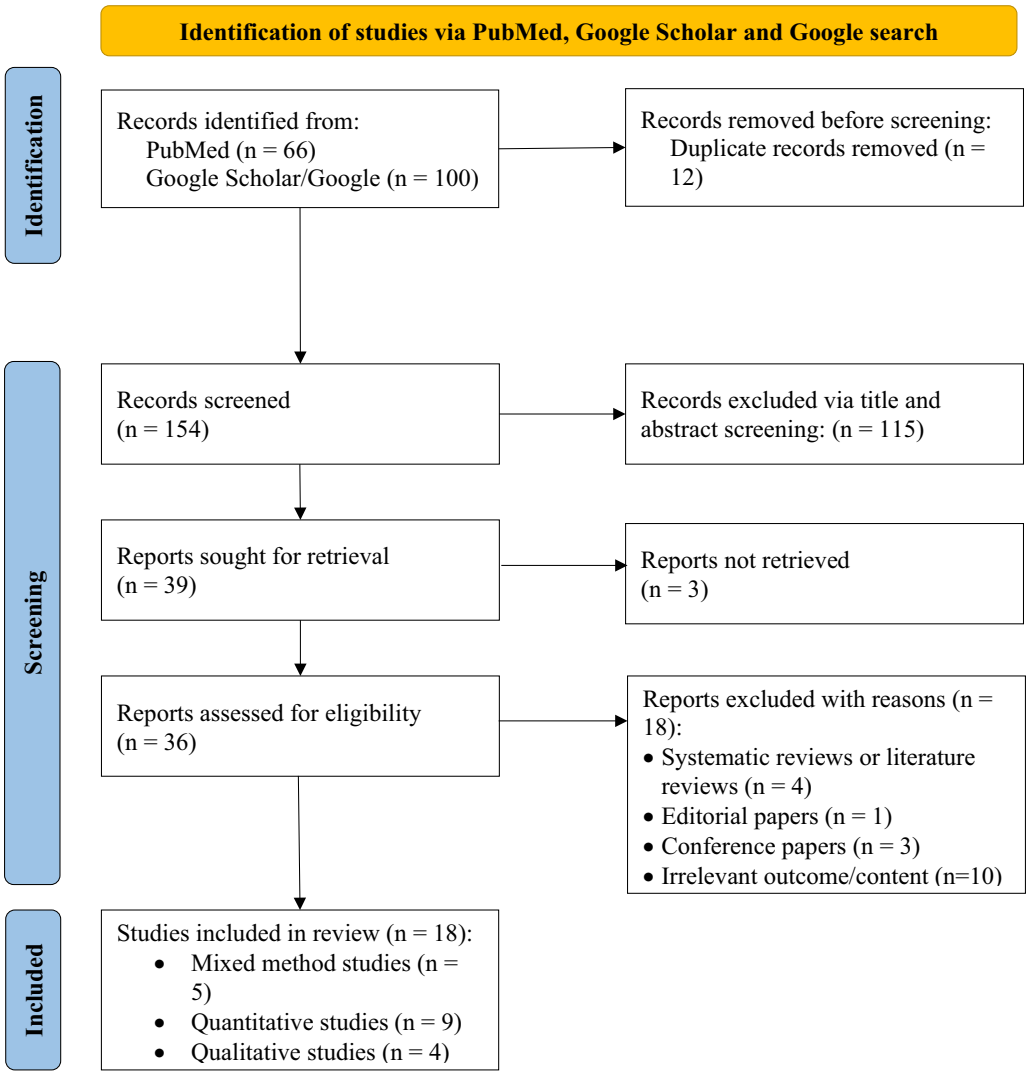

Fig. 1 Prisma flow diagram for rapid review, 2021

of health facilities for data collection. We developed a checklist to assess all eligible healthcare facilities' readiness with a focus on maternal and child health (MCH) staff composition, MCH services availability and amenities for ADHERE. The health facility readiness assessment checklist is attached as additional file (Additional File 1). We primarily contacted the healthcare facility head who linked us to the MCH coordinator and/or MCH case team leader. At each healthcare facility, we observed MCH room arrangement, including the distance between each room. The distance between each unit was a rough estimate obtained by paces (walking steps). The MCH rooms arrangement considered acceptable if the distance between MCH units (ANC units, labour and delivery units, high-risk units and PNC units) was less than 100 paces. The distance below 100 paces was considered acceptable because of its suitability to establish a local area network (LAN) system with one Wi-Fi-router point to connect the MCH units. We also checked for availability and function of desktop computers, tablets, network cables, power supply, access point/Wi-Fi routers and network installation kits. We also assessed the presence of interventions similar to our intervention. The document review was used to assess the availability of MCH guidelines, reporting forms and MCH caseload in the visited healthcare facilities. Additionally, the document review method was used to review a national level eHealth related-documents as well as MCH documents to address one of the CFIR domain (outer setting) and its underlining subdomains.

The study employed a quantitative approach to assess acceptability and feasibility of ADHERE system. We used a five-point Likert scale to measure feasibility and acceptability of the eHealth system by healthcare providers. The

data were collected using a self-administered English version questionnaire. The measurement tool had 23 items: 10 items were designed to assess feasibility, while 13 items were designed to assess acceptability. In addition to the Likert scale, the questionnaire had an open-ended question that allowed the participants to leave their comments regarding the ADHERE system (Additional File 2). The questionnaire was administered at the end a 5-day hands-on training on the system. The data collection was facilitated by investigator team members. The study population consisted of all HCPs working in the MCH units of the intervention arm healthcare facilities.

Furthermore, the research team identified potential stakeholders in-line with the project interest through brainstorming followed by stakeholder analysis following stakeholder analysis matrix. We also executed various stakeholder engagement activities during the preparation phase of the project. We conducted two co-creation workshops (with national and sub-national stakeholders each) and on-site iterative discussion at each intervention group healthcare facility. The IR investigators team had a guided visit and experience sharing at Abebech Gobena MCH Hospital, a fully automated MCH centre in Addis Ababa city.

