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Intervention fidelity and factors affecting the process of a mobile phone text messaging intervention among adolescents living with HIV: a convergent mixed methods study in southern Ethiopia

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Intervention fidelity and factors affecting the process of a mobile phone text messaging intervention among adolescents living with HIV: a convergent mixed methods study in southern Ethiopia

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Objective: To assess the intervention fidelity and explore contextual factors affecting the process of a mobile phone text messaging intervention in improving adherence to and retention in care among adolescents living with HIV, their families, and their healthcare providers in southern Ethiopia.

Design: A convergent mixed-methods design guided by the process evaluation theoretical framework and the RE-AIM framework was used alongside a randomised controlled trial to examine the fidelity and explore the experiences of participants in the intervention.

Setting: Six hospitals and five health centres providing HIV treatment and care to adolescents in five zones in southern Ethiopia.

Participants: Adolescents (aged 10–19), their families and their healthcare providers.

Intervention: Mobile phone text messages daily for 6 months or standard care (control).

Results: 306 participants were enrolled in the process evaluation. Among the intervention participants (N =153), 171 (55.9%) of whom were men, most resided in an urban area 225 (73.5%), and participants had a mean age of 15 (2.62). The overall experiences of implementing the text messages reminder intervention were described as helpful in terms of treatment support for adherence but had room for improvement. During the study, 30,700 text messages were sent, and fidelity was high, with 99.4% successfully receiving text messages during the intervention. Barriers such as failed text messages delivery, limitations in phone ownership, and technical limitations affected fidelity. Technical challenges can hinder maintenance, but a belief in the future of digital communication permeates the experiences of the text messages reminders.

Conclusions: Overall fidelity was high, and participants' overall experiences of mobile phone text messages were expressed as helpful. Contextual factors, such as local telecommunications networks and local electric power, as well as technical and individual factors must be considered when planning future interventions.

Trial registration: Pan African Clinical Trials PACTR202107638293593, first registration

20/07/2021.

Strengths and limitations with this study

- Secure and confidential delivery of high-volume messages through a 4-digit short code.
- The use of a mixed methods design and the inclusion of family members and healthcare providers is a strength of this process evaluation study.
- There was a limited number of adolescents' family and healthcare providers included in the interviews.

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INTRODUCTION

Globally, 38.4 million people were living with HIV in 2021. Of these, 1.71 million were adolescents aged 10–19, 88% of whom live in Sub-Saharan Africa (1, 2). To control the epidemic, the Joint United Nations Programme on HIV/AIDS (UNAIDS) launched the 95%–95%–95% targets aimed at HIV testing, treatment, and viral suppression by 2030 (3). However, by 2021, 75% percent of the 38.4 million people living with HIV (PLHIV) were receiving antiretroviral therapy (ART), a treatment gap of 5.9 million people (4). Moreover, achieving the recommended optimal adherence level of >95% which is required for ART to be effective, remains a challenge within the HIV care continuum (5). This poses a significant threat to HIV interventions in resource-limited settings (6).

Poor adherence to ART has several consequences, including increased risk of viral drug resistance and reduced treatment effectiveness toward viral suppression, leading to disease progression, greater risk of death, and increased risk of viral transmission (7). Some of the major barriers to ART adherence include socioeconomic status,(8, 9) fear of being stigmatised or discriminated against as a result of one's HIV status,(10) forgetting to take medication on time,(11) treatment fatigue,(12) and patient–provider communication (13). Several interventions to overcome these barriers have been studied in a variety of settings (14). The use of digital health strategies to enhance HIV treatment is one of the priority interventions in Sub-Saharan Africa (15). Targeted digital client communication using mobile phone-based short text messaging has been recommended for adherence support for a range of health intervention in achieving desired health outcomes is dependent on the context in which they are implemented (15, 16). Context plays a crucial role in either the success or failure of an intervention. The same intervention may have

different effects in different contexts, due to weaknesses in its design or improper implementation (17). Observing what is delivered in practice with close reference to the theory of the intervention can help evaluators in distinguishing the intervention fit in different contexts and changes that undermine intervention fidelity (15, 17). Trials should continue to rigorously assess outcomes, but also include integral process evaluations that use qualitative and quantitative data to develop and test hypotheses about how interventions work (18). In a multi-centre trial, a process evaluation is necessary to understand whether the intervention was implemented and received similarly across all sites (9). However, trials assessing mHealth adherence interventions for HIV often do not include process evaluations to examine the fidelity and quality of the intervention delivery, causal mechanisms for the health outcomes, contextual factors affecting the delivery, and costs of implementation (16, 19). Understanding the entire implementation process of an mHealth intervention allows practitioners to interpret the results and replicate the intervention in other contexts (20, 21). Therefore, this study aimed to evaluate the process of a mobile text messaging intervention conducted among adolescents living with HIV in Ethiopia. This information can be used to explain the outcomes of the trial and can guide the development and evaluation of similar interventions.

METHODS

Study design

A convergent mixed-methods design (17) combining quantitative and qualitative techniques was used. The design was guided by the process evaluation theoretical framework (22) and structured by the RE-AIM dimensions (Reach, Effectiveness, Adoption, Implementation and Maintenance) (18) to evaluate intervention effectiveness alongside a randomised controlled trial (RCT) to examine the study's fidelity and to explore the experiences of the participants in the intervention. The trial was registered in Pan African Clinical Trials Registry with the registration number PACTR202107638293593 on 17/07/2021.

Study setting and participants

Six hospitals and five health centres that provide HIV treatment and care to adolescents in the Gamo, Gofa, Konso, South Omo, and Wolayita zones in Southern Ethiopia were included in the study. These zones are home to over 25 distinct ethnic groups, each with its own culture and context. Between July 5, 2022, and February 28, 2023, 306 adolescents living with HIV were included in the study, in either the intervention or in the control group. The quantitative data included process indicators, while the qualitative interviews included ten adolescents from the main trial, four adolescents' families, and two healthcare providers who were involved in the process evaluation.

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Theoretical Framework of Process Evaluation

The RE-AIM framework (18) was used for the process evaluation to comprehensively examine the level of implementation. This involves understanding the implementation of interventions in terms of (1) fidelity, defined as to what extent the intervention was implemented consistently with the underlying theory as planned; (2) delivery, defined as to what extent all of the intended activities, training, and materials were provided to program participants; (3) reach, defined as the absolute number, proportion, and representativeness of individuals who are willing to participate in a given initiative, intervention, or program; (4) receipt, defined as how participants reacted to specific aspects of the intervention; and (5) context, defined as what contextual factors influence implementation or the intervention outcome.

Description of the intervention

The MRC framework,(22) a systematic literature review,(23) interviews with adolescents,(24) and the theoretical health belief model (HBM) (25) were used to develop the intervention. Adolescents living with HIV, healthcare providers, and research project technical advisory team members participated in the design (26) under the guidance of a research advisory committee. The HBM is a theoretical model that has been constructed from six domains: susceptibility, severity, barriers, benefit, cues to action, and self-efficacy. After the intervention's development, text messages were uploaded to the server and an automated message-pushing software was used to push tailored daily text messages through a four-digit code obtained from Ethiopia Telecom company. Other various configurations such as wide-area network (WAN) internet protocol (IP), local area network (LAN) IP, Ethio telecom central server IP, a virtual private network (VPN) line, and office servers were used as infrastructure, as required to support the study. The text messages were categorised and

delivered based on each adolescent's customised medication schedule and time. The software sent the message 15 minutes before each participant's medication time. The server was checked daily to troubleshoot network/cell phone issues. Based on the server information, the first author contacted the facility level care provider to contact the adolescent with corrective actions; for example, subscriber identity module card (SIM card) replacement, damaged mobile phones, and network troubleshooting for maintenance and replacement.

Sample and data collection

Related to the intervention, activity logs (checked by researchers and the advisory committee), adverse events related to the study (monitored by care providers at each facility through an adverse event monitoring form), and routine records of sent and failed messages from the server were assessed by researchers. Each facility representative assessed any adverse event related to study, filled in the form, and sent it to researchers every week, and the researcher tracks the related server information related with sent/failed messages daily.

A purposive sampling of 10 adolescents with HIV (aged 12–19), four family members/relatives (aged 36–45), and two healthcare providers (aged 31–36) from different healthcare facilities were asked to be interviewed about their experiences in the intervention between June and July 2022 at healthcare facilities by the first author (AT), and one colleague in the research advisory committee. An interview guide was used to gain a rich, in-depth understanding, and to allow the participants to concretise their experiences of their use of text messages, communication, and technical aspects of the intervention. The interview guide included subsections adapted to the participants; i.e., adolescents, families, and healthcare providers. Hence, the questions were different, depending on to whom they were addressed. The introductory question to the adolescents was: "Are you receiving the mobile text-message reminder from the hospital?", followed by follow-up questions

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such as, "What do you think about the messages?" The families were initially asked "How do family/social related factors affect ART adherence among adolescents?" Healthcare providers were asked "How did you experience communication with the adolescents with regard to the intervention?" Follow-up questions and prompts were used throughout the whole interview. The interviews were audiotaped, transcribed verbatim, and translated from Amharic to English by the first author, and checked for accuracy by one independent language expert.

Data analysis

The number of SMS messages sent and delivered to participants were tracked as a measure of intervention fidelity. When SMS messages did not arrive on the phone, the project advisory team investigated the external network and other infrastructure issues. If the message could not be delivered during this period, the computer automatically recorded it as a delivery failure and sent the message again. Data captured on the delivery status of the SMS messages were recorded as: delivered (the phone had reception marked as green); undelivered (the phone was switched off or marked as red in the server). The program could not record whether messages delivered to the phones were opened.

Interviews were analysed by using the principles for content analysis described by Graneheim and Lundman (19, 27). First, the transcripts were read several times to gain a sense of the whole by the first and the last author. Thereafter, meaning units were identified and condensed to reduce the text while maintaining the core meaning. Condensed meaning units were then labelled with a code, which were kept close to the text on a manifest level. Next, sub-themes were created from the code frame by the first and last authors. The sub-themes were then abstracted into themes. Finally, the underlying meaning—the latent content—was described into a main theme. Thereafter one of the

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RESULTS

The results are structured using the Reach, Effectiveness, Adoption, Implementation and Maintenance dimensions of the RE-AIM framework (18) and corresponding themes (Table 1).

Table 1. Overview of the	qualitative themes related	to the dimensions in the	e RE-AIM framework.

RE-AIM dimension (18)	Definition (18)	Qualitative theme
Reach	The number, proportion, and representativeness of eligible individuals who participate in each initiative.	
Effectiveness	The impact of an intervention on the relevant outcomes, including potential adverse effects, quality	Text message reminders were helpful for adherence but there was room for improvement
	of life, and economic outcomes.	Text messages reminders increase medication adherence.
		Feeling comfortable receiving text messages reminders
		The code delivered with text messages reminders minimises the risk of stigma.
Adoption	The reach and effectiveness/efficacy of an intervention at the setting level.	Treatment support
Implementation	The intervention agents' fidelity to the various elements of an intervention's protocol, including	Failing text messages delivery influences medication intake
	consistency of intended delivery.	Limitations in phone ownership
		Technical limitations
Maintenance	Connects with both setting-level indicators (the extent to which a program or a policy becomes part	Seeing potential in SMS services

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of organisational practices and	Possibilities of text messages reminders
policies), and individual-level	
indicators (monitoring of	
effectiveness of an intervention or	
program six months or more after	
the most recent contact).	

Reach:

The total number of individuals that were assessed for eligibility was 435, of which 306 (70.34 %) meet eligibility criteria. Thus, 306 participants were enrolled and randomised: n = 153 in the intervention, and n = 153 in the control group. Among the 306 enrolled participants, 171 (55.88%) were men, and 135 (44.12%) were women, respectively. The mean and standard deviation age of the participants is 15 (2.62). Of these, 225 (73.53%) resided in an urban area, 190 (62.3%) had primary school level education, and only 31(9.9%) had owned mobile phones during recruitment.

Effectiveness:

The number of participants retained in the 6-month follow-up of the intervention group was higher than the control group in this study.

Text messages reminders were helpful for adherence but there was room for improvement

The overall experiences of the intervention among adolescents living with HIV was that text messages reminders were helpful when it came to their adherence to medication, but direct access to phones and better timing of messages should be assured to increase their functioning and usability. The retention rate was improved, and was the best achieved since the intervention was introduced. Despite this, more effort was requested concerning technical issues to make the

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reminders even more helpful. The participants described facilitating aspects like increased medication intake and communication. Also, the well-being of the adolescents and the support function was highlighted. However, technical problems like lost telephones or text messages reminders arriving after medication time were emphasised as barriers.

Text messages reminders increase medication adherence.

The adolescents felt that the text messages reminders had helped them to increase adherence to their medication so that it was taken at the right time. The adolescents described that before the intervention, their medication was often forgotten, which resulted in it being taken later than it should have been due to forgetfulness. Sometimes the adolescent realised that they had forgotten to take their medication but then waited until dinner to take it. The adolescents described that text messages reminders were associated with taking their medicine and delays were avoided. Also, family members described situations when the adolescent's medication routines were interrupted, and where text messages reminders played a big role.

"...Yes, it supports treatment adherence, because most of time we follow the television program but sometimes the power goes off, we missed the exact time to see medication time. Currently this text message comes 10 to 15 minutes before our medication time." (Father, aged 45)

Feeling comfortable receiving text message reminders

The text messages reminders contributed to positive attitudes and to decreased stigmatisation for adolescents, even when HIV/AIDS stigma is deeply rooted in the culture. Thus, the perception of

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the adolescents was that the text messages reminders played an important role for their overall well-being, because sometimes they had low moods. The text messages reminders were described as offering hope and supported the adolescents in achieving consistency in their medication adherence which helped them avoid, for example, fatigue.

"...The benefit of this message is it comes always and reminds me to take the drug on time. The other benefit is when I receive the message, I feel good." (Adolescent, aged

13)

The code-delivered text messages reminders minimises the risk of stigma

The adolescent felt safe regarding privacy in the text messages reminders due to a code sent out to their telephone. The healthcare provider noticed a change in the views of both adolescents and family regarding increased trust and improved engagement with healthcare facilities during the intervention. Family expressed receiving coded text messages reminders could enable adolescents to live like other HIV-free adolescents. However, the adolescents experienced that far from everyone talked openly about their HIV disclosure, which was also reflected in the interviews. Some members of the families were open with their HIV disclosure while others were not.

"My status has already been made public, and everybody knows about my family as well ... However, my husband lives in another area because of work, and knows his HIV status and makes things secret. He did not even take his medication when he come back home." (Mother, aged 45)

Adoption:

In this study, eleven health facilities with 153 participants received an intervention across 5 different geographic areas. The healthcare workers expressed that the intervention's retention rate

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was the best that had been achieved since the introduction of this study to the hospital, which is listed under a sub-theme in the qualitative findings.

Treatment support

The healthcare providers emphasised that text messages reminders were an important support for adolescents in their medication intake to avoid poor adherence. In addition to this, families indicated that they had a mission to support the adolescents in avoiding ART treatment fatigue. Several adolescents expressed that they had received support from their family concerning medication intake. Thus, the text messages reminders were perceived as helpful, as they made participants feel happy and hopeful, even if they felt angered or were in a depressed mood that day.

"...The messages may help people pass good days, despite days that do not carry good fortune. It therefore helps people have good days and reminds them of medication times. One day, for example, being consumed with some ideas, I did not recall that I have medication to take; it is this text message that triggered me take my medicine." (Adolescent, aged 19)

Implementation:

There were 306 mobile phones provided to adolescents during assignments into intervention and control groups. The advisory committee was involved in the implementation of the intervention using standard operational procedure (SOP). During the study, 30,700 SMS text messages were sent to 153 study participants in the intervention group (Figure 1).