(c) Implementation process evaluation

We applied the Framework for Reporting Adaptations and Modifications to Evidence-based Implementation Strategies (FRAME-IS) to capture implementation learnings and document modifications to implementation strategies during the intervention [32]. Prospective data were captured per facility during each supervision by the supervisory team through interviews/discussions, ADHERE system or document reviews and observations using a checklist (Additional File 3). During supervision, discussions were held with front-line healthcare providers (HCPs) and healthcare facility managers about the IR project's progress. Additionally, functionality of the ADHERE system was checked (Additional File 4).

The research team produced a compiled sets of determinants outlined according to the CFIR framework assisted through rapid review, formative assessments and implementation learnings. Two investigators (D.N. and M.A.) were assigned to rate the determinants level of influence. The determinants were rated according to previous studies recommendation, ranging from −2 to +2; where −2 'strong barrier', −1 'barrier', +1 'facilitator', +2 'strong facilitator' and 0 reflects a neutral and (−/+) mixed influence [25, 33, 34].

Implementation research team

This IR was a collaborative project between academia, health system (program managers and HCPs) and development partners. The IR team was organized into various categories with designated roles and responsibilities (Table 1). The core IR team oversaw the overall project activities and was led by the principal investigator (PI). The core IR team had three subteams: study coordination, implementation learning and support and data management. Each subteam comprised members from academia, the health system and development partners. The other team category was the supervisory team which

Table 1 ADHERE project implementation teams and respective roles and responsibilities

Team	Roles and responsibilities
Core implementation research	– Oversee overall project implementation – Monitor and evaluate each subteam's performance
Study coordination	- Administrative and resource management - Coordination of stakeholders – Planning and follow up of activities - Coordinating data collection – Evidence dissemination and translation
Implementation learning and support	– Supervision schedule and technical support – Ongoing documentation of learning – Study tool development – ADHERE tool update – Training data collectors and health care providers – Organize and lead review meetings
Data management	– Receiving, organizing, and archiving data – Check and monitor data quality – Facilitate data cleaning and analysis – Report write-up
Supervisory	– Regular study sites supervision – Complete supervisory checklist – Provide technical support and feedback – Submit supervision report

included experts from ICT, public health professionals, clinicians, program managers and development partners.

Results

Background information

A total of 18 studies were fully reviewed. Of these studies, six were mixed-method [35–40], nine quantitative [41–49] and three qualitative studies [50–52]. The detail summary results are given as additional file (Additional File 5).