Overall, intervention fidelity was high with (30,510/30,700) or 99.38% successfully received SMS text messages during the intervention.

The non-receiving participants in the intervention group were tracked and cross-checked using individual participant codes from the server, and then approached by each health facility to confirm whether they were to be followed-up.

Changing phone numbers/SIM cards, phones being damaged, lost, or shared with others were identified as participant-related reasons for not receiving the messages, and were registered in the logbooks, and corrective measures were used either to replace phones with new devices or repair/maintain the phones as soon as was feasible.

Failing text message delivery influences medication intake

The adolescents identified several reasons for not receiving messages. In connection with the technical aspect, the adolescents highlighted problems such as not having a charged phone battery, or having lost their phone. They described that sometimes the text messages reminders arrived after their medication time. Another issue observed by both healthcare providers and family members was a missing SIM card. Furthermore, the continuity in the text messages reminders was requested by the adolescents to continue the benefits.

"... the receiving time varies; sometimes I receive it 10 minutes before medication time, which is 3p.m. local time in the evening, and sometimes it arrives after I take the drug." (Adolescent, aged 13)

Limitations in phone ownership

Sometimes adolescents were not permitted to use the telephone by themselves, due to restrictions from their family, as they thought that the adolescents were too young to use the telephone. Instead, the family used the telephone, which resulted in text messages reminders never reaching the adolescent. The absence of SIM cards may be because adolescents did not receive a SIM

card, or because someone else in the family was using them. The family reported that they passed information from healthcare providers to the adolescents. Some of the families lacked information about the intervention and did not know what to do when the telephone arrived. The healthcare providers emphasised that some families denied the adolescents use of the telephone, which could cause problems, and text messages reminders were not received. Furthermore, the importance of informing families about the intervention was stressed, as several adolescents were restricted from using the telephone.

> "...I think families should be communicated with regarding why their children are provided with mobile phones from the hospital, so as to avoid denial to access or adults using the phones for themselves." (Healthcare provider, aged 36)

Technical limitations

One major issue stressed by adolescents, families, and healthcare providers, was that the electric power system went off quite often in their communities, which caused problems with receiving text messages reminders if the battery in the telephone was not charged. The adolescents usually did not experience problems with delays in text messages reminders, but they had observed that the text messages reminders did not always arrive on time. The messages could come long before their scheduled medication time or sometimes very close to or after their scheduled medication time. Sometimes the text message reminder was absent for entire days.

"...The message helped me a lot to remember my medication time. However, the skips in message delivery dates and untimely arrivals should be corrected so that it is more helpful." (Adolescent, aged 18)

Maintenance:

After initial configuration, a single server can send text messages to thousands of participants across a large geographic area. In this study, a server sent text messages to 153 participants across

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5 different geographic areas. The technical challenges experienced in delivering the intervention were related to navigating the messaging server and feedback responses from the participants. The non-receiving participants in the intervention group were tracked and cross-checked using a four-digit individual participant codes from the server and were then approached by each facility to confirm whether they were indeed in that group or lost. Despite technical barriers, and adverse conditions, and a belief in the future of text messages reminders emerged, which was also expressed in the qualitative interviews.

Seeing potential in SMS services

The benefits of SMS reminders were perceived as valuable; especially when adolescents missed appointments for medication refills and virus load tests. Before the intervention, there were difficulties getting in touch with the adolescents, because they lived in rural areas and did not have a telephone. The healthcare providers thought about how to incorporate text messages reminders into routine health care. A wish among the adolescents was expressed that more text messages reminders could be helpful in raising awareness about their condition. Both the adolescents and the healthcare providers raised a need to continue the text message reminders.

> "I think this must continue. The mobile provision has played significant roles in adherence and retention, as many of the adolescents do not have phones...because of this provision, adolescents can be reached directly with health messages and receive important lessons just from their phones." (Adolescent, aged 19)

Possibilities with text messages reminders

The healthcare provider described that possibilities to communicate with the adolescents had increased after the intervention, and the adolescents' attitudes towards healthcare facilities had become more positive. The adolescents found the improved digital communication to be an

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advantage, because the healthcare provider no longer needed to call their family but could call them directly.

"Previously, healthcare providers from hospital reached me through neighbourhood phone numbers. She now uses this number to reach me directly through the phone provided by the hospital. This is a benefit for my privacy and for the information we discuss over the phone." (Adolescent, aged 18)

DISCUSSION

Our process evaluation which was based on the RE-AIM framework (18) showed that intervention fidelity was high with only about 0.6% of the SMS messages not delivered as intended. Both providers and patients described the SMS reminders as being helpful. A few barriers were noted including glitches at telecommunication networks, electric power disruptions, issues with phone ownership at household levels. Our results highlight that SMS message reminders can be delivered with high coverage if proper processes are followed. The 4-digit short code messaging system was a key enabler in ensuring confidentiality and security of the messages. Further scale-up of such interventions will depend on addressing broader systems issues including phone ownership, fixing network interruptions and reliable power sources. However, a study conducted in Philippines showed that intervention fidelity was low (77.9%) in the message group. The identified reason for low intervention fidelity was poor reliability of local telecommunication networks, and frequency of messages received (28). The local context for cellular phone infrastructure and operational challenges, such as multiple users on a single cell phone, has an impact on text messaging interventions (29). It is important to assess the setting before using the SMS intervention as a strategy to improve adherence. There is emerging evidence that mobile phones can play an important role in healthcare delivery, especially in resource-limited settings (30). SMS text messaging is a particularly useful application that can be used to collect or share information and

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to enhance communication between healthcare personnel and patients in a low-cost manner (31). Treatment support was highlighted as an important factor for adolescents to avoid poor adherence. Text messages could be a facilitator for adolescents to remain hopeful and avoid unwanted side effects given that previous research (32, 33) has shown that a lack of support systems was perceived to negatively affect adherence among young people. Our findings provide additional evidence in support of research to identify effective interventions to improve adherence and retention in care for adolescents with HIV and enhance their engagement in these services. Thus, findings of this process evaluation can guide further research towards interventions concerning readiness among healthcare facilities, because settings can impact implementation. Giving importance to the voice of adolescents living with HIV can offer hope to many more in the same situation. This study thereby has a potential clinical impact and contributes to UN Sustainability Goal (34).

There are both strengths and limitations identified in this process evaluation. First, the intervention has several strengths, and a key strength is the use of a 4-digit short code for text messages that enables rapid, high-volume outbound messaging, is easy to read and remember, and assists text recipients in identifying the sender based on their preferences for message delivery time, message content, and messaging language. The use of the unique code can contribute to maintaining security and confidentiality among participants.

Secondly, the messaging server is adaptable and user-friendly, as the researcher or local IT provider can add and remove new data fields to navigate dropped or missed individuals and update SMS text message content to avoid message-related fatigue.

In addition, the process evaluation also has several strengths that were identified. The first strength is the use of mixed methods, where different forms of data—both quantitative and qualitative methods—are combined to capture the multi-dimensionality of the intervention. The data

supplement one another and aid in obtaining a comprehensive picture of the study results, which can contribute to a deeper understanding of the participants' experiences.(35) If the participants are given the opportunity to highlight their own individual priorities, it might be possible for us to improve our understanding of the impact of the intervention.

Finally, three different perspectives (adolescents, families, and healthcare providers) were included in the qualitative interviews, which allowed different voices to be heard. However, limited numbers of included participants from adolescents' families and healthcare providers can limit the study's transferability.(36)

Conclusion

The mobile phone text messaging intervention to support ART adherence and retention in care was well-received by participants, and overall intervention fidelity was high. However, the intervention's feasibility was dependent on the reliability of local telecommunication networks, local electric power, and monitoring of adolescents' families, all of which had a significant impact on the intervention's usability, fidelity, and doses received. The participants experienced the text messaging function as helpful, therefore the development of different aspects, such as addressing technical problems, would be desirable to further improve impact. Further research needs to be directed toward readiness within the healthcare facilities to capture an increased understanding of barriers and facilitators in implementation.

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Contributors

AT, DJ, and IKH conceptualised and developed the study design. AT collected the data and managed study implementation. DJ and IKH supervised data collection and study implementation. All four authors contributed to data analysis and interpretation. AT and HÅP drafted the manuscript. All authors contributed to critical revision of the manuscript and approved the final manuscript. 1eg

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Competing interests

None declared.

Patient consent for publication

Not applicable.

Ethics approval

The study was conducted according to the guidelines in the Declaration of Helsinki (37) and approved by the Swedish Regional Ethical Review Board (Dnr 2019-03433), National Research Ethics Review Committee in Ethiopia (MoSHE/RD/142/2869/20), and the Institutional Research Ethics Review Board in Arba Minch University (IRB-113/11). The participants received both oral and written information about the purpose of the study, about the confidential treatment of the data and the voluntary nature of participation. Informed consent was provided from the participants elien. before the study began.

Provenance and peer review

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Data availability statement

No datasets were generated or analysed during the current study. All relevant data from this study will be made available upon reasonable written request and in accordance with ethical approval, from the corresponding author.

Supplemental material

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Figure 1. The flow diagram of mobile phone text messaging reminder in the intervention group

Intervention fidelity and factors affecting the process of implementing a mobile phone text messaging intervention among adolescents living with HIV: a convergent mixedmethods study in southern Ethiopia

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1	Intervention fidelity and factors affecting the process of implementing a mobile phone text
2	messaging intervention among adolescents living with HIV: a convergent mixed methods
3	study in southern Ethiopia
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Abstract

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Objective: To assess the intervention fidelity and explore contextual factors affecting the process 29 of implementing a mobile phone text messaging intervention in improving adherence to and 30 retention in care among adolescents living with HIV, their families, and their healthcare providers 31 32 in southern Ethiopia. **Design:** A convergent mixed-methods design guided by the process evaluation theoretical 33 framework and the RE-AIM framework was used alongside a randomised controlled trial to 34 examine the fidelity and explore the experiences of participants in the intervention. 35 Setting: Six hospitals and five health centres providing HIV treatment and care to adolescents in 36 five zones in southern Ethiopia. 37 **Participants:** Adolescents (aged 10–19), their families and their healthcare providers. 38 Intervention: Mobile phone text messages daily for 6 months or standard care (control). 39 Results: 306 participants were enrolled in the process evaluation. Among the intervention 40 41 participants (N = 153), 171 (55.9%) of whom were men, most resided in an urban area 225 (73.5%), and participants had a mean age of 15 (2.62). The overall experiences of implementing the text 42 messages reminder intervention were described as helpful in terms of treatment support for 43 adherence but had room for improvement. During the study, 30,700 text messages were sent, and 44 fidelity was high, with 99.4% successfully receiving text messages during the intervention. Barriers 45 such as failed text messages delivery, limitations in phone ownership, and technical limitations 46 affected fidelity. Technical challenges can hinder maintenance, but a belief in the future of digital 47 communication permeates the experiences of the text messages reminders. 48

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49	Conclusions: Overall fidelity was high, and participants' overall experiences of mobile phone text
50	messages were expressed as helpful. Contextual factors, such as local telecommunications
51	networks and local electric power, as well as technical and individual factors must be considered
52	when planning future interventions.
53	Trial registration: Pan African Clinical Trials PACTR202107638293593, first registration
54	20/07/2021.
55	Strengths and limitations with this study
56	• Secure and confidential delivery of high-volume messages through a 4-digit short code.
57	• The use of a mixed methods design and the inclusion of family members and healthcare
58	providers is a strength of this process evaluation study.
59	• There was a limited number of adolescents' family and healthcare providers included in the
60	interviews.
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71 INTRODUCTION

Globally, 38.4 million people were living with HIV in 2021. Of these, 1.71 million were adolescents aged 10–19, 88% of whom live in Sub-Saharan Africa (1, 2). To control the epidemic, the Joint United Nations Programme on HIV/AIDS (UNAIDS) launched the 95%-95%-95% targets aimed at HIV testing, treatment, and viral suppression by 2030 (3). However, by 2021, 75% percent of the 38.4 million people living with HIV (PLHIV) were receiving antiretroviral therapy (ART), a treatment gap of 5.9 million people (4). Moreover, achieving the recommended optimal adherence level of >95% which is required for ART to be effective, remains a challenge within the HIV care continuum (5). This poses a significant threat to HIV interventions in resource-limited settings (6).

Poor adherence to ART has several consequences, including increased risk of viral drug resistance and reduced treatment effectiveness toward viral suppression, leading to disease progression, greater risk of death, and increased risk of viral transmission (7). Some of the major barriers to ART adherence include socioeconomic status, (8, 9) fear of being stigmatised or discriminated against as a result of one's HIV status,(10) forgetting to take medication on time,(11) treatment fatigue.(12) and patient-provider communication (13). Several interventions to overcome these barriers have been studied in a variety of settings (14). The use of digital health strategies to enhance HIV treatment is one of the priority interventions in Sub-Saharan Africa (15). Targeted digital client communication using mobile phone-based short text messaging has been recommended for adherence support for a range of health issues and adherence to antiretroviral treatment (16). The success and effectiveness of an mHealth intervention in achieving desired health outcomes is dependent on the context in which they are implemented (15, 16). Context plays a crucial role in either the success or failure of an intervention.

In addition to design and implementation, the success of interventions is diverse and may be influenced by factors such as sociodemographic and culture (17). Observing what is delivered in practice with close reference to the theory of the intervention can help evaluators in distinguishing the intervention fit in different contexts and changes that undermine intervention fidelity (15, 17). Trials should continue to rigorously assess outcomes, but also include integral process evaluations that use qualitative and quantitative data to develop and test hypotheses about how interventions work (18). In a multi-centre trial, a process evaluation is necessary to understand whether the intervention was implemented and received similarly across all sites (9). However, trials assessing mHealth adherence interventions for HIV often do not include process evaluations to examine the fidelity and quality of the intervention delivery, causal mechanisms for the health outcomes, contextual factors affecting the delivery, and costs of implementation (16, 19). Understanding the entire implementation process of an mHealth intervention allows practitioners to interpret the results and replicate the intervention in other contexts (20, 21). Therefore, this study aimed to evaluate the process of a mobile text messaging intervention conducted among adolescents living with HIV in Ethiopia.

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METHODS Study design A convergent mixed-methods design (17) combining quantitative and qualitative techniques was used. The design was guided by the process evaluation theoretical framework (22) and structured by the RE-AIM dimensions (Reach, Effectiveness, Adoption, Implementation and Maintenance) (18) to evaluate intervention effectiveness alongside a randomised controlled trial (RCT) to examine the study's fidelity and to explore the experiences of the participants in the intervention. The trial was registered in Pan African Clinical Trials Registry with the registration number PACTR202107638293593 on 17/07/2021. Study setting and participants Six hospitals and five health centres that provide HIV treatment and care to adolescents in the Gamo, Gofa, Konso, South Omo, and Wolayita zones in Southern Ethiopia were included in the main study. These zones are home to over 25 distinct ethnic groups, each with its own culture and context. Between July 5, 2022, and February 28, 2023, 306 adolescents living with HIV were included in the study, in either the intervention or in the control group. The quantitative data included process indicators, while the qualitative interviews included ten adolescents from the main trial, four adolescents' families, and two healthcare providers who were involved in the process evaluation. We used the following technique to identify eligible adolescents: first, we identified the number of adolescents of eligible age in each facility. Then, using their address, we called each adolescent and their parents or caregivers directly via phone numbers, care providers, or adherence supports. Then, data collectors approached adolescents and posed literacy questions about their ability to read text by displaying sample texts. Then, eligible participants in the study were asked to give consent and assent. Thus, adolescents aged 10 to 19 years, diagnosed with HIV, currently

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participating in ART care, and planning to stay in the designated facility for at least six months following study enrolment were eligible. Participants who were above the age limit, did not disclose their HIV status, were unable to read text, or had a disability were all excluded. Finally, the data collector showed each eligible adolescent how to use their mobile device, including text saving and deletion.

144 Theoretical Framework of Process Evaluation

The RE-AIM framework (18) was used for the process evaluation to comprehensively examine the level of implementation. This involves understanding the implementation of interventions in terms of (1) fidelity, defined as to what extent the intervention was implemented consistently with the underlying theory as planned; (2) delivery, defined as to what extent all of the intended activities, training, and materials were provided to program participants; (3) reach, defined as the absolute number, proportion, and representativeness of individuals who are willing to participate in a given initiative, intervention, or program; (4) receipt, defined as how participants reacted to specific aspects of the intervention; and (5) context, defined as what contextual factors influence implementation or the intervention outcome.

154 Description of the intervention

The MRC framework,(22) a systematic literature review,(23) interviews with adolescents,(24) and the theoretical health belief model (HBM) (25) were used to develop the intervention. Adolescents living with HIV, healthcare providers, and research project technical advisory team members participated in the design (26) under the guidance of a research advisory committee. The HBM is a theoretical model that has been constructed from six domains: susceptibility, severity, barriers, benefit, cues to action, and self-efficacy. After the intervention's development, text messages were uploaded to the server, and an automated message-pushing software was used to send tailored daily

text messages using a four-digit code from Ethiopia Telecom. This code helps adolescents in
 avoiding messaging source-related stigma and distinguishing intervention messages from other
 messages.

Other various configurations such as wide-area network (WAN) internet protocol (IP), local area network (LAN) IP, Ethio telecom central server IP, a virtual private network (VPN) line, and office servers were used as infrastructure, as required to support the study. The text messages were categorised and delivered based on each adolescent's customised medication schedule and time. The software sent the message 15 minutes before each participant's medication time. The type of message was short and mainly focused on advice about the benefits of taking on time, the risk/consequences of missing/not taking on time, encouragement, and without mentioning anything about HIV or the name of the drug. For example, "Those who use it properly know its benefits", "I'm taking it properly and on time". For example, these messages in Amharic are "心ትhha የሚጠቀሙት ጥቅሞቹን ያውቃሉ) and በትክክል እና በሰዓት እወስዳለሁ respectively. The server was checked daily to troubleshoot network/cell phone issues. Based on the server information, the first author contacted the facility level care provider to contact the adolescent with corrective actions; for example, subscriber identity module card (SIM card) replacement, damaged mobile phones, and network troubleshooting for maintenance and replacement.

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184 Sample and data collection

The quantitative data was collected from the server, activity logs, an adverse event monitoring form, and an interview with adolescents. The researcher collects data on intervention fidelity by tracking the number of text messages sent, received, and failed from the server daily. Furthermore, each facility representative documented any adverse event related to the trial, filled the form, and sent it to researchers every week. Furthermore, during the follow-up data collection phase, adolescents asked if they received text messages on a regular schedule.

A purposive sampling of 10 adolescents with HIV (aged 12–19), four family members/relatives (aged 36–45), and two healthcare providers (aged 31–36) from five different healthcare facilities were asked to be interviewed about their experiences in the intervention between June and July 2022 at healthcare facilities by the first author. The interviews were conducted in all respondent languages, such as Amharic, Wolaytigna, Gamogna, Gofigna, Arigna, and Konsegna in a quiet and confidential area at the respective health facilities by the first author and one research assistant and lasted on average 30 minutes.

An interview guide was used to gain a rich, in-depth understanding, and to allow the participants to concretise their experiences of their use of text messages, communication, and technical aspects of the intervention. The interview guide included subsections adapted to the participants, i.e., adolescents, families, and healthcare providers. Hence, the questions were different, depending on to whom they were addressed. The introductory question to the adolescents was: "Are you receiving the mobile text-message reminder from the hospital?", followed by follow-up questions such as, "What do you think about the messages?" The families were initially asked "How do family/social related factors affect ART adherence among adolescents?" Healthcare providers were

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asked "How did you experience communication with the adolescents with regard to theintervention?" Follow-up questions and prompts were used throughout the whole interview.

208 The interviews were audiotaped, transcribed verbatim, and translated from Amharic to English by

209 the first author, and checked for accuracy by one independent language expert.

210 Data analysis

The number of SMS messages sent and delivered to participants were tracked as a measure of intervention fidelity. When SMS messages did not arrive on the phone, the project advisory team investigated the external network and other infrastructure issues. If the message could not be delivered during this period, the computer automatically recorded it as a delivery failure and sent the message again. Data captured on the delivery status of the SMS messages were recorded as: delivered (the phone had reception marked as green); undelivered (the phone was switched off or marked as red in the server). The program could not record whether messages delivered to the phones were opened. The descriptive statistical analysis was used to summarize data in frequency, percentages, mean and standard deviation. The quantitative effectiveness data is analyzed separately and not included in the process evaluation. The RE-AIM outcomes framework components of Reach, Effectiveness, Adoption, Implementation, and Maintenance were used to present mixed method findings about the delivery of a reminder message, success, and intervention barriers for the intervention implementation process (18).

Interviews were analysed by using the principles for content analysis described by Graneheim and Lundman (19, 27). First, the transcripts were read several times to gain a sense of the whole by the first and the last author. Thereafter, meaning units were identified and condensed to reduce the text while maintaining the core meaning. The first author developed a coding frame for the analysis by using NVivo software, which were discussed by all authors. Condensed meaning units were then

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labelled with a code, which were kept close to the text on a manifest level. Next, sub-themes were
created from the code frame by the first and last authors. The sub-themes were then abstracted into
themes. Finally, the underlying meaning—the latent content—was described into a main theme.
Thereafter one of the authors (HÅP) read the transcripts, extracted meaning units, codes, and
themes. The content was discussed and reflected upon together with all authors and lasted until an
agreement was reached.

235 Patient and Public Involvement

Representatives of adolescents were involved in the development of messages for the SMS reminders and interview guides. Their feedback was used to adapt its contents and to set strategies to promote inclusivity in study participation during participant recruitment. In addition, participants, healthcare providers, and the participants' families were involved in reporting any incidence related to mobile devices and other issues.

RESULTS

250 The characteristics of adolescents assigned in the intervention arm are shown in table 1.

251 Table 1. Participant characteristics

Characteristics of add	olescents assigned in the in	tervention			
Characteristics Frequency /Mean (SD)					
Adolescent age, Mean (sta	ndard deviation (SD))	15(0.21) years			
Adolescents age category	10-14	60 (39.22)			
	15-19	93 (60.78)			
Adolescents gender	Male	78 (49.02)			
	Female	75 (43.8)			
Languages of adolescent during	Amharic	62 (40.52)			
interview	Wolaytigna	27 (17.65)			
	Gamogna	39 (25.49)			
	Gofigna	13 (8.5)			
	Arigna	6 (3.3)			
	Konsegna	6 (3.3)			
Educational status of adolescent	Grade 1-8	97 (63.40)			
	Grade 9 and above	56 (36.60)			
Residence of adolescent	Urban	111(72.55)			
	rural	42 (27.45)			
Living arrangement	Live alone	10 (6.54)			
	Live with family	143 (93.46)			
Psycho-social peer-support	Participate	47 (30.72)			
	Do not Participate	106 (69.28)			
Interviewee characteristics					
Adolescents (Sex/age)	Male (10-14 years)	2			
	Female (10-14 years)	3			
Adolescents (Sex/age)	Male (15-19 years)	2			
	Female (15-19 years) 🛀	3			
Adolescents level of education	Grade 1-8	5			
	Grade 9 and above	5			
healthcare providers (Sex/Age)	Male	1 (36 years)			
	Female	1 (31 years)			
Parent/care giver (Sex/Age)	Non-biological care	2 (1 male and 1 female,			
	giver	36 and 45 years			
		respectively			
	Biological	2 (1 mother and 1			
		father, 39 and 45 years			
		respectively)			

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252	The results are structured	using the RE-AIM	framework (18) and	corresponding themes	(Table 2).
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RE-AIM dimension (18)	Definition (18)	Qualitative theme
Reach	The number, proportion, and representativeness of eligible individuals who participate in each initiative.	
Effectiveness	The impact of an intervention on the relevant outcomes, including potential adverse effects, quality of life, and economic outcomes.	Text message reminders were helpful for adherence but there was room for improvement Text messages reminders support adherence
		Feeling comfortable receiving text messages reminders
	Č,	The code delivered with text messages reminders minimises the risk of stigma
Adoption	The reach and effectiveness/efficacy of an intervention at the setting level.	Supporting the text messages reminder
Implementation	The intervention agents' fidelity to the various elements of an intervention's protocol, including	Failing text messages delivery influences medication intake
	consistency of intended delivery.	Limitations in phone ownership
		Technical limitations
Maintenance	Connects with both setting-level indicators (the extent to which a program or a policy becomes part	Seeing potential in SMS services
	of organisational practices and policies), and individual-level indicators (monitoring of effectiveness of an intervention or program six months or more after the most recent contact).	Possibilities of text messages reminder

253	Table 2.	Overview	of the q	ualitative	themes	related to	the	dimensions	s in the	RE-AIM	framework	
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Reach: The total number of individuals that were assessed for eligibility was 435, of which 306 (70.34 %) meet eligibility criteria. The remaining 129 participants excluded for the following reasons: 27 (20.9%) were unable to stay in the study area for the duration of the study, 39 (30.2%) were unable to read, 24 (18.6%) were did not know their status, 21 (16.3%) were could not reached, 13 (10.1%) refused to participate, and 5 (3.9%) had an impairment. Thus, 306 participants were enrolled and randomised: n = 153 in the intervention, and n = 153 in the control group. Among the 153 enrolled in intervention arm, 78 (49.02%) were male, and 75 (43.8%) were female, respectively. The mean and standard deviation age of the participants is 15 (0.21). Of these, 111 (72.55%) resided in an urban area, 97 (63.40%) had primary school level education, and 10(6.54%) live alone(orphan). **Effectiveness:** The number of participants retained in the 6-month follow-up of the intervention group was higher than the control group in this study. Text messages reminders were helpful for adherence but there was room for improvement The overall experiences of the intervention among adolescents living with HIV was that text messages reminders were helpful when it came to their adherence to medication, but direct access to phones and better timing of messages should be assured to increase their functioning and usability. The retention rate was improved, and was the best achieved since the intervention was introduced. Despite this, more effort was requested concerning technical issues to make the reminders even more helpful. The participants described facilitating aspects like increased medication intake and communication. Also, the well-being of the adolescents and the support

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function was highlighted. However, technical problems like lost telephones or text messagesreminders arriving after medication time were emphasised as barriers.

279 Text messages reminders support adherence

They described that before the intervention, their medication was often forgotten, which resulted in it being taken later than it should have been due to forgetfulness. Sometimes the adolescent realised that they had forgotten to take their medication but then waited until dinner to take it. The adolescents described that text messages reminders were associated with taking their medicine and delays were avoided. Also, family members described situations when the adolescent's medication routines were interrupted, and where text messages reminders played a big role.

287 "... Yes, it supports treatment adherence, because most of time we follow the television
288 program but sometimes the power goes off, we missed the exact time to see medication
289 time. Currently this text message comes 10 to 15 minutes before our medication time."
290 (Father, aged 45)

291 Feeling positive about the text messages reminder

The text messages reminders contributed to positive attitudes and to decreased stigmatisation for adolescents, even when HIV/AIDS stigma is deeply rooted in the culture. Thus, the perception of the adolescents was that the text messages reminders played an important role for their overall well-being, because sometimes they had low moods. The text messages reminders were described as offering hope and supported the adolescents in achieving consistency in their medication adherence which helped them avoid, for example, fatigue.

"... The benefit of this message is it comes always and reminds me to take the drug on time. The other benefit is when I receive the message, I feel good." (Adolescent, aged

13)

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3 4	301	The code-delivered text messages reminders minimise the risk of stigma
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6	302	The adolescent felt safe regarding privacy in the text messages reminders due to a code sent out
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o 9	303	to their telephone. The healthcare provider noticed a change in the views of both adolescents and
10		
11	304	family regarding increased trust and improved engagement with healthcare facilities during the
12	205	intervention. For its commenced manipulate and destructions are main dama acculd another adalaceants
14	305	intervention. Family expressed receiving coded text messages reminders could enable adolescents
15	306	to live like other HIV-free adolescents. However, the adolescents indicated that after their
16	500	
17	307	family's HIV status was made public, they were subjected to stigma, which was reflected in the
19		
20	308	interview. Some members of the families were open with their HIV disclosure while others were
21		
22 23	309	not.
24		
25	310	"My status has already been made public, and everybody knows about my family as
26	311	well However, my husband lives in another area because of work, and knows his
27 28	312	HIV status and makes things secret. He did not even take his medication when he come
29	313	back home." (Mother, aged 45)
30	214	Adoption
31	514	Adoption.
32 33		
34	315	In this study, eleven health facilities with 153 participants received an intervention across 5
35	24.6	different communities and a solution to health one provide the meter of restantion and a
36 37	316	different geographic areas. According to healthcare providers, the rate of retention among
38	317	adolescents has increased since the study began in the hospital as described in the qualitative
39	517	adorescents has mercased since the study began in the hospital, as described in the quantative
40	318	findings under a sub-theme.
41 42		
43		
44	319	" By the way, in terms of retention, we have observed the best retention rate ever in this year
45	220	since ADT started in this beseries. Of sources our follow we is there and there are other a sectores
46 47	320	since ART started in this hospital. Of course, our jollow-up is there and there are other partners
48	371	like CDC and ICAP. But this messaging has augmented the service we provide, and it increased
49	521	the CDC and ICHI . Dat this messaging has dagmented the service we provide, and it meredsed
50	322	our communication with them and helped them remind their medication irrespective of
51 52		
53	323	inconsistencies in messaging and medication time; the message delivery reminds them something
54		
55 56	324	targeted." (healthcare provider, aged 36)
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> Supporting the text messages reminders The healthcare providers emphasised that text messages reminders were an important support for adolescents in their medication intake to avoid poor adherence. In addition to this, families indicated that they had a mission to support the adolescents in avoiding ART treatment fatigue. Several adolescents expressed that they had received support from their family concerning medication intake during the intervention. Thus, the text messages reminders were perceived as helpful, as they made participants feel happy and hopeful, even if they felt angered or were in a depressed mood that day. "...The messages may help people pass good days, despite days that do not carry good fortune. It therefore helps people have good days and reminds them of medication times. One day, for example, being consumed with some ideas, I did not recall that I have medication to take; it is this text message that triggered me take my medicine." (Adolescent, aged 19) **Implementation:** There were 306 mobile phones provided to adolescents during assignments into intervention and control groups. The advisory committee was involved in the implementation of the intervention using standard operational procedure (SOP). During the study, 30,700 SMS text messages were sent to 153 study participants in the intervention group (Figure 1). Overall, intervention fidelity was high with (30,510/30,700) or 99.38% successfully received SMS text messages during the intervention. The non-receiving participants in the intervention group were tracked and cross-checked using individual participant codes from the server, and then approached by each health facility to confirm whether they were to be followed-up.