Eleven healthcare facilities, all providing MCH services, were assessed for readiness to deploy ADHERE. Eight had acceptable MCH rooms arrangement (i.e. the distance between ANC units, labour and delivery units, high-risk units and PNC units was less than 100 paces) to establish a LAN system, while three had MCH rooms arrangement at a distance greater than 100 paces. This information helped us to estimate the number of Wi-fi router points and network cables required to connect the MCH units. All had electric power supply from the national gridline and had at least one fuel-based backup power generator. Three health centres had a solar-based power source with a limited capacity to provide illumination only. Almost all the facilities had no desktop computers or tablets dedicated to MCH units. A total of 10 healthcare facilities had no internet service at their MCH unit, and only four healthcare facilities had internet access as an institution. None of the facilities had a Wi-Fi router, network cables and network installation kits in their store.

A total of 109 HCPs who were working in six healthcare facilities were surveyed for acceptability and feasibility study. A total of 41% of the HCPs were in the age range of 30–34 years; 64% were females, 91.7% were first degree holders and 82.6% were midwives by profession (Additional File 6). The acceptability study revealed that 62.4% of the HCPs scored acceptability score greater than 4. The feasibility study also indicated that 47.7% of HCPs scored feasibility score greater than 4.

eHealth innovations implementation path consolidation with IRLM

We developed two versions of IRLM for the eHealth IR: the preparation phase and the intervention phase IRLM. The preparation phase of IRLM was developed and refined on the basis of the rapid review synthesis and formative evaluation results while the implementation phase IRLM was adapted on the basis of the results of the prospective implementation learnings. The barriers and facilitators of eHealth implementation identified through rapid review and formative assessment are summarized in table (Additional File 7). The IR of ADHERE system was done among health facilities representing three contexts: urban, peri-urban and rural/remote. The IRLM shows the interaction among eHealth innovations implementation core elements: implementation determinants across multiple contexts, implementation strategies, mechanisms of action and implementation outcomes (Fig. 2).

Implementation determinants

The determinants were organized into five themes: intervention characteristics, inner setting, outer setting, individual characteristics and process. Most of the identified implementation determinants applied across the three contexts (urban, peri-urban and rural), while a few were context specific.

Intervention characteristics

The ADHERE system was implemented at the point of care (POP) in the ANC, delivery care and PNC units. The system operates using local area network to avoid service interruptions due to internet connectivity problems. The quality improvement components of the system included an eDecision support system (eDSS), ePartograph and safe childbirth checklist. The ePartograph allows for automated recording instead of manual partograph drawing, which is time consuming, burdensome and subject to human error. Flexibility of a system for customizing to the local context, evidence-base to improve quality of care and the availability of a decision support system facilitated eHealth interventions. The major challenges identified for effective implementation were the complexity of eHealth innovations, system lock or interruption and interoperability with other systems. All these challenges apply across the various implementation contexts.

Inner setting

We identified various inner-setting barriers and facilitators of eHealth implementation. Lack of ICT infrastructure, such as computers, tablets, smart phones and internet services, was a major challenge. Additional challenges across context were dual documentation both manual and digital patient information recording, weakened provider–patient interaction/relationship, unsatisfactory technical support and lack of financial incentives.

On the other hand, we identified implementation barriers that varied in type or extent by context. Network connectivity and electric power interruptions were strong barriers to eHealth implementation in remote healthcare facilities, while they had slightly lower influence in urban healthcare facilities. High workload or patient flow poses a more challenge in urban healthcare facilities than peri-urban or remote healthcare facilities.

Facilitators of eHealth innovations across all three settings include the availability of a backup electric power

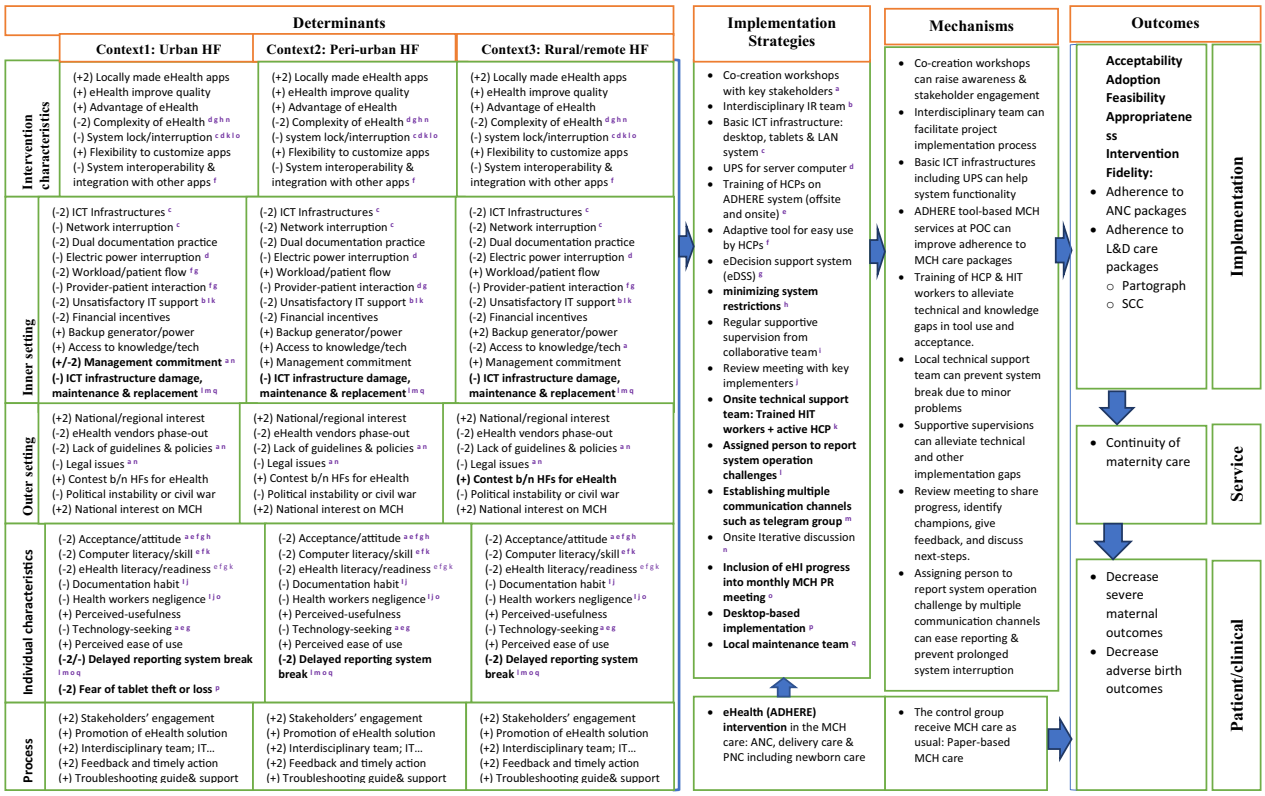

Fig. 2 Implementation research logic model (IRLM) adapted in the ADHERE project implementation research, Ethiopia. The ratings given imply (+2) strong facilitator, (+) facilitator, (−2) strong barrier, (−) barrier and (−/+) mixed influence; superscript letters (a, b, c, …, q) show the link between determinants and proposed implementation strategies; bolded text indicates modifications to the determinants and implementation strategies from the preparation phase to the implementation phase IRLM. *eHI* eHealth innovation, *HF* healthcare facility, *MCH* maternal and child health, *IT* information technology, *LAN* local area network, *HCP* healthcare provider, *HIT* health information technology, *PR* performance report, *PNC* postnatal care

source and committed facility management. Access to knowledge hubs including eHealth knowledge support or sources, such as digital libraries, training centres or academic institutions, was a strong challenge in remote healthcare facilities, while it plays a facilitator role in urban or peri-urban healthcare facilities.

Outer setting

We recognized Ethiopia's strong national and regional interest in digital health to transform its health systems. This was expressed in the 2014 National eHealth Strategy [9], the launch of Digital Health Innovation and Learning Center [53], the 2009 and 2016 National ICT Policy and Strategy documents [54, 55], the 2012 National Health Information System Road Map [56], the 2016 Information Revolution Roadmap [57], the Health Sector Transformation Plan I and II [58, 59] and the 2021 Digital Health Blue Print [60].