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2		
2 3 4	348	Changing phone numbers/SIM cards, phones being damaged, lost, or shared with others were
5 6 7	349	identified as participant-related reasons for not receiving the messages, and were registered in the
7 8 9	350	logbooks, and corrective measures were used either to replace phones with new devices or
10 11 12	351	repair/maintain the phones as soon as was feasible.
13 14 15	352	Failing text message delivery influences medication intake
15 16 17	353	The adolescents identified several reasons for not receiving messages. In connection with the
18 19	354	technical aspect, the adolescents highlighted problems such as not having a charged phone
20 21 22	355	battery or having lost their phone. During the feasibility study period, there was fluctuation in
23 24	356	messaging time, and the text message reminders arrived after their medication time. Another
25 26 27	357	issue observed by both healthcare providers and family members was a missing SIM card.
27 28 29	358	Furthermore, the continuity in the text messages reminders was requested by the adolescents to
30 31 32	359	continue the benefits.
33	360	" the receiving time varies; sometimes I receive it 10 minutes before medication
34 35	361 362	time, which is 3p.m. local time in the evening, and sometimes it arrives after I take the drug." (Adolescent, aged 13)
36 37 38	363	Limitations in phone ownership
39 40 41	364	Sometimes adolescents were not permitted to use the telephone by themselves, due to restrictions
42 43	365	from their family, as they thought that the adolescents were too young to use the telephone.
44 45 46	366	Instead, the family used the telephone, which resulted in text messages reminders never reaching
47 48	367	the adolescent. The absence of SIM cards may be because adolescents did not receive a SIM
49 50 51	368	card, or because someone else in the family was using them. The family reported that they passed
52 53	369	information from healthcare providers to the adolescents. Some of the families lacked
54 55	370	information about the intervention and did not know what to do when the telephone arrived. The
56 57 58	371	healthcare providers emphasised that some families denied the adolescents use of the telephone, 18

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which could cause problems, and text messages reminders were not received. Furthermore, the
importance of informing families about the intervention was stressed, as several adolescents were
restricted from using the telephone. *"…I think families should be communicated with regarding why their children are*

provided with mobile phones from the hospital, so as to avoid denial to access or

adults using the phones for themselves." (Healthcare provider, aged 36)

378 Technical limitations

One major issue stressed by adolescents, families, and healthcare providers, was that the electric power system went off quite often in their communities, which caused problems with receiving text messages reminders if the battery in the telephone was not charged. The adolescents usually did not experience problems with delays in text messages reminders, but they had observed that the text messages reminders did not always arrive on time. The messages could come long before their scheduled medication time or sometimes very close to or after their scheduled medication time. Sometimes the text message reminder was absent for entire days.

> "...The message helped me a lot to remember my medication time. However, the skips in message delivery dates and untimely arrivals should be corrected so that it is more helpful." (Adolescent, aged 18)

389 Maintenance:

After initial configuration, a single server can send text messages to thousands of participants across a large geographic area. In this study, a server sent text messages to 153 participants across five different geographic areas. The technical challenges experienced in delivering the intervention were related to navigating the messaging server and feedback responses from the participants. The non-receiving participants in the intervention group were tracked and cross-checked using a fourdigit individual participant codes from the server and were then approached by each facility to

confirm whether they were indeed in that group or lost. Despite technical barriers, and adverse
conditions, and a belief in the future of text messages reminders emerged, which was also expressed
in the qualitative interviews.

399 Seeing potential in SMS services

The benefits of SMS reminders were perceived as valuable; especially when adolescents missed appointments for medication refills and virus load tests. Before the intervention, there were difficulties getting in touch with the adolescents, because they lived in rural areas and did not have a telephone. The healthcare providers thought about how to incorporate text messages reminders into routine health care. A wish among the adolescents was expressed that more text messages reminders could be helpful in raising awareness about their condition. Both the adolescents and the healthcare providers raised a need to continue the text message reminders.

"I think this must continue. The mobile provision has played significant roles in adherence and retention, as many of the adolescents do not have phones...because of this provision, adolescents can be reached directly with health messages and receive important lessons just from their phones." (Adolescent, aged 19)

Possibilities with text messages reminders

The healthcare provider described that possibilities to communicate with the adolescents had increased after the intervention, and the adolescents' attitudes towards healthcare facilities had become more positive. The adolescents found the improved digital communication to be an advantage because the healthcare provider no longer needed to call their family but could call them directly.

> "Previously, healthcare providers from hospital reached me through neighbourhood phone numbers. She now uses this number to reach me directly through the phone

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DISCUSSION

provided by the hospital. This is a benefit for my privacy and for the information we discuss over the phone." (Adolescent, aged 18)

Our process evaluation which was based on the RE-AIM framework (18) showed that intervention fidelity was high with only about 0.6% of the SMS messages not delivered as intended. Both providers and patients described the SMS reminders as being helpful. A few barriers were noted including glitches at telecommunication networks, electric power disruptions, issues with phone ownership at household levels. Our results highlight that SMS message reminders can be delivered with high coverage if proper processes are followed. The 4-digit short code messaging system was a key enabler in ensuring confidentiality and security of the messages. Further scale-up of such interventions will depend on addressing broader systems issues including phone ownership, fixing network interruptions and reliable power sources. However, a study conducted in Philippines showed that intervention fidelity was low (77.9%) in the message group. The identified reason for low intervention fidelity was poor reliability of local telecommunication networks, and frequency of messages received (28). The local context for cellular phone infrastructure and operational challenges, such as multiple users on a single cell phone, has an impact on text messaging interventions (29). It is important to assess the setting before using the SMS intervention as a strategy to improve adherence. There is emerging evidence that mobile phones can play an important role in healthcare delivery, especially in resource-limited settings (30). SMS text messaging is a particularly useful application that can be used to collect or share information and to enhance communication between healthcare personnel and patients in a low-cost manner (31). Treatment support was highlighted as an important factor for adolescents to avoid poor adherence. Text messages could be a facilitator for adolescents to remain hopeful and avoid unwanted side effects given that previous research (32, 33) has shown that a lack of support systems was perceived Page 23 of 30

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to negatively affect adherence among young people. Our findings provide additional evidence in support of research to identify effective interventions to improve adherence and retention in care for adolescents with HIV and enhance their engagement in these services. Thus, findings of this process evaluation can guide further research towards interventions concerning readiness among healthcare facilities, because settings can impact implementation. Giving importance to the voice of adolescents living with HIV can offer hope to many more in the same situation. This study thereby has a potential clinical impact and contributes to UN Sustainability Goal (34). Methodological concerns/ limitations There are both strengths and limitations identified in this process evaluation. First, the intervention has several strengths, and a key strength is the use of a 4-digit short code for text messages that enables rapid, high-volume outbound messaging, is easy to read and remember, and assists text recipients in identifying the sender based on their preferences for message delivery time, message content, and messaging language. The use of the unique code can contribute to maintaining security and confidentiality among participants. Secondly, the messaging server is adaptable and user-friendly, as the researcher or local IT provider can add and remove new data fields to navigate dropped or missed individuals and update SMS text message content to avoid message-related fatigue. In addition, the process evaluation also has several strengths that were identified. The first strength is the use of mixed methods, where different forms of data—both quantitative and qualitative methods—are combined to capture the multi-dimensionality of the intervention. The data supplement one another and aid in obtaining a comprehensive picture of the study results, which can contribute to a deeper understanding of the participants' experiences (35). If the participants

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are given the opportunity to highlight their own individual priorities, it might be possible for us toimprove our understanding of the impact of the intervention.

Finally, three different perspectives (adolescents, families, and healthcare providers) were included
in the qualitative interviews, which allowed different voices to be heard. However, limited numbers
of included participants from adolescents' families and healthcare providers can limit the study's
transferability (36).

471 Conclusion

The mobile phone text messaging intervention to support ART adherence and retention in care was well-received by participants, and overall intervention fidelity was high. However, the intervention's feasibility was dependent on the reliability of local telecommunication networks, local electric power, and monitoring of adolescents' families, all of which had a significant impact on the intervention's usability, fidelity, and doses received. The participants experienced the text messaging function as helpful, therefore the development of different aspects, such as addressing technical problems, would be desirable to further improve impact. Further research needs to be directed toward readiness within the healthcare facilities to capture an increased understanding of barriers and facilitators in implementation.

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Contributors

AT, DJ, and IKH conceptualized and developed the study design. AT collected the data and transcribed verbatim and translated from Amharic to English. DJ and IKH supervised data collection and study implementation. All authors read the transcripts, extracted meaning units, codes, and data analysis. Sub-themes were created from the code frame by the first and last authors. AT and HÅP drafted the manuscript, and all authors contributed to critical revision and approved the final manuscript.

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508 Not applicable.

509 Ethics approval

The study was conducted according to the guidelines in the Declaration of Helsinki (37) and approved by the Swedish Regional Ethical Review Board (Dnr 2019-03433), National Research Ethics Review Committee in Ethiopia (MoSHE/RD/142/2869/20), and the Institutional Research Ethics Review Board in Arba Minch University (IRB-113/11). The participants received both oral and written information about the purpose of the study, about the confidential treatment of the data and the voluntary nature of participation. Informed consent was provided from all participants over the age of 18 before the study began. Similarly, parental consent and adolescent assent were obtained from all participants under the age of 18 before the start of the trial.

Provenance and peer review

519 Not commissioned, externally peer reviewed.

520 Data availability statement

521 No datasets were generated or analysed during the current study. All relevant data from this study

522 will be made available upon reasonable written request and in accordance with ethical approval,

523 from the corresponding author.

- 524 Supplemental material
- 17 525 ---

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Figure 1. The flow diagram of mobile phone text messaging reminder in the intervention group

Intervention fidelity and factors affecting the process of implementing a mobile phone text messaging intervention among adolescents living with HIV: a convergent mixed methods study in southern Ethiopia

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2 3 4	1	Intervention fidelity and factors affecting the process of implementing a mobile phone text
5 6	2	messaging intervention among adolescents living with HIV: a convergent mixed methods
7 8	3	study in southern Ethiopia
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43 44 45	20	Abstract
45 46 47	21	Objective: To assess the intervention fidelity and explore contextual factors affecting the process
48 49	22	of implementing a mobile phone text messaging intervention in improving adherence to and
50 51 52	23	retention in care among adolescents living with HIV, their families, and their healthcare providers
53 54 55 56 57 58	24	in southern Ethiopia.

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Design: A convergent mixed-methods design guided by the process evaluation theoretical framework and the RE-AIM framework was used alongside a randomised controlled trial to examine the fidelity and explore the experiences of participants in the intervention. Setting: Six hospitals and five health centres providing HIV treatment and care to adolescents in five zones in southern Ethiopia. **Participants:** Adolescents (aged 10–19), their families and their healthcare providers. **Intervention:** Mobile phone text messages daily for 6 months or standard care (control). **Results:** 153 participants were enrolled in the process evaluation. Among the 153 enrolled in intervention arm, 78 (49.02%) were male, and 75 (43.8%) were female, respectively. The mean and standard deviation age of the participants is 15(0.21). The overall experiences of implementing

the text messages reminder intervention were described as helpful in terms of treatment support for adherence but had room for improvement. During the study, 30,700 text messages were sent, and fidelity was high, with 99.4% successfully delivered text messages during the intervention. Barriers such as failed text messages delivery, limitations in phone ownership, and technical limitations affected fidelity. Technical challenges can hinder maintenance, but a belief in the future of digital communication permeates the experiences of the text messages reminders.

41 Conclusions: Overall fidelity was high, and participants' overall experiences of mobile phone text
42 messages were expressed as helpful. Contextual factors, such as local telecommunications
43 networks and local electric power, as well as technical and individual factors must be considered
44 when planning future interventions.

45 Trial registration: Pan African Clinical Trials PACTR202107638293593, first registration
46 20/07/2021.

47 Strengths and limitations with this study

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- Secure and confidential delivery of high-volume messages through a 4-digit short code.
- The use of a mixed methods design and the inclusion of family members and healthcare providers is a strength of this process evaluation study.

There was a limited number of adolescents' family and healthcare providers included in the interviews.

INTRODUCTION

Globally, 38.4 million people were living with HIV in 2021. Of these, 1.71 million were adolescents aged 10–19, 88% of whom live in Sub-Saharan Africa (1, 2). To control the epidemic, the Joint United Nations Programme on HIV/AIDS (UNAIDS) launched the 95%-95%-95% targets aimed at HIV testing, treatment, and viral suppression by 2030 (3). However, by 2021, 75% percent of the 38.4 million people living with HIV (PLHIV) were receiving antiretroviral therapy (ART), a treatment gap of 5.9 million people (4). Moreover, achieving the recommended optimal adherence level of >95% which is required for ART to be effective, remains a challenge within the HIV care continuum (5). This poses a significant threat to HIV interventions in resource-limited settings (6).

Poor adherence to ART has several consequences, including increased risk of viral drug resistance and reduced treatment effectiveness toward viral suppression, leading to disease progression, greater risk of death, and increased risk of viral transmission (7). Some of the major barriers to ART adherence include socioeconomic status (8, 9) fear of being stigmatised or discriminated against as a result of one's HIV status,(10) forgetting to take medication on time,(11) treatment fatigue,(12) and patient-provider communication (13). Several interventions to overcome these barriers have been studied in a variety of settings (14). The use of digital health strategies to enhance HIV treatment is one of the priority interventions in Sub-Saharan Africa (15). Targeted Page 5 of 28

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digital client communication using mobile phone-based short text messaging has been recommended for adherence support for a range of health issues and adherence to antiretroviral treatment (16). The success and effectiveness of an mHealth intervention in achieving desired health outcomes is dependent on the context in which they are implemented (15, 16). Context plays a crucial role in either the success or failure of an intervention.

In addition to design and implementation, the success of interventions is diverse and may be influenced by factors such as sociodemographic and culture (17). Observing what is delivered in practice with close reference to the theory of the intervention can help evaluators in distinguishing the intervention fit in different contexts and changes that undermine intervention fidelity (15, 17). Trials should continue to rigorously assess outcomes, but also include integral process evaluations that use qualitative and quantitative data to develop and test hypotheses about how interventions work (18). In a multi-centre trial, a process evaluation is necessary to understand whether the intervention was implemented and received similarly across all sites (9). However, trials assessing mHealth adherence interventions for HIV often do not include process evaluations to examine the fidelity and quality of the intervention delivery, causal mechanisms for the health outcomes, contextual factors affecting the delivery, and costs of implementation (16, 19). Understanding the entire implementation process of an mHealth intervention allows practitioners to interpret the results and replicate the intervention in other contexts (20, 21). Therefore, this study aimed to evaluate the process of a mobile text messaging intervention conducted among adolescents living with HIV in Ethiopia.

91 METHODS

92 Study design

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A convergent mixed-methods design (17) combining quantitative and qualitative techniques was used. The design was guided by the process evaluation theoretical framework (22) and structured by the RE-AIM dimensions (Reach, Effectiveness, Adoption, Implementation and Maintenance) (18) to evaluate intervention effectiveness alongside a randomised controlled trial (RCT) to examine the study's fidelity and to explore the experiences of the participants in the intervention. The trial was registered in Pan African Clinical Trials Registry with the registration number

- PACTR202107638293593 on 17/07/2021.

Study setting and participants

Six hospitals and five health centres that provide HIV treatment and care to adolescents in the Gamo, Gofa, Konso, South Omo, and Wolayita zones in Southern Ethiopia were included in the main study. These zones are home to over 25 distinct ethnic groups, each with its own culture and context. Between July 5, 2022, and February 28, 2023, 306 adolescents living with HIV were included in the study, in either the intervention or in the control group. The quantitative data included process indicators, while the qualitative interviews included ten adolescents from the main trial, four adolescents' families, and two healthcare providers who were involved in the process evaluation. We used the following technique to identify eligible adolescents: first, we identified the number of adolescents of eligible age in each facility. Then, using their address, we called each adolescent and their parents or caregivers directly via phone numbers, care providers, or adherence supports. Then, data collectors approached adolescents and posed literacy questions about their ability to read text by displaying sample texts. Then, eligible participants in the study were asked to give consent and assent. Thus, adolescents aged 10 to 19 years, diagnosed with HIV, currently participating in ART care, and planning to stay in the designated facility for at least six months following study enrolment were eligible. Participants who were above the age limit, did not

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disclose their HIV status, were unable to read text, or had a disability were all excluded. Finally,
the data collector showed each eligible adolescent how to use their mobile device, including text
saving and deletion.