ADHERE project fitted well with the national and regional priority on maternal and newborn health [61]. There was also strong institutional interest to deploy EMR among urban healthcare facilities, but the interest level declined among remote healthcare facilities. The major challenges identified across the three contexts were eHealth vendors phase-out, lack of guidelines and policies for the design and implementation of eHealth innovations, and legal issues attached to eHealth innovation implementation. Evidence demonstrates that most of the EMR or eHealth solutions deployed were donor-driven and very liable to vendor phase-out. Moreover, the occurrence of political instability or civil war in the northern part of Ethiopia, which encompasses the study area, could potentially hinder the successful implementation of the project. This is because it might divert the government's, development partners' and other key implementers' attention towards emergency and humanitarian crisis responses, posing a long-term challenge for the project's success.

Individual characteristics

HCPs were the primary implementers of the eHealth solution. The review synthesis and formative evaluation

revealed various challenges potentially related to the characteristics of HCPs which were similar across the three eHealth implementation contexts. The main challenges were HCPs' low acceptance or negative attitude to eHealth innovations, low computer literacy, low eHealth literacy or readiness, low data documenting habits and health workers' negligence. On the other hand, the facilitators of eHealth implementation were HCPs' perceived ease of use, perceived usefulness of eHealth tool and younger age. The remote and peri-urban healthcare facilities were staffed with mostly young staff, whereas the urban healthcare facilities had older and young staff, which could be a potential barrier to eHealth implementation.

During implementation, we recognized that the individual characteristics of local health managers were crucial for successful eHealth implementation. The managers' attitude or non-acceptance of eHealth solutions were a strong barrier in urban healthcare facilities while these factors didn't pose a significant challenge in peri-urban and remote healthcare facilities.

Process

The eHealth implementation facilitators were engaging stakeholders, promoting eHealth solutions by managers, forming interdisciplinary teams, providing timely feedback and action and applying troubleshooting guidelines and support from the core IR team.

Implementation strategies for eHealth

The implementation strategies were designed to address implementation gaps or challenges at various levels: individual, healthcare facility and health system. The individual-level implementation strategies were training of HCPs on the ADHERE system and performance review. We trained all the HCPs working in MCH units. The implementation strategies that applied at the healthcare facility level were equipping healthcare facilities with basic amenities to run the ADHERE system, technical support, healthcare facilities performance review and provision of a troubleshooting guide. We set the ADHERE system to function with the LAN system and the project provided an uninterruptible power supply (UPS) for the server computer set at each facility. The health system level strategy was engaging key stakeholders including health system managers at different levels via co-creation workshops, iterative discussions, supportive supervisions and review meetings.

We conducted two co-creation workshops during the preparation phase of the project. The co-creation workshops laid the groundwork for stakeholder engagement and gave a chance to refine the implementation strategies. The first workshop was for 3 days in Addis Ababa. In the end, we established the core IR team with designated roles and responsibilities (Table 1), developed an action plan and refined the ADHERE tool and project protocol according to the feedback. The second workshop was conducted for 1 day in Bahir Dar City. We communicated the project aim to key implementers with a practical demonstration of the ADHERE system. Key implementation strategies were identified and refined during the workshop.

We also conducted iterative discussions at each intervention healthcare facility. The discussions helped us to identify contextual challenges and propose implementation strategies to overcome the challenges.

During the ADHERE project implementation, we conducted review meetings with key implementers. These meetings included a general review meeting and on-site review meetings. The general review meeting was held at the half point of the project implementation and was attended by district/city health department managers, healthcare facility managers, MCH case-team leaders and coordinators and HCPs. During the meeting, the implementation team made two consecutive presentations: (1) overall ADHERE project progress and (2) adaptive updates made on the ADHERE system. The general review meeting allowed us to share best practices between implementers, motivate implementation champions, identify implementation challenges and propose potential solutions to mitigate the challenges. The review meeting was successful in motivating HCPs, healthcare facility managers and health office managers to perform better on project implementation. After the review meeting, competitive peer pressure emerged among intervention healthcare facilities, resulting in improvement in the use of tablets in some facilities.

As part of our implementation strategy, we engaged multiple stakeholders in supportive supervision. Health managers from Amhara Regional Health Bureau (ARHB), city health departments and Amhara Public Health Institute (APHI) were involved in this process. By doing so, they were able to monitor the project progress, identify practical challenges in implementing eHealth systems and provide feedback to the implementers.

Our interdisciplinary IR team was divided into three subteams: study coordination, learning and support and data management, as presented in Table 1. We also continuously improved the ADHERE system to make it more user-friendly for healthcare providers at the point of care.

Implementation mechanisms

The project team proposed several ways to implement eHealth. Co-creation platforms were crucial in raising awareness, fostering a sense of ownership, customizing the eHealth innovation to suit the local context and

getting stakeholders engaged in the implementation of eHealth solutions. Additionally, they can help with the acceptance, adoption and long-term success of the intervention. Providing training for healthcare professionals on the proposed eHealth innovation can address any technical or knowledge gaps in the implementation process and increase the acceptability and adoption of these solutions. The training comes in two types: an initial training in a computer lab setting and a 1-day on-site hands-on training after deploying the ADHERE system. Deploying ADHERE system-based MCH services at the POC can improve adherence to MCH care packages due to the built-in eDSS and mandatory fields. The configuration of the ADHERE system to function with the LAN system and the availability of a UPS for a server computer help to mitigate the impact of short-duration network and power interruptions during the project implementation. The implementation team designed these strategies with the assumption that the availability of chargeable tablets and UPS for server computers, when backed up with a generator as an alternate power source, can minimize system disruptions due to electric power interruption.

The IR team meticulously planned and executed supportive supervisions at each healthcare facility. We conducted both regular and on-demand supervisions. These supervisions provided an opportunity to identify implementation gaps and propose solutions, as well as offer technical support for effective implementation. Additionally, the review meetings enabled the IR team and participants to share implementation progress, recognize implementation champions, provide feedback and discuss the way forward.

Implementation outcomes

We evaluated the ADHERE system by measuring its acceptability, feasibility, implementation cost and fidelity. As the primary users of the system, we focused on the acceptability of the ADHERE system by HCPs. We also measured the feasibility of the system by comparing the time taken to record on ADHERE system with the consultation duration and by assessing the resources and capacity of the healthcare facilities to run and sustain the system. To determine the implementation cost, we planned to quantify the cost incurred from using the ADHERE system in different healthcare settings. Furthermore, we measured the implementation fidelity by tracking the frequency of use of each recommended intervention, timeliness of intervention, appropriateness of intervention and proportion of high-risk mothers detected. We also tracked adherence to ANC packages, labour and delivery care packages and PNC. The data source for implementation fidelity was obtained through regular data abstraction from clinical records and ADHERE system data.

In addition to the implementation outcomes, we planned to measure patient-level outcomes such as the proportion of positive maternal and newborn health outcomes among intervention and control groups. Positive pregnancy and childbirth outcomes such as live-birth rate, spontaneous vaginal delivery, term births and normal birthweight will be compared between intervention and control healthcare facilities.

Learning through implementation

During intervention, we utilized the FRAME-IS framework to document the adaptations and modifications made. We made a few modifications to the IRLM we developed during the preparation phase (Fig. 2).

First, we initially planned to implement the eHealth innovation in six healthcare facilities. However, one facility was withdrawn from the study at the early stage of the project implementation. We realized that management support played a vital role in implementing eHealth innovations. During the implementation, we observed that most healthcare facility managers were strongly supportive of eHealth implementation, while others either provided partial support or completely blocked the implementation.

Second, we planned to provide technical support for healthcare facilities from the core implementation team. However, a few months into implementation, we learned that it was crucial to establish on-site technical support. The healthcare facility managers suggested that the health information technology (HIT) workers in the respective facilities could provide on-site technical support. We also realized that on-site technical support was more critical for remote healthcare facilities than the easily accessible ones. As a result, we trained the HIT workers at the intervention facilities to provide support for the use of the ADHERE system. We also added one healthcare provider (HCP) with better computer skills, depending on the number of HIT workers available. The on-site technical team provided technical support on basic computer skills, was a troubleshooting guide and checked the LAN system functionality. We found this strategy to be effective in managing minor issues resulting in system interruptions. The strategy was more effective when the central team offered phone call guidance, when necessary, to resolve the technical issues.