119 Theoretical Framework of Process Evaluation

The RE-AIM framework (18) was used for the process evaluation to comprehensively examine the level of implementation. This involves understanding the implementation of interventions in terms of (1) fidelity, defined as to what extent the intervention was implemented consistently with the underlying theory as planned; (2) delivery, defined as to what extent all of the intended activities, training, and materials were provided to program participants; (3) reach, defined as the absolute number, proportion, and representativeness of individuals who are willing to participate in a given initiative, intervention, or program; (4) receipt, defined as how participants reacted to specific aspects of the intervention; and (5) context, defined as what contextual factors influence implementation or the intervention outcome.

Description of the intervention

The MRC framework,(22) a systematic literature review,(23) interviews with adolescents,(24) and the theoretical health belief model (HBM) (25) were used to develop the intervention. Adolescents living with HIV, healthcare providers, and research project technical advisory team members participated in the design (26) under the guidance of a research advisory committee. The HBM is a theoretical model that has been constructed from six domains: susceptibility, severity, barriers, benefit, cues to action, and self-efficacy. After the intervention's development, text messages were uploaded to the server, and an automated message-pushing software was used to send tailored daily text messages using a four-digit code from Ethiopia Telecom. This code helps adolescents in

avoiding messaging source-related stigma and distinguishing intervention messages from othermessages.

Other various configurations such as wide-area network (WAN) internet protocol (IP), local area network (LAN) IP, Ethio telecom central server IP, a virtual private network (VPN) line, and office servers were used as infrastructure, as required to support the study. The text messages were categorised and delivered based on each adolescent's customised medication schedule and time. The software sent the message 15 minutes before each participant's medication time. The type of message was short and mainly focused on advice about the benefits of taking on time, the risk/consequences of missing/not taking on time, encouragement, and without mentioning anything about HIV or the name of the drug. For example, "Those who use it properly know its benefits", "I'm taking it properly and on time". For example, these messages in Amharic are "心ት的為 የሚጠቀሙት ጥቅሞቹን ያውቃሉ) and በትክክል እና በሰዓት እወስዳለሁ respectively. The server was checked daily to troubleshoot network/cell phone issues. Based on the server information, the first author contacted the facility level care provider to contact the adolescent with corrective actions; for example, subscriber identity module card (SIM card) replacement, damaged mobile phones, and network troubleshooting for maintenance and replacement.

41
42154Sample and data collection

The quantitative data was collected from the server, activity logs, an adverse event monitoring
form, and an interview with adolescents. The researcher collects data on intervention fidelity by
tracking the number of text messages sent, delivered, and failed from the server daily.

Furthermore, each facility representative documented any adverse event related to the trial, filled
the form, and sent it to researchers every week. Furthermore, during the follow-up data collection
phase, adolescents asked if they received text messages on a regular schedule.

A purposive sampling of 10 adolescents with HIV (aged 12–19), four family members/relatives (aged 36–45), and two healthcare providers (aged 31–36) from five different healthcare facilities were asked to be interviewed about their experiences in the intervention between July 5, 2022, and February 28, 2023, at healthcare facilities by the first author. The interviews were conducted in all respondent languages, such as Amharic, Wolaytigna, Gamogna, Gofigna, Arigna, and Konsegna in a quiet and confidential area at the respective health facilities by the first author and one research assistant and lasted on average 30 minutes. All interviews were audio-recorded with the permission of the participants.

An interview guide was used to gain a rich, in-depth understanding, and to allow the participants to concretise their experiences of their use of text messages, communication, and technical aspects of the intervention. The interview guide included subsections adapted to the participants, i.e., adolescents, families, and healthcare providers. Hence, the questions were different, depending on to whom they were addressed. The introductory question to the adolescents was: "Are you receiving the mobile text-message reminder from the hospital?", followed by follow-up questions such as, "What do you think about the messages?" The families were initially asked "How do family/social related factors affect ART adherence among adolescents?" Healthcare providers were asked "How did you experience communication with the adolescents with regard to the intervention?" Follow-up questions and prompts were used throughout the whole interview.

179 The interviews were audiotaped, transcribed verbatim, and translated from Amharic to English by180 the first author, and checked for accuracy by one independent language expert.

0 181 Data analysis

182 The number of SMS messages sent and delivered to participants were tracked as a measure of183 intervention fidelity. When SMS messages did not arrive on the phone, the project advisory team

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investigated the external network and other infrastructure issues. If the message could not be delivered during this period, the computer automatically recorded it as a delivery failure and sent the message again. Data captured on the delivery status of the SMS messages were recorded as: delivered (the phone had reception marked as green); undelivered (the phone was switched off or marked as red in the server). The program could not record whether messages delivered to the phones were opened.

The descriptive statistical analysis was used to summarize data in frequency, percentages, mean and standard deviation. The quantitative effectiveness data is analyzed separately and not included in the process evaluation. The RE-AIM outcomes framework components of Reach, Effectiveness, Adoption, Implementation, and Maintenance were used to present mixed method findings about the delivery of a reminder message, success, and intervention barriers for the intervention implementation process (18).

Interviews were analysed by using the principles for content analysis described by Graneheim and Lundman (19, 27). First, the transcripts were read several times to gain a sense of the whole by the first and the last author. Thereafter, meaning units were identified and condensed to reduce the text while maintaining the core meaning. The first author developed a coding frame for the analysis by using NVivo software, which were discussed by all authors. Condensed meaning units were then labelled with a code, which were kept close to the text on a manifest level. Next, sub-themes were created from the code frame by the first and last authors. The sub-themes were then abstracted into themes. Finally, the underlying meaning—the latent content—was described into a main theme. Thereafter one of the authors (HÅP) read the transcripts, extracted meaning units, codes, and themes. The content was discussed and reflected upon together with all authors and lasted until an agreement was reached.
Representatives of adolescents were involved in the development of messages for the SMS reminders and interview guides. Their feedback was used to adapt its contents and to set strategies to promote inclusivity in study participation during participant recruitment. In addition, participants, healthcare providers, and the participants' families were involved in reporting any

Patient and Public Involvement

212 incidence related to mobile devices and other issues.

RESULTS

The characteristics of adolescents assigned in the intervention arm are shown in table 1.

215 Table 1. Participant characteristics

Characteristics of adolescents assigned in the intervention		
Characteristics		Frequency /Mean (SD)/
Adolescent age, Mean (st	andard deviation (SD))	15(0.21) years
Adolescents age category	10-14	60 (39.22)
	15-19	93 (60.78)
Adolescents gender	Male	78 (49.02)
	Female	75 (43.8)
Languages of adolescent during	Amharic	62 (40.52)
interview	Wolaytigna	27 (17.65)
	Gamogna	39 (25.49)
	Gofigna	13 (8.5)
	Arigna	6 (3.3)
	Konsegna 🗧	6 (3.3)
Educational status of adolescent	Grade 1-8	97 (63.40)
	Grade 9 and above	56 (36.60)
Residence of adolescent	Urban	111(72.55)
	rural	42 (27.45)
Living arrangement	Live alone	10 (6.54)
	Live with family	143 (93.46)
Psycho-social peer-support	Participate	47 (30.72)
	Do not Participate	106 (69.28)
Interviewee characteristics		
	Male (10-14 years)	2
Adolescents (Sex/age)	Female (10-14 years)	3

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	Male (15-19 years)	2
	Female (15-19 years)	3
Adolescents level of education	Grade 1-8	5
	Grade 9 and above	5
healthcare providers (Sex)	Male	1
	Female	1
Parent/care giver (Sex)	Non-biological care	2 (1 male and 1 female)
	giver	
	Biological	2 (1 mother and 1
		father)

216 The results are structured using the RE-AIM framework (18) and corresponding themes (Table 2).

RE-AIM dimension (18)	Definition (18)	Qualitative theme
Reach	The number, proportion, and representativeness of eligible individuals who participate in each initiative.	
Effectiveness	The impact of an intervention on the relevant outcomes, including potential adverse effects, quality	Text message reminders were helpful for adherence but there was room for improvement
	of life, and economic outcomes.	Text messages reminders support adherence
		Feeling comfortable receiving text messages reminders
		The code delivered with text messages reminders minimises the risk of stigma.
Adoption	The reach and effectiveness/efficacy of an intervention at the setting level.	Supporting the text messages reminders
Implementation	The intervention agents' fidelity to the various elements of an intervention's protocol, including	Failing text messages delivery influences medication intake
	consistency of intended delivery.	Limitations in phone ownership
		Technical limitations

Table 2. Overview of the qualitative themes related to the dimensions in the RE-AIM framework.

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	Maintenance	Connects with both setting-level	Seeing potential in SMS services
		indicators (the extent to which a program or a policy becomes part	
		of organisational practices and policies), and individual-level indicators (monitoring of effectiveness of an intervention or program six months or more after	Possibilities of text messages reminders
		the most recent contact).	
218	Reach:		
219	The total number	r of individuals that were assessed for	eligibility was 435, of which 306 (70.34 %)
220	meet eligibility	criteria. The remaining 129 participa	nts excluded for the following reasons: 27
221	(20.9%) were un	able to stay in the study area for the du	uration of the study, 39 (30.2%) were unable
222	to read, 24 (18.6	%) were did not know their status, 21 ((16.3%) were could not reached, 13 (10.1%)
223	refused to partic	ipate, and 5 (3.9%) had an impairmer	nt. Thus, 306 participants were enrolled and
224	randomised: n =	153 in the intervention, and $n = 153$ in	the control group. Among the 153 enrolled
225	in intervention arm, 78 (49.02%) were male, and 75 (43.8%) were female, respectively. The mea		
226	and standard dev	viation age of the participants is 15 ((0.21). Of these, 111 (72.55%) resided in an
227	urban area, 97 (6	53.40%) had primary school level educ	cation, and 10(6.54%) live alone(orphan).
228	Effectiveness:		
229	The number of p	articipants retained in the 6-month fol	llow-up of the intervention group was
230	higher than the c	ontrol group in this study.	
231	Text messages re	eminders were helpful for adherence b	out there was room for improvement
232	The overall expe	riences of the intervention among add	plescents living with HIV was that text
233	messages remind	lers were helpful when it came to thei	r adherence to medication, but direct access
234	to phones and be	etter timing of messages should be ass	ured to increase their functioning and
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usability. The retention rate was improved, and was the best achieved since the intervention was introduced. Despite this, more effort was requested concerning technical issues to make the reminders even more helpful. The participants described facilitating aspects like increased medication intake and communication. Also, the well-being of the adolescents and the support function was highlighted. However, technical problems like lost telephones or text messages reminders arriving after medication time were emphasised as barriers. *Text messages reminders support adherence* They described that before the intervention, their medication was often forgotten, which resulted in it being taken later than it should have been due to forgetfulness. Sometimes the adolescent realised that they had forgotten to take their medication but then waited until dinner to take it. The adolescents described that text messages reminders were associated with taking their medicine and delays were avoided. Also, family members described situations when the adolescent's medication routines were interrupted, and where text messages reminders played a big role. "...Yes, it supports treatment adherence, because most of time we follow the television program but sometimes the power goes off, we missed the exact time to see medication time. Currently this text message comes 10 to 15 minutes before our medication time." (*Father*, aged 45) Feeling positive about the text messages reminder The text messages reminders contributed to positive attitudes and to decreased stigmatisation for adolescents, even when HIV/AIDS stigma is deeply rooted in the culture. Thus, the perception of the adolescents was that the text messages reminders played an important role for their overall well-being, because sometimes they had low moods. The text messages reminders were described

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2 3 4	258	as offering hope and supported the adolescents in achieving consistency in their medication
5 6 7	259	adherence which helped them avoid, for example, fatigue.
8 9	260	"The benefit of this message is it comes always and reminds me to take the drug on
10	261	time. The other benefit is when I receive the message. I feel good." (Adolescent, aged
11 12 12	262	13)
14 15	263	The code-delivered text messages reminders minimise the risk of stigma
16 17 18	264	The adolescent felt safe regarding privacy in the text messages reminders due to a code sent out
19 20	265	to their telephone. The healthcare provider noticed a change in the views of both adolescents and
21 22 23	266	family regarding increased trust and improved engagement with healthcare facilities during the
24 25	267	intervention. Family expressed receiving coded text messages reminders could enable adolescents
26 27 28	268	to live like other HIV-free adolescents. However, the adolescents indicated that after their
20 29 30	269	family's HIV status was made public, they were subjected to stigma, which was reflected in the
31 32	270	interview. Some members of the families were open with their HIV disclosure while others were
33 34 35	271	not.
36	272	"My status has already been made public, and everybody knows about my family as
37	273	well However, my husband lives in another area because of work, and knows his
38	274	HIV status and makes things secret. He did not even take his medication when he come
39 40	275	back home." (Mother, aged 45)
41 42	276	Adoption:
43 44 45	277	In this study, eleven health facilities with 153 participants received an intervention across 5
46 47 48	278	different geographic areas. According to healthcare providers, the rate of retention among
49 50	279	adolescents has increased since the study began in the hospital, as described in the qualitative
51 52 53	280	findings under a sub-theme.
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281	" By the way, in terms of retention, we have observed the best retention rate ever in this year
282	since ART started in this hospital. Of course, our follow-up is there and there are other partners
283	like CDC and ICAP. But this messaging has augmented the service we provide, and it increased
284	our communication with them and helped them remind their medication irrespective of
285	inconsistencies in messaging and medication time; the message delivery reminds them something
286	targeted." (healthcare provider, aged 36)
287	Supporting the text messages reminders
288	The healthcare providers emphasised that text messages reminders were an important support for
289	adolescents in their medication intake to avoid poor adherence. In addition to this, families
290	indicated that they had a mission to support the adolescents in avoiding ART treatment fatigue.
291	Several adolescents expressed that they had received support from their family concerning
292	medication intake during the intervention. Thus, the text messages reminders were perceived as
293	helpful, as they made participants feel happy and hopeful, even if they felt angered or were in a
294	depressed mood that day.
295 296 297 298 299	"The messages may help people pass good days, despite days that do not carry good fortune. It therefore helps people have good days and reminds them of medication times. One day, for example, being consumed with some ideas, I did not recall that I have medication to take; it is this text message that triggered me take my medicine." (Adolescent, aged 19)
300	Implementation:
301	There were 306 mobile phones provided to adolescents during assignments into intervention and
302	control groups. The advisory committee was involved in the implementation of the intervention
303	using standard operational procedure (SOP). During the study, 30,700 SMS text messages were
304	sent to 153 study participants in the intervention group (Figure 1).

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Overall, intervention fidelity was high with (30,510/30,700) or 99.38% successfully delivered SMS text messages during the intervention.

The non-receiving participants in the intervention group were tracked and cross-checked using
individual participant codes from the server, and then approached by each health facility to confirm
whether they were to be followed-up.

Changing phone numbers/SIM cards, phones being damaged, lost, or shared with others were identified as participant-related reasons for not receiving the messages, and were registered in the logbooks, and corrective measures were used either to replace phones with new devices or repair/maintain the phones as soon as was feasible.

314 Failing text message delivery influences medication intake

The adolescents identified several reasons for not receiving messages. In connection with the technical aspect, the adolescents highlighted problems such as not having a charged phone battery or having lost their phone. During the feasibility study period, there was fluctuation in messaging time, and the text message reminders arrived after their medication time. Another issue observed by both healthcare providers and family members was a missing SIM card. Furthermore, the continuity in the text messages reminders was requested by the adolescents to continue the benefits.