Third, during on-site iterative-discussions, HCPs expressed their fear and anxiety about the ADHERE system. They were concerned about the mandatory fields and system restrictions, which hindered the adoption and acceptability of the eHealth system. We understood their concerns and realized that applying more system

restrictions would only exacerbate their fears and anxiety. Therefore, we decided to remove some of the system restrictions to facilitate the ADHERE system adoption and acceptability. For instance, in the case of ePartograph use, there was initially a time restriction to enter measurement dues. However, HCPs frequently expressed their concerns about this feature of the system. To accommodate their concerns, we built an override to let HCPs enter overdue measurements. The system will show a warning message 'time passed' in red colour code to ensure timely entry of measurements.

Additional lesson we learned during the implementation of the ADHERE system was related to the use of tablets. We distributed both desktop computers and tablets based on formative assessment results. Initially, we thought that using tablets would make it easier for HCPs to record patient data at the bedside, as tablets are portable and can be charged quickly. However, managing the tablets in real-life situations proved to be challenging. Some HCPs requested additional tablets equal to the number of staff they had, while others kept the tablets in storage for fear of misuse. We also noticed that some HCPs used the tablets for purposes unrelated to the project. The practical challenges of managing tablets were more serious in large and urban healthcare facilities than in small and remote ones. To address this issue, we proposed handing over the tablets, such as other medical devices, that are not subject to private use or are not privately owned. However, this proposal raised concerns about ownership, theft, loss and damage. As a strategic modification, we decided to add more desktops to most healthcare facilities and plan for more desktops than tablets for similar future projects.

Finally, we observed delayed reporting of system interruptions. To address this issue, we assigned a responsible person and created a telegram group at each site. However, we also faced challenges related to ICT infrastructure damage, such as computer hardware and UPS damage due to power fluctuations, and delays in maintenance and replacement. We proposed that the facility itself should handle maintenance issues, but we learned that there was no local maintenance team. To facilitate timely maintenance of hardware such as computers and UPS, we proposed the creation of a local hardware maintenance team.

Discussion

We adapted and used IRLM for the successful implementation of eHealth innovations across different healthcare facility settings providing MCH care in Ethiopia. The proposed IRLM facilitated the easy and successful planning, execution, reporting and evaluation of eHealth innovations in LMICs. Literature indicates that interventions involving eHealth innovations follow the principle of complex interventions and best function when they are customized to local conditions instead of being entirely standardized [16]. For complex interventions such as eHealth, implementation science provides the required ideas and tools to ensure quality and increase healthcare effectiveness [62]. Our study affirms that the IRLM provides a method to understand causal pathways, including determinants, implementation strategies, mechanisms and implementation outcomes in IR projects [21, 63].

During our project, we used IRLM to evaluate the factors that influence the implementation of eHealth, based on the CFIR framework. We customized these factors into three contexts: urban, peri-urban and remote healthcare facilities. Although this classification was helpful, it did not capture all the unique characteristics of each healthcare facility we observed during implementation. However, we opted for this classification to streamline the model. Smith et al. noted that the IRLM integrates existing implementation science frameworks as its core elements [21], including the CFIR framework [22], the ERIC taxonomy for implementation strategies [24] and the framework for implementation outcomes [12, 23]. Embedded in the IRLM, the CFIR domains and constructs can foster clarity regarding the implementation effort and allow for comparability with other implementation studies [15]. The CFIR is a pragmatic meta-theoretical framework [22] that represents the synthesis of 19 theories associated with implementation science [64]. Proactively using the CFIR can identify relevant modifiable factors that promote or undermine the adoption, implementation and maintenance of intervention [65]. Our proposed IRLM identified over 35 determinants that may facilitate or hinder eHealth implementation in resource-limited settings. We also suggested over 17 implementation strategies to overcome the challenges of eHealth innovations by reviewing the ERIC taxonomy, conducting formative assessments and ongoing evaluations of the project implementation.

IRLM is a flexible tool that can be easily adapted to various complex interventions. Since its inception by Smith et al. in 2020, a growing body of research has demonstrated the usefulness and adaptable application of IRLM in various circumstances. The exemplar works range from the planning stage to the synthesis of the findings of IR projects [66–76] and its adaptation to the clinical trial setting [77]. Examples of IRLM include the implementation of exercise in cancer care field [73], screening in colorectal cancer care in Malaysia field [76], smartphone app-based model of care for patients with acute coronary syndrome and heart failure in Australia field [68], strategy for clinical practice guideline implementation in the diagnosis and management of paediatric hypertension

Field [69] and patient engagement in IR program field [72]. Similarly, we adapted IRLM in the planning and implementation of the ADHERE project, which aims to improve the quality of ANC, delivery care and PNC by using eHealth innovation in public healthcare facilities in Ethiopia.