> "... the receiving time varies; sometimes I receive it 10 minutes before medication time, which is 3p.m. local time in the evening, and sometimes it arrives after I take the drug." (Adolescent, aged 13)

325 *Limitations in phone ownership*

Sometimes adolescents were not permitted to use the telephone by themselves, due to restrictions from their family, as they thought that the adolescents were too young to use the telephone.

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328	Instead, the family used the telephone, which resulted in text messages reminders never reaching
329	the adolescent. The absence of SIM cards may be because adolescents did not receive a SIM
330	card, or because someone else in the family was using them. The family reported that they passed
331	information from healthcare providers to the adolescents. Some of the families lacked
332	information about the intervention and did not know what to do when the telephone arrived. The
333	healthcare providers emphasised that some families denied the adolescents use of the telephone,
334	which could cause problems, and text messages reminders were not received. Furthermore, the
335	importance of informing families about the intervention was stressed, as several adolescents were
336	restricted from using the telephone.
337	"I think families should be communicated with regarding why their children are
338	provided with mobile phones from the hospital, so as to avoid denial to access or
339	adults using the phones for themselves." (Healthcare provider, aged 36)
340	Technical limitations
341	One major issue stressed by adolescents, families, and healthcare providers, was that the electric
342	power system went off quite often in their communities, which caused problems with receiving
343	text messages reminders if the battery in the telephone was not charged. The adolescents usually
344	did not experience problems with delays in text messages reminders, but they had observed that
345	the text messages reminders did not always arrive on time. The messages could come long before
346	their scheduled medication time or sometimes very close to or after their scheduled medication
347	time. Sometimes the text message reminder was absent for entire days.
348 349 350	"The message helped me a lot to remember my medication time. However, the skips in message delivery dates and untimely arrivals should be corrected so that it is more helpful." (Adolescent, aged 18)
351	Maintenance:

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After initial configuration, a single server can send text messages to thousands of participants across a large geographic area. In this study, a server sent text messages to 153 participants across five different geographic areas. The technical challenges experienced in delivering the intervention were related to navigating the messaging server and feedback responses from the participants. The non-receiving participants in the intervention group were tracked and cross-checked using a four-digit individual participant codes from the server and were then approached by each facility to confirm whether they were indeed in that group or lost. Despite technical barriers, and adverse conditions, and a belief in the future of text messages reminders emerged, which was also expressed in the qualitative interviews.

361 Seeing potential in SMS services

The benefits of SMS reminders were perceived as valuable; especially when adolescents missed appointments for medication refills and virus load tests. Before the intervention, there were difficulties getting in touch with the adolescents, because they lived in rural areas and did not have a telephone. The healthcare providers thought about how to incorporate text messages reminders into routine health care. A wish among the adolescents was expressed that more text messages reminders could be helpful in raising awareness about their condition. Both the adolescents and the healthcare providers raised a need to continue the text message reminders.

> "I think this must continue. The mobile provision has played significant roles in adherence and retention, as many of the adolescents do not have phones...because of this provision, adolescents can be reached directly with health messages and receive important lessons just from their phones." (Adolescent, aged 19)

Possibilities with text messages reminders

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> The healthcare provider described that possibilities to communicate with the adolescents had increased after the intervention, and the adolescents' attitudes towards healthcare facilities had become more positive. The adolescents found the improved digital communication to be an advantage because the healthcare provider no longer needed to call their family but could call them directly.

> > "Previously, healthcare providers from hospital reached me through neighbourhood phone numbers. She now uses this number to reach me directly through the phone provided by the hospital. This is a benefit for my privacy and for the information we discuss over the phone." (Adolescent, aged 18)

383 DISCUSSION

Our process evaluation which was based on the RE-AIM framework (18) showed that intervention fidelity was high with only about 0.6% of the SMS messages not delivered as intended. Both providers and patients described the SMS reminders as being helpful. A few barriers were noted including glitches at telecommunication networks, electric power disruptions, issues with phone ownership at household levels. Our results highlight that SMS message reminders can be delivered with high coverage if proper processes are followed. The 4-digit short code messaging system was a key enabler in ensuring confidentiality and security of the messages. Further scale-up of such interventions will depend on addressing broader systems issues including phone ownership, fixing network interruptions and reliable power sources. However, a study conducted in Philippines showed that intervention fidelity was low (77.9%) in the message group. The identified reason for low intervention fidelity was poor reliability of local telecommunication networks, and frequency of messages received (28). The local context for cellular phone infrastructure and operational challenges, such as multiple users on a single cell phone, has an impact on text messaging interventions (29). It is important to assess the setting before using the SMS intervention as a strategy to improve adherence. There is emerging evidence that mobile phones can play an

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important role in healthcare delivery, especially in resource-limited settings (30). SMS text messaging is a particularly useful application that can be used to collect or share information and to enhance communication between healthcare personnel and patients in a low-cost manner (31). Treatment support was highlighted as an important factor for adolescents to avoid poor adherence. Text messages could be a facilitator for adolescents to remain hopeful and avoid unwanted side effects given that previous research (32, 33) has shown that a lack of support systems was perceived to negatively affect adherence among young people. Our findings provide additional evidence in support of research to identify effective interventions to improve adherence and retention in care for adolescents with HIV and enhance their engagement in these services. Thus, findings of this process evaluation can guide further research towards interventions concerning readiness among healthcare facilities, because settings can impact implementation. Giving importance to the voice of adolescents living with HIV can offer hope to many more in the same situation. This study thereby has a potential clinical impact and contributes to UN Sustainability Goal (34). Methodological concerns/ limitations There are both strengths and limitations identified in this process evaluation. First, the intervention has several strengths, and a key strength is the use of a 4-digit short code for text messages that enables rapid, high-volume outbound messaging, is easy to read and remember, and assists text recipients in identifying the sender based on their preferences for message delivery time, message

content, and messaging language. The use of the unique code can contribute to maintaining security and confidentiality among participants.

Secondly, the messaging server is adaptable and user-friendly, as the researcher or local IT provider can add and remove new data fields to navigate dropped or missed individuals and update SMS text message content to avoid message-related fatigue.

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In addition, the process evaluation also has several strengths that were identified. The first strength is the use of mixed methods, where different forms of data—both quantitative and qualitative methods—are combined to capture the multi-dimensionality of the intervention. The data supplement one another and aid in obtaining a comprehensive picture of the study results, which can contribute to a deeper understanding of the participants' experiences (35). If the participants are given the opportunity to highlight their own individual priorities, it might be possible for us to improve our understanding of the impact of the intervention.

Finally, three different perspectives (adolescents, families, and healthcare providers) were included in the qualitative interviews, which allowed different voices to be heard. However, limited numbers of included participants from adolescents' families and healthcare providers can limit the study's transferability (36). The way research results are presented can be influenced by their nature and outcome, leading to what is known as reporting bias. To minimize outcome reporting bias, the study protocol was pre-registered in the pan-African clinical trials registry. A composite adherence measurement was used, and CONSORT recommendations were followed (37). The fact that adherence data was self-reported by healthcare professionals within the same facilities through interviews may have a significant impact on the study's validity and make it prone to social desirability bias. However, in this study, the primary author conducted the interviews in a separate, private room. Furthermore, providing cell phones to adolescents during recruitment may reduce the likelihood of interview refusal in the intervention phase, causing acquiescence bias.

441 Trustworthiness is the most commonly used criterion for evaluating qualitative content analysis, 442 and it is often expressed using terms such as credibility, conformability, dependability, and 443 transferability (36). To ensure the credibility of the study, an appropriate data collection method 444 needs to be used(38). This study used separate interview questions for adolescents, family, and Page 23 of 28

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professional interviews to explore their experiences and issues with mobile text messaging interventions. In this study, the five-dimension components of the RE-AIM framework were used to collect information about the intervention setting, implementation, personnel and circumstances, and findings by considering individual level and external context challenges(18). To ensure the dependability of the study, an interview guide adapted to the participants, and audio-recorded was used. For the confirmability of this study, the first author transcribed the audio data to verbatim text and translated from Amharic to English by considering both manifest and latent content. Then, all authors involved in reading the transcripts, extracted meaning units, codes, and data analysis.

Finally, the authors previous qualitative research experiences and knowledge, as well as a bracketing technique were used to increase the trustworthiness of their findings. Accordingly, the primary author maintained a positive relationship with participants during intervention follow-ups and established independence from caregiving facilities to minimize social desirability bias and boss views. To reduce bias and subjective interpretation, interviews were audio recorded, transcribed, and thoroughly evaluated, with participant quotes used to support the authors' findings.

459 Conclusion

The mobile phone text messaging intervention to support ART adherence and retention in care was well-received by participants, and overall intervention fidelity was high. However, the intervention's feasibility was dependent on the reliability of local telecommunication networks, local electric power, and monitoring of adolescents' families, all of which had a significant impact on the intervention's usability, fidelity, and doses received. The participants experienced the text messaging function as helpful, therefore the development of different aspects, such as addressing technical problems, would be desirable to further improve impact. Further research needs to be

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467	directed toward readiness within the healthcare facilities to capture an increased understanding of
468	barriers and facilitators in implementation.
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478	Contributors
479	AT, DJ, and IKH conceptualized and developed the study design. AT collected the data and
480	transcribed verbatim and translated from Amharic to English. DJ and IKH supervised data
481	collection and study implementation. All authors read the transcripts, extracted meaning units,
482	codes, and data analysis. Sub-themes were created from the code frame by the first and last authors.
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Competing interests
None declared.
Patient and public involvement
Patient consent for publication
Not applicable.
Ethics approval
The study was conducted according to the guidelines in the Declaration of Helsinki (39) and
approved by the Swedish Regional Ethical Review Board (Dnr 2019-03433), National Research
Ethics Review Committee in Ethiopia (MoSHE/RD/142/2869/20), and the Institutional Research
Ethics Review Board in Arba Minch University (IRB-113/11). The participants received both oral
and written information about the purpose of the study, about the confidential treatment of the data
and the voluntary nature of participation. Informed consent was provided from all participants over
the age of 18 before the study began. Similarly, parental consent and adolescent assent were
obtained from all participants under the age of 18 before the start of the trial.
Provenance and peer review
Not commissioned, externally peer reviewed.
Data availability statement
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No datasets were generated or analysed during the current study. All relevant data from this study will be made available upon reasonable written request and in accordance with ethical approval,

from the corresponding author.

- Supplemental material

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Figure 1. The flow diagram of mobile phone text messaging reminder in the intervention group

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Intervention fidelity and factors affecting the process of implementing a mobile phone text messaging intervention among adolescents living with HIV: a convergent mixed methods study in southern Ethiopia

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4 5	2	messaging intervention among adolescents living with HIV: a convergent mixed methods		
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41 42	19	221 00 Lund, Sweden		
43 44 45	20	Abstract		
46 47	21	Objective: To assess the intervention fidelity and explore contextual factors affecting the process		
48 49	22	of implementing a mobile phone text messaging intervention in improving adherence to and		
50 51 52	23	retention in care among adolescents living with HIV, their families, and their healthcare providers		
53 54 55 56 57 58	24	in southern Ethiopia.		

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3 4	25	Design: A convergent mixed-methods design guided by the process evaluation theoretical
5 6	26	framework and the RE-AIM framework was used alongside a randomised controlled trial to
/ 8 9	27	examine the fidelity and explore the experiences of participants in the intervention.
10 11 12	28	Setting: Six hospitals and five health centres providing HIV treatment and care to adolescents in
13 14	29	five zones in southern Ethiopia.
15 16 17	30	Participants: Adolescents (aged 10–19), their families and their healthcare providers.
17 18 19	31	Intervention: Mobile phone text messages daily for 6 months or standard care (control).
20 21	32	Results: 153 participants were enrolled in the process evaluation. Among the 153 enrolled in
22 23	33	intervention arm, 78 (49.02%) were male, and 75 (43.8%) were female, respectively. The mean
24 25 26	34	and standard deviation age of the participants is 15 (0.21). The overall experiences of implementing
20 27 28	35	the text messages reminder intervention were described as helpful in terms of treatment support for
29 30	36	adherence but had room for improvement. During the study, 30,700 text messages were sent, and
31 32	37	fidelity was high, with 99.4% successfully delivered text messages during the intervention. Barriers
33 34 35	38	such as failed text messages delivery, limitations in phone ownership, and technical limitations
36 37	39	affected fidelity. Technical challenges can hinder maintenance, but a belief in the future of digital
38 39	40	communication permeates the experiences of the text messages reminders.
40 41 42 43	41	Conclusions: Overall fidelity was high, and participants' overall experiences of mobile phone text

messages were expressed as helpful. Contextual factors, such as local telecommunications
networks and local electric power, as well as technical and individual factors must be considered
when planning future interventions.

45 Trial registration: Pan African Clinical Trials PACTR202107638293593, first registration
46 20/07/2021.

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Strengths and limitations with this study

- Secure and confidential delivery of high-volume messages through a 4-digit short code.
 - The use of a mixed methods design and the inclusion of family members and healthcare providers is a strength of this process evaluation study.
 - There was a limited number of adolescents' family and healthcare providers included in the interviews.

INTRODUCTION

Globally, 38.4 million people were living with HIV in 2021. Of these, 1.71 million were adolescents aged 10–19, 88% of whom live in Sub-Saharan Africa (1, 2). To control the epidemic, the Joint United Nations Programme on HIV/AIDS (UNAIDS) launched the 95%-95%-95% targets aimed at HIV testing, treatment, and viral suppression by 2030 (3). However, by 2021, 75% percent of the 38.4 million people living with HIV (PLHIV) were receiving antiretroviral therapy (ART), a treatment gap of 5.9 million people (4). Moreover, achieving the recommended optimal adherence level of >95% which is required for ART to be effective, remains a challenge within the HIV care continuum (5). This poses a significant threat to HIV interventions in resource-limited settings (6).

Poor adherence to ART has several consequences, including increased risk of viral drug resistance and reduced treatment effectiveness toward viral suppression, leading to disease progression, greater risk of death, and increased risk of viral transmission (7). Some of the major barriers to ART adherence include socioeconomic status (8, 9) fear of being stigmatised or discriminated against as a result of one's HIV status,(10) forgetting to take medication on time,(11) treatment fatigue,(12) and patient-provider communication (13). Several interventions to overcome these barriers have been studied in a variety of settings (14). The use of digital health strategies to enhance HIV treatment is one of the priority interventions in Sub-Saharan Africa (15). Targeted Page 5 of 30

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digital client communication using mobile phone-based short text messaging has been recommended for adherence support for a range of health issues and adherence to antiretroviral treatment (16). The success and effectiveness of an mHealth intervention in achieving desired health outcomes is dependent on the context in which they are implemented (15, 16). Context plays a crucial role in either the success or failure of an intervention.

In addition to design and implementation, the success of interventions is diverse and may be influenced by factors such as sociodemographic and culture (17). Observing what is delivered in practice with close reference to the theory of the intervention can help evaluators in distinguishing the intervention fit in different contexts and changes that undermine intervention fidelity (15, 17). Trials should continue to rigorously assess outcomes, but also include integral process evaluations that use qualitative and quantitative data to develop and test hypotheses about how interventions work (18). In a multi-centre trial, a process evaluation is necessary to understand whether the intervention was implemented and received similarly across all sites (9). However, trials assessing mHealth adherence interventions for HIV often do not include process evaluations to examine the fidelity and quality of the intervention delivery, causal mechanisms for the health outcomes, contextual factors affecting the delivery, and costs of implementation (16, 19). Understanding the entire implementation process of an mHealth intervention allows practitioners to interpret the results and replicate the intervention in other contexts (20, 21). Therefore, this study aimed to evaluate the process of a mobile text messaging intervention conducted among adolescents living with HIV in Ethiopia.