During the implementation process, we utilized the IRLM and the FRAME-IS framework to document any modifications or adaptations made to the implementation strategies. We also came across literature that applied the FRAME-IS framework and acknowledged its effectiveness in recording changes made to implementation strategies in the healthcare sector [78–81]. During the project implementation phase, we made modifications to the IRLM that we had proposed during the preparation phase based on our ongoing learnings. We implemented several adaptive strategies that proved to be successful, including having an on-site technical support team, applying flexibility on system restrictions, adapting the eHealth system to the local context, implementing the ADHERE system on desktops, designating a point of contact for system outages and setting up a telegram channel for communication at each implementation site. We learned that using both the IRLM and the FRAME-IS frameworks from planning to implementation stages, and adapting the IRLM can help in designing, executing and evaluating impactful implementation of future eHealth innovations in LMICs contexts.

This study has limitations. The current eHealth innovation implementation project does not involve the MCH service clients' perspective (consumers side), which could be a potential limitation. The implementation challenges of eHealth innovations involving MCH service users and the corresponding implementation strategies to be used may differ greatly from the one we suggested here. Hence, the model we proposed here might not be directly applied for implementation projects involving MCH service customers such as women or other community members. Another limitation of this study may be related to the withdrawal of one health facility from intervention arm. The withdrawal of any pre-planned health facility or individual from a study may have impact on the project since they were reasonably included in the study from the outset.

Conclusions

Based on our research, we have found that the implementation research logic model (IRLM) is an effective and comprehensive tool for planning, executing, reporting and evaluating eHealth innovations, such as the ADHERE system. In addition, the FRAME-IS framework was deemed crucial for capturing adaptive strategies to overcome emerging challenges during the implementation of quality improvement eHealth innovations in LMICs settings. Our IRLM framework comprises over 35 barriers or facilitators and 17 implementation strategies. The proposed model illustrates the interaction between implementation determinants and implementation strategies to achieve the intended outcomes. We strongly believe that the newly adapted IRLM will assist researchers and implementing partners in designing, executing, reporting and evaluating impactful eHealth innovations implementation in LMICs settings. We also recommend to use the FRAME-IS framework to capture adaptive implementation strategies to overcome emerging challenges during the implementation of eHealth innovations in resource-limited settings.

Abbreviations

ANC	Antenatal care
CFIR	Consolidated framework for implementation research
DHIs	Digital health interventions
eDSS	Electronic decision support system
eHealth	Electronic health
EMRs	Electronic medical records
ERIC	Expert recommendations for implementing change
FRAME-IS	Reporting adaptations and modifications to evidence-based implementation strategies
HC	Health centre
HCPs	Healthcare providers
HIT	Health information technology
ICT	Information and communication technology
IR	Implementation research
IRLM	Implementation research logic model
LMICs	Low- and middle-income countries
MCH	Maternal and child health
PNC	Postnatal care
POC	Point of care

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12961-024-01259-8.

Additional file 1.
Additional file 2.
Additional file 3.
Additional file 4.
Additional file 5.
Additional file 6.
Additional file 7.

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Author contributions
D.N. conceived the study, performed the data analysis and interpretation and drafted and critically reviewed the manuscript. T.K., E.A., E.M., E.A. and M.A. engaged in the design and supervision of the IR process and reviewed the manuscript. T.G. guided the overall IR process and the manuscript contents and critically reviewed the manuscript. M.W. contributed for the research concept mature and reviewed the manuscript. D.A.E. critically reviewed the manuscript. All the authors read and approved the manuscript that was ready for submission.

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Availability of data and materials
The data that are relevant to produce this manuscript were either embedded in the manuscript or provided as additional files.

Declarations

Ethics approval and consent to participate
Ethics approval was obtained from the Bahir Dar University College of Medicine and Health Sciences Institutional Review Board. The Amhara Public Health Institute (APHI) gave support letters to the relevant healthcare facilities or public health administrations. Besides, we sought written informed consent from each study participant. The study team ensured the anonymity and confidentiality of information throughout the study process.

Consent to publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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