91 METHODS

92 Study design

BMJ Open: first published as 10.1136/bmjopen-2023-077128 on 3 July 2024. Downloaded from http://bmjopen.bmj.com/ on June 13, 2025 at Agence Bibliographique de l Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.

A convergent mixed-methods design (17) combining quantitative and qualitative techniques was used. The design was guided by the process evaluation theoretical framework (22) and structured by the RE-AIM dimensions (Reach, Effectiveness, Adoption, Implementation and Maintenance) (18) to evaluate intervention effectiveness alongside a randomised controlled trial (RCT) to examine the study's fidelity and to explore the experiences of the participants in the intervention. The trial was registered in Pan African Clinical Trials Registry with the registration number

- PACTR202107638293593 on 17/07/2021.

Study setting and participants

Six hospitals and five health centres that provide HIV treatment and care to adolescents in the Gamo, Gofa, Konso, South Omo, and Wolayita zones in Southern Ethiopia were included in the main study. These zones are home to over 25 distinct ethnic groups, each with its own culture and context. Between July 5, 2022, and February 28, 2023, 306 adolescents living with HIV were included in the study, in either the intervention or in the control group. The quantitative data included process indicators, while the qualitative interviews included ten adolescents from the main trial, four adolescents' families, and two healthcare providers who were involved in the process evaluation. We used the following technique to identify eligible adolescents: first, we identified the number of adolescents of eligible age in each facility. Then, using their address, we called each adolescent and their parents or caregivers directly via phone numbers, care providers, or adherence supports. Then, data collectors approached adolescents and posed literacy questions about their ability to read text by displaying sample texts. Then, eligible participants in the study were asked to give consent and assent. Thus, adolescents aged 10 to 19 years, diagnosed with HIV, currently participating in ART care, and planning to stay in the designated facility for at least six months following study enrolment were eligible. Participants who were above the age limit, did not

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disclose their HIV status, were unable to read text, or had a disability were all excluded. Finally, the data collector showed each eligible adolescent how to use their mobile device, including text saving and deletion.

119 Theoretical Framework of Process Evaluation

The RE-AIM framework (18) was used for the process evaluation to comprehensively examine the level of implementation. This involves understanding the implementation of interventions in terms of (1) fidelity, defined as to what extent the intervention was implemented consistently with the underlying theory as planned; (2) delivery, defined as to what extent all of the intended activities, training, and materials were provided to program participants; (3) reach, defined as the absolute number, proportion, and representativeness of individuals who are willing to participate in a given initiative, intervention, or program; (4) receipt, defined as how participants reacted to specific aspects of the intervention; and (5) context, defined as what contextual factors influence implementation or the intervention outcome.

Description of the intervention

The MRC framework,(22) a systematic literature review,(23) interviews with adolescents,(24) and the theoretical health belief model (HBM) (25) were used to develop the intervention. Adolescents living with HIV, healthcare providers, and research project technical advisory team members participated in the design (26) under the guidance of a research advisory committee. The HBM is a theoretical model that has been constructed from six domains: susceptibility, severity, barriers, benefit, cues to action, and self-efficacy. After the intervention's development, text messages were uploaded to the server, and an automated message-pushing software was used to send tailored daily text messages using a four-digit code from Ethiopia Telecom. This code helps adolescents in

avoiding messaging source-related stigma and distinguishing intervention messages from other

139 messages.

Other various configurations such as wide-area network (WAN) internet protocol (IP), local area network (LAN) IP, Ethio telecom central server IP, a virtual private network (VPN) line, and office servers were used as infrastructure, as required to support the study. The text messages were categorised and delivered based on each adolescent's customised medication schedule and time. The software sent the message 15 minutes before each participant's medication time. The type of message was short and mainly focused on advice about the benefits of taking on time, the risk/consequences of missing/not taking on time, encouragement, and without mentioning anything about HIV or the name of the drug. For example, "Those who use it properly know its benefits", "I'm taking it properly and on time". For example, these messages in Amharic are "心ት的為 የሚጠቀሙት ጥቅሞቹን ያውቃሉ) and በትክክል እና በሰዓት እወስዳለሁ respectively. The server was checked daily to troubleshoot network/cell phone issues. Based on the server information, the first author contacted the facility level care provider to contact the adolescent with corrective actions; for example, subscriber identity module card (SIM card) replacement, damaged mobile phones, and network troubleshooting for maintenance and replacement.

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42154Sample and data collection

The quantitative data was collected from the server, activity logs, an adverse event monitoring
form, and an interview with adolescents. The researcher collects data on intervention fidelity by
tracking the number of text messages sent, delivered, and failed from the server daily.

Furthermore, each facility representative documented any adverse event related to the trial, filled
the form, and sent it to researchers every week. Furthermore, during the follow-up data collection
phase, adolescents asked if they received text messages on a regular schedule.

A purposive sampling of 10 adolescents with HIV (aged 12–19), four family members/relatives (aged 36–45), and two healthcare providers (aged 31–36) from five different healthcare facilities were asked to be interviewed about their experiences in the intervention between July 5, 2022, and February 28, 2023, at healthcare facilities by the first author. The interviews were conducted in all respondent languages, such as Amharic, Wolaytigna, Gamogna, Gofigna, Arigna, and Konsegna in a quiet and confidential area at the respective health facilities by the first author and one research assistant and lasted on average 30 minutes. All interviews were audio-recorded with the permission of the participants.

An interview guide was used to gain a rich, in-depth understanding, and to allow the participants to concretise their experiences of their use of text messages, communication, and technical aspects of the intervention. The interview guide included subsections adapted to the participants, i.e., adolescents, families, and healthcare providers (interview guide attached as supplement file). Hence, the questions were different, depending on to whom they were addressed. The introductory question to the adolescents was: "Are you receiving the mobile text-message reminder from the hospital?", followed by follow-up questions such as, "What do you think about the messages?" The families were initially asked "How do family/social related factors affect ART adherence among adolescents?" Healthcare providers were asked "How did you experience communication with the adolescents with regard to the intervention?" Follow-up questions and prompts were used throughout the whole interview.

180 The interviews were audiotaped, transcribed verbatim, and translated from Amharic to English by
 181 the first author, and checked for accuracy by one independent language expert.

182 Data analysis

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The number of SMS messages sent and delivered to participants were tracked as a measure of intervention fidelity. When SMS messages did not arrive on the phone, the project advisory team investigated the external network and other infrastructure issues. If the message could not be delivered during this period, the computer automatically recorded it as a delivery failure and sent the message again. Data captured on the delivery status of the SMS messages were recorded as: delivered (the phone had reception marked as green); undelivered (the phone was switched off or marked as red in the server). The program could not record whether messages delivered to the phones were opened.

191 The descriptive statistical analysis was used to summarize data in frequency, percentages, mean 192 and standard deviation. The quantitative effectiveness data is analyzed separately and not included 193 in the process evaluation. The RE-AIM outcomes framework components of Reach, Effectiveness, 194 Adoption, Implementation, and Maintenance were used to present mixed method findings about 195 the delivery of a reminder message, success, and intervention barriers for the intervention 196 implementation process (18).

Interviews were analysed by using the principles for content analysis described by Graneheim and Lundman (19, 27). First, the transcripts were read several times to gain a sense of the whole by the first and the last author. Thereafter, meaning units were identified and condensed to reduce the text while maintaining the core meaning. The first author developed a coding frame for the analysis by using NVivo software, which were discussed by all authors. Condensed meaning units were then labelled with a code, which were kept close to the text on a manifest level. Next, sub-themes were created from the code frame by the first and last authors. The sub-themes were then abstracted into themes. Finally, the underlying meaning—the latent content—was described into a main theme. Thereafter one of the authors (HÅP) read the transcripts, extracted meaning units, codes, and

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themes. The content was discussed and reflected upon together with all authors and lasted until an 206 agreement was reached. 207 **Patient and Public Involvement** 208 Representatives of adolescents were involved in the development of messages for the SMS 209 reminders and interview guides. Their feedback was used to adapt its contents and to set strategies 210 to promote inclusivity in study participation during participant recruitment. In addition, 211 participants, healthcare providers, and the participants' families were involved in reporting any 212 incidence related to mobile devices and other issues. 213 RESULTS 214 The characteristics of adolescents assigned in the intervention arm are shown in table 1. 215 Table 1. Participant characteristics 216 Characteristics of adolescents assigned in the intervention Frequency /Mean (SD)/ Characteristics Percent Adolescent age, Mean (standard deviation (SD)) 15(0.21) years Adolescents age category 10-14 60 (39.22) 15-19 93 (60.78) Adolescents gender Male 78 (49.02) Female 75 (43.8) Languages of adolescent during Amharic 62 (40.52) interview Wolaytigna 27 (17.65) 39 (25.49) Gamogna Gofigna 13 (8.5) Arigna 6 (3.3) $\overline{6}(3.3)$ Konsegna Educational status of adolescent Grade 1-8 97 (63.40) Grade 9 and above 56 (36.60) Residence of adolescent 111(72.55) Urban rural 42 (27.45) Live alone 10 (6.54) Living arrangement Live with family 143 (93.46) Psycho-social peer-support Participate 47 (30.72)

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	Do not Participate	106 (69.28)
Interviewee characteristics		
	Male (10-14 years)	2
Adolescents (Sex/age)	Female (10-14 years)	3
	Male (15-19 years)	2
	Female (15-19 years)	3
Adolescents level of education	Grade 1-8	5
	Grade 9 and above	5
healthcare providers (Sex)	Male	1
	Female	1
Parent/care giver (Sex)	Non-biological care	2 (1 male and 1 fe
	giver	
	Biological	2 (1 mother and 1
		father)

Table 2. Overview of the qualitative themes related to the dimensions in the RE-AIM framework.

RE-AIM dimension (18)	Definition (18)	Qualitative theme
Reach	The number, proportion, and representativeness of eligible individuals who participate in each initiative.	•
Effectiveness	The impact of an intervention on the relevant outcomes, including potential adverse effects, quality	Text message reminders were helpful for adherence but there was room for improvement
	of life, and economic outcomes.	Text messages reminders support adherence
		Feeling comfortable receiving text messages reminders
		The code delivered with text messages reminders minimises the risk of stigma.
Adoption	The reach and effectiveness/efficacy of an intervention at the setting level.	Supporting the text messages reminders
Implementation	The intervention agents' fidelity to the various elements of an intervention's protocol, including	Failing text messages delivery influences medication intake
	consistency of intended delivery.	Limitations in phone ownership

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		Technical limitations
Maintenance	Connects with both setting-level indicators (the extent to which a program or a policy becomes part	Seeing potential in SMS services
	policies), and individual-level indicators (monitoring of effectiveness of an intervention or	Possibilities of text messages reminders
	the most recent contact).	

219 Reach:

The total number of individuals that were assessed for eligibility was 435, of which 306 (70.34 %) 220 meet eligibility criteria. The remaining 129 participants excluded for the following reasons: 27 221 (20.9%) were unable to stay in the study area for the duration of the study, 39 (30.2%) were unable 222 223 to read, 24 (18.6%) were did not know their status, 21 (16.3%) were could not reached, 13 (10.1%) refused to participate, and 5 (3.9%) had an impairment. Thus, 306 participants were enrolled and 224 randomised: n = 153 in the intervention, and n = 153 in the control group. Among the 153 enrolled 225 226 in intervention arm, 78 (49.02%) were male, and 75 (43.8%) were female, respectively. The mean 227 and standard deviation age of the participants is 15 (0.21). Of these, 111 (72.55%) resided in an 228 urban area, 97 (63.40%) had primary school level education, and 10(6.54%) live alone(orphan).

229 Effectiveness:

The overall rate of retention at six months in the intervention group was 152/153 (99.4%), while
in the control group was 151/153 (98.69%).

232 *Text messages reminders were helpful for adherence but there was room for improvement.*

The overall experiences of the intervention among adolescents living with HIV was that text

234 messages reminders were helpful when it came to their adherence to medication, but direct access

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to phones and better timing of messages should be assured to increase their functioning and usability. The adherence was improved, and was the best achieved since the intervention was introduced. After six months of follow-up, the intervention group had a higher rate (114/152, 75%) than the control group (77/151, 51%). Despite this, more effort was requested concerning technical issues to make the reminders even more helpful. The participants described facilitating aspects like increased medication intake and communication. Also, the well-being of the adolescents and the support function was highlighted. However, technical problems like lost telephones or text messages reminders arriving after medication time were emphasised as barriers. Text messages reminders support adherence They described that before the intervention, their medication was often forgotten, which resulted in it being taken later than it should have been due to forgetfulness. Sometimes the adolescent realised that they had forgotten to take their medication but then waited until dinner to take it. The adolescents described that text messages reminders were associated with taking their medicine and delays were avoided. Also, family members described situations when the adolescent's medication routines were interrupted, and where text messages reminders played a big role. "...Yes, it supports treatment adherence, because most of time we follow the television program but sometimes the power goes off, we missed the exact time to see medication time. Currently this text message comes 10 to 15 minutes before our medication time." (Father, aged 45)

Feeling positive about the text messages reminder

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The text messages reminders contributed to positive attitudes and to decreased stigmatisation for adolescents, even when HIV/AIDS stigma is deeply rooted in the culture. Thus, the perception of the adolescents was that the text messages reminders played an important role for their overall well-being, because sometimes they had low moods. The text messages reminders were described as offering hope and supported the adolescents in achieving consistency in their medication adherence which helped them avoid, for example, fatigue. "...The benefit of this message is it comes always and reminds me to take the drug on time. The other benefit is when I receive the message, I feel good." (Adolescent, aged 13) The code-delivered text messages reminders minimise the risk of stigma The adolescent felt safe regarding privacy in the text messages reminders due to a code sent out to their telephone. The healthcare provider noticed a change in the views of both adolescents and family regarding increased trust and improved engagement with healthcare facilities during the intervention. Family expressed receiving coded text messages reminders could enable adolescents to live like other HIV-free adolescents. However, the adolescents indicated that after their family's HIV status was made public, they were subjected to stigma, which was reflected in the interview. Some members of the families were open with their HIV disclosure while others were not. "My status has already been made public, and everybody knows about my family as well ... However, my husband lives in another area because of work, and knows his HIV status and makes things secret. He did not even take his medication when he come back home." (Mother, aged 45) **Adoption:** In this study, eleven health facilities with 153 participants received an intervention across 5 different geographic areas. According to healthcare providers, the rate of retention among

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> adolescents has increased since the study began in the hospital, as described in the qualitative findings under a sub-theme. ".... By the way, in terms of retention, we have observed the best retention rate ever in this year since ART started in this hospital. Of course, our follow-up is there and there are other partners like CDC and ICAP. But this messaging has augmented the service we provide, and it increased our communication with them and helped them remind their medication irrespective of inconsistencies in messaging and medication time; the message delivery reminds them something targeted." (healthcare provider, aged 36) Supporting the text messages reminders The healthcare providers emphasised that text messages reminders were an important support for adolescents in their medication intake to avoid poor adherence. In addition to this, families indicated that they had a mission to support the adolescents in avoiding ART treatment fatigue. Several adolescents expressed that they had received support from their family concerning medication intake during the intervention. Thus, the text messages reminders were perceived as helpful, as they made participants feel happy and hopeful, even if they felt angered or were in a depressed mood that day. "...The messages may help people pass good days, despite days that do not carry good fortune. It therefore helps people have good days and reminds them of medication times. One day, for example, being consumed with some ideas, I did not recall that I have medication to take; it is this text message that triggered me take my medicine." (Adolescent, aged 19) **Implementation:** There were 306 mobile phones provided to adolescents during assignments into intervention and control groups. The advisory committee was involved in the implementation of the intervention
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using standard operational procedure (SOP). During the study, 30,700 SMS text messages were 06 sent to 153 study participants in the intervention group (Figure 1). 07 Overall, intervention fidelity was high with (30,510/30,700) or 99.38% successfully delivered SMS 80 text messages during the intervention. 09 The non-receiving participants in the intervention group were tracked and cross-checked using 10 individual participant codes from the server, and then approached by each health facility to confirm 11 whether they were to be followed-up. 12 Changing phone numbers/SIM cards, phones being damaged, lost, or shared with others were 13 identified as participant-related reasons for not receiving the messages, and were registered in the 14 logbooks, and corrective measures were used either to replace phones with new devices or 15 16 repair/maintain the phones as soon as was feasible. Failing text message delivery influences medication intake 17 The adolescents identified several reasons for not receiving messages. In connection with the 18 technical aspect, the adolescents highlighted problems such as not having a charged phone 19 battery or having lost their phone. During the feasibility study period, there was fluctuation in 20 21 messaging time, and the text message reminders arrived after their medication time. Another 22 issue observed by both healthcare providers and family members was a missing SIM card. 23 Furthermore, the continuity in the text messages reminders was requested by the adolescents to 24 continue the benefits. 25 "... the receiving time varies; sometimes I receive it 10 minutes before medication time, which is 3p.m. local time in the evening, and sometimes it arrives after I take the 26 drug." (Adolescent, aged 13) 27 28 *Limitations in phone ownership* 16

329	Sometimes adolescents were not permitted to use the telephone by themselves, due to restrictions
330	from their family, as they thought that the adolescents were too young to use the telephone.
331	Instead, the family used the telephone, which resulted in text messages reminders never reaching
332	the adolescent. The absence of SIM cards may be because adolescents did not receive a SIM
333	card, or because someone else in the family was using them. The family reported that they passed
334	information from healthcare providers to the adolescents. Some of the families lacked
335	information about the intervention and did not know what to do when the telephone arrived. The
336	healthcare providers emphasised that some families denied the adolescents use of the telephone,
337	which could cause problems, and text messages reminders were not received. Furthermore, the
338	importance of informing families about the intervention was stressed, as several adolescents were
339	restricted from using the telephone.
340	"I think families should be communicated with regarding why their children are
341	provided with mobile phones from the hospital, so as to avoid denial to access or
342	adults using the phones for themselves." (Healthcare provider, aged 36)
343	Technical limitations
344	One major issue stressed by adolescents, families, and healthcare providers, was that the electric
245	normen another mont off mits often in their communities which could be him with monitoin-

power system went off quite often in their communities, which caused problems with receiving text messages reminders if the battery in the telephone was not charged. The adolescents usually did not experience problems with delays in text messages reminders, but they had observed that the text messages reminders did not always arrive on time. The messages could come long before their scheduled medication time or sometimes very close to or after their scheduled medication time. Sometimes the text message reminder was absent for entire days.

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Maintenance:

"... The message helped me a lot to remember my medication time. However, the skips in message delivery dates and untimely arrivals should be corrected so that it is more helpful." (Adolescent, aged 18)

After initial configuration, a single server can send text messages to thousands of participants across a large geographic area. In this study, a server sent text messages to 153 participants across five different geographic areas. The technical challenges experienced in delivering the intervention were related to navigating the messaging server and feedback responses from the participants. The non-receiving participants in the intervention group were tracked and cross-checked using a four-digit individual participant codes from the server and were then approached by each facility to confirm whether they were indeed in that group or lost. Despite technical barriers, and adverse conditions, and a belief in the future of text messages reminders emerged, which was also expressed in the qualitative interviews. 24.5

Seeing potential in SMS services

The benefits of SMS reminders were perceived as valuable; especially when adolescents missed appointments for medication refills and virus load tests. Before the intervention, there were difficulties getting in touch with the adolescents, because they lived in rural areas and did not have a telephone. The healthcare providers thought about how to incorporate text messages reminders into routine health care. A wish among the adolescents was expressed that more text messages reminders could be helpful in raising awareness about their condition. Both the adolescents and the healthcare providers raised a need to continue the text message reminders.

> "I think this must continue. The mobile provision has played significant roles in adherence and retention, as many of the adolescents do not have phones...because of this provision, adolescents can be reached directly with health messages and receive important lessons just from their phones." (Adolescent, aged 19)

376 Possibilities with text messages reminders

The healthcare provider described that possibilities to communicate with the adolescents had increased after the intervention, and the adolescents' attitudes towards healthcare facilities had become more positive. The adolescents found the improved digital communication to be an advantage because the healthcare provider no longer needed to call their family but could call them directly.

> "Previously, healthcare providers from hospital reached me through neighbourhood phone numbers. She now uses this number to reach me directly through the phone provided by the hospital. This is a benefit for my privacy and for the information we discuss over the phone." (Adolescent, aged 18)

386 DISCUSSION

Our process evaluation which was based on the RE-AIM framework (18) showed that intervention fidelity was high with only about 0.6% of the SMS messages not delivered as intended. Both providers and patients described the SMS reminders as being helpful. A few barriers were noted including glitches at telecommunication networks, electric power disruptions, issues with phone ownership at household levels. Our results highlight that SMS message reminders can be delivered with high coverage if proper processes are followed. The 4-digit short code messaging system was a key enabler in ensuring confidentiality and security of the messages. Further scale-up of such interventions will depend on addressing broader systems issues including phone ownership, fixing network interruptions and reliable power sources. However, a study conducted in Philippines showed that intervention fidelity was low (77.9%) in the message group. The identified reason for low intervention fidelity was poor reliability of local telecommunication networks, and frequency of messages received (28). The local context for cellular phone infrastructure and operational challenges, such as multiple users on a single cell phone, has an impact on text messaging

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interventions (29). It is important to assess the setting before using the SMS intervention as a strategy to improve adherence. There is emerging evidence that mobile phones can play an important role in healthcare delivery, especially in resource-limited settings (30). SMS text messaging is a particularly useful application that can be used to collect or share information and to enhance communication between healthcare personnel and patients in a low-cost manner (31). Treatment support was highlighted as an important factor for adolescents to avoid poor adherence. Text messages could be a facilitator for adolescents to remain hopeful and avoid unwanted side effects given that previous research (32, 33) has shown that a lack of support systems was perceived to negatively affect adherence among young people. Our findings provide additional evidence in support of research to identify effective interventions to improve adherence and retention in care for adolescents with HIV and enhance their engagement in these services. Thus, findings of this process evaluation can guide further research towards interventions concerning readiness among healthcare facilities, because settings can impact implementation. Giving importance to the voice of adolescents living with HIV can offer hope to many more in the same situation. This study thereby has a potential clinical impact and contributes to UN Sustainability Goal (34).

415 Methodological concerns/ limitations

There are both strengths and limitations identified in this process evaluation. First, the intervention has several strengths, and a key strength is the use of a 4-digit short code for text messages that enables rapid, high-volume outbound messaging, is easy to read and remember, and assists text recipients in identifying the sender based on their preferences for message delivery time, message content, and messaging language. The use of the unique code can contribute to maintaining security and confidentiality among participants.

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> 422 Secondly, the messaging server is adaptable and user-friendly, as the researcher or local IT provider 423 can add and remove new data fields to navigate dropped or missed individuals and update SMS 424 text message content to avoid message-related fatigue.

In addition, the process evaluation also has several strengths that were identified. The first strength is the use of mixed methods, where different forms of data—both quantitative and qualitative methods—are combined to capture the multi-dimensionality of the intervention. The data supplement one another and aid in obtaining a comprehensive picture of the study results, which can contribute to a deeper understanding of the participants' experiences (35). If the participants are given the opportunity to highlight their own individual priorities, it might be possible for us to improve our understanding of the intervention.

Finally, three different perspectives (adolescents, families, and healthcare providers) were included in the qualitative interviews, which allowed different voices to be heard. However, limited numbers of included participants from adolescents' families and healthcare providers can limit the study's transferability (36). The way research results are presented can be influenced by their nature and outcome, leading to what is known as reporting bias. To minimize outcome reporting bias, the study protocol was pre-registered in the pan-African clinical trials registry. A composite adherence measurement was used, and CONSORT recommendations were followed (37). The fact that adherence data was self-reported by healthcare professionals within the same facilities through interviews may have a significant impact on the study's validity and make it prone to social desirability bias. However, in this study, the primary author conducted the interviews in a separate, private room. Furthermore, providing cell phones to adolescents during recruitment may reduce the likelihood of interview refusal in the intervention phase, causing acquiescence bias.

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Trustworthiness is the most commonly used criterion for evaluating qualitative content analysis. and it is often expressed using terms such as credibility, conformability, dependability, and transferability (36). To ensure the credibility of the study, an appropriate data collection method needs to be used(38). This study used separate interview questions for adolescents, family, and professional interviews to explore their experiences and issues with mobile text messaging interventions. In this study, the five-dimension components of the RE-AIM framework were used to collect information about the intervention setting, implementation, personnel and circumstances, and findings by considering individual level and external context challenges(18). To ensure the dependability of the study, an interview guide adapted to the participants, and audio-recorded was used. For the confirmability of this study, the first author transcribed the audio data to verbatim text and translated from Amharic to English by considering both manifest and latent content. Then, all authors involved in reading the transcripts, extracted meaning units, codes, and data analysis.

Finally, the authors previous qualitative research experiences and knowledge, as well as a bracketing technique were used to increase the trustworthiness of their findings. Accordingly, the primary author maintained a positive relationship with participants during intervention follow-ups and established independence from caregiving facilities to minimize social desirability bias and boss views. To reduce bias and subjective interpretation, interviews were audio recorded, transcribed, and thoroughly evaluated, with participant quotes used to support the authors' findings.

462 Conclusion

The mobile phone text messaging intervention to support ART adherence and retention in care was
well-received by participants, and overall intervention fidelity was high. However, the
intervention's feasibility was dependent on the reliability of local telecommunication networks,
local electric power, and monitoring of adolescents' families, all of which had a significant impact

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on the intervention's usability, fidelity, and doses received. The participants experienced the text
messaging function as helpful, therefore the development of different aspects, such as addressing
technical problems, would be desirable to further improve impact. Further research needs to be
directed toward readiness within the healthcare facilities to capture an increased understanding of
barriers and facilitators in implementation.

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Contributors

AT, DJ, and IKH conceptualized and developed the study design. AT collected the data and
transcribed verbatim and translated from Amharic to English. DJ and IKH supervised data
collection and study implementation. All authors read the transcripts, extracted meaning units,
codes, and data analysis. Sub-themes were created from the code frame by the first and last authors.
AT and HÅP drafted the manuscript, and all authors contributed to critical revision and approved
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2 3 4	510	Provenance and peer review Not commissioned, externally peer reviewed.							
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12 13	513	Extra data can be accessed via the Dryad data repository at							
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17 18 19	515	Supplemental material							
20 21 22	516	Semi-structured interview guide was attached Open access							
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Mehra N, Tunje A, Hallström IK, Jerene D. Effectiveness of mobile phone text message reminder 23. interventions to improve adherence to antiretroviral therapy among adolescents living with HIV: A systematic review and meta-analysis. Plos one. 2021;16(7):e0254890. Tunje A, Jerene D, Kristensson Hallström I. Antiretroviral Therapy and Retention in Care 24. Experiences and Needs of Adolescents Living with HIV in Southern Ethiopia. HIV/AIDS-Research and Palliative Care. 2021:999-1007. McPherson AC, Gofine ML, Stinson J. Seeing is believing? A mixed-methods study exploring the 25. guality and perceived trustworthiness of online information about chronic conditions aimed at children and young people. Health Communication. 2014;29(5):473-82. 26. Spinuzzi C. The methodology of participatory design. Technical communication. 2005;52(2):163-74. 27. Lindgren B-M, Lundman B, Graneheim UH. Abstraction and interpretation during the qualitative content analysis process. International journal of nursing studies. 2020;108:103632. O'Connor C, Leyritana K, Doyle AM, Birdthistle I, Lewis JJ, Gill R, Salvaña EM. Delivering an 28. mHealth adherence support intervention for patients with HIV: Mixed methods process evaluation of the Philippines connect for life study. JMIR Formative Research. 2022;6(8):e37163. Sánchez SA, Ramay BM, Zook J, de Leon O, Peralta R, Juarez J, Cocohoba J. Toward improved 29. adherence: a text message intervention in an human immunodeficiency virus pediatric clinic in Guatemala City. Medicine. 2021;100(10). 30. Mukund Bahadur K-C, Murrayb PJ. Cell phone short messaging service (SMS) for HIV/AIDS in South Africa: a literature review. MEDINFO 2010. 2010:530-4. 31. Lester R, Karanja S. Mobile phones: exceptional tools for HIV/AIDS, health, and crisis management. The Lancet infectious diseases. 2008;8(12):738-9. Hlophe LD, Tamuzi JL, Shumba C, Nyasulu PS. Barriers to anti-retroviral therapy adherence 32. among adolescents aged 10 to 19 years living with HIV in sub-Saharan Africa: A mixed-methods systematic review protocol. Plos one. 2022;17(9):e0273435. 33. Ammon N, Mason S, Corkery J. Factors impacting antiretroviral therapy adherence among human immunodeficiency virus-positive adolescents in Sub-Saharan Africa: a systematic review. Public health. 2018;157:20-31. United Nations Social and Economic Council. Progress towards the Sustainable Development 34. Goals. Report of the Secretary-General. NY. USA; 2022. Creswell JW, Klassen AC, Plano Clark VL, Smith KC. Best practices for mixed methods research in 35. the health sciences. Bethesda (Maryland): National Institutes of Health. 2011;2013:541-5. 36. Lincoln YS, Guba EG. Naturalistic inquiry: sage; 1985. 37. Schulz KF, Altman DG, Moher D. CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. Journal of Pharmacology and pharmacotherapeutics. 2010;1(2):100-7. Graneheim UH, Lundman B. Qualitative content analysis in nursing research: concepts, 38. procedures and measures to achieve trustworthiness. Nurse education today. 2004;24(2):105-12. 39. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. Jama. 2013;310(20):2191-4. **Figure legend/caption** Figure 1 Flow Chart Diagram Caption: The flowchart shows the flow diagram of mobile phone text messaging reminder in the intervention group. For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml



Figure 1. The flow diagram of mobile phone text messaging reminder in the intervention group

Semistructured interview guide

Sociodemography of participants

S.no.	Age	Sex	Educational level	Caregiver/adolescent/healthcare provider	Hospital (site)

Adolescents

1. Are you receiving the mobile text-message reminder from the hospital?

Probe on:

- Do you remember the code through which you receive the text-message reminder?
- What would you like about the message?
- Is there any difficulty in the use of text terms for the time schedule or messaging frequency?

2. How did you find the text message reminder?

Probe:

•Benefits

•Challenges

3. What would you like to change or improve regarding the mobile text-messaging intervention?

4. For what other purposes do you use the mobile phone provided by the hospital?

5. Was there any technical problems regarding receiving text messages?

Probe: damage to devices, battery failure, text compatibility with phone,

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6. How do you compare the text message reminder for medication against preintervention period? **Parents/caregivers:** 1. How do family- and social-related factors affect ART adherence in adolescents? 2. What is the role of parents/caregivers in preventing adolescent antiretroviral treatment fatigue? 3. Have you heard about the text message intervention that your child receives? 4. How happy are you of the text-message reminder intervention? 5. Do you think that sending text-message reminders supports adherence? 6. Are the adolescent properly using the mobile phone provided from hospital? (probe: damage, stolen, used by other than the adolescent) Health care providers 1. How did you experience the communication with the adolescents regarding this intervention? 2. Do you think this intervention improves the retention and adherence of adolescents? 3. Reporting damaged equipment 4. Benefits, challenges, and hope to integrate with the health care system? For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml