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Feasibility and Usability of Mobile Technology to Assist HIV Self-Testing in Youth in Zimbabwe: A Mixed-Methods Study

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A B S T R A C T

Purpose: Mobile technology is increasingly being used to widen access to and support the delivery of public health interventions. Human immunodeficiency viruses (HIV) self-testing (HIVST) enables individuals to have autonomy. We evaluated the feasibility of a novel application called ITHAKA to support HIVST among youth aged 16–24 years in Zimbabwe.

Methods: This study was nested within a trial of community-based delivery of integrated HIV and sexual and reproductive health services called CHIEDZA. Youth accessing CHIEDZA were offered provider-delivered HIV testing or HIVST supported by ITHAKA, either on a tablet on-site at a community centre or on their mobile phone off-site. ITHAKA incorporated pre and post-test counselling, and instructions for conducting the test and the appropriate actions to take depending on test result, including reporting HIV test results to health providers. The outcome was completion of the testing journey. Semistructured interviews with CHIEDZA providers explored the perceptions of and experiences with the application.

Results: Between April and September 2019, of the 2,181 youth who accepted HIV testing in CHIEDZA, 128 (5.8%) initiated HIVST (the remainder opting for provider-delivered testing) using ITHAKA. Nearly all who performed HIVST on-site (108/109 (99.1%)) compared to only 9/19 (47.4%) who tested off-site completed their testing journey. Low digital literacy, lack of agency, erratic network coverage, lack of dedicated phone ownership, the limited functionality of smartphones challenged implementation of ITHAKA.

IMPLICATIONS AND CONTRIBUTIONS

A free-of-cost mobile application to support human immunodeficiency virusesself-testing among youth in Zimbabwe had low uptake and feasibility. Digital human immunodeficiency viruses self-testing may not be practicable in settings where there is limited digital literacy and/or access to mobile devices, and poor network coverage. Feasibility and usability should be carefully assessed before implementation.

Conflicts of interest: The authors have no conflicts of interest to declare.

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Discussion: Digitally supported HIVST had low uptake among youth. The feasibility and usability of digital interventions should be carefully assessed before implementation, paying careful attention to digital literacy, network availability, and access to devices.

Human immunodeficiency viruses (HIV) testing is a critical entry point for accessing HIV care or prevention. While access to HIV testing has increased globally in recent years, HIV testing rates vary by age, sex, and within region by country [1]. HIV testing rates remain low among youth, particularly in southern Africa, where population-level HIV prevalence remains high [2] in Zimbabwe. In the 2020 Zimbabwe population-based HIV impact assessment (ZIMPHIA) HIV prevalence was 2.4% and 5% among 15–24-year-old men and women, respectively. Furthermore, 81% of adults aged 15 years and above had at least 1 HIV test, but only 68% of youth aged 15–24 years had ever tested. Similar trends have been reported across the region [1,3].

The World Health Organization (WHO) recommends HIV self-testing (HIVST) as one of the several approaches to improve testing rates among youth [4,5]. HIVST is the process of a person collecting their own specimen, performing the test, and interpreting the test result [6]. Location and timing of the test is self-determined, potentially increasing self-efficacy, empowerment, and reducing the burden on health systems [7,8]. A commonly used test for HIVST is an oral mucosal transudate test (OMT), which requires the collection of a salivary sample [6]. The OraQuick OMT (Orasure, PA) has been given US Food and Drug Administration approval and has been deployed in HIVST programmes globally [6].

HIVST can be facilitated using digital technology, including provision of general or HIV-specific health messages, annual HIV testing reminders, information where HIVST kits are available, and applications (apps) supporting people through the testing process and linkage to care in the event of a reactive test [9]. Digital health technology is gaining traction in high- and middle-income countries to close gaps in service delivery, especially since the start of the COVID-19 pandemic, which led to disruptions in supply chains and health care provision [10]. HIVST with digital supports offers an opportunity to address stigma and confidentiality concerns that are often cited by youth in relation to HIV testing [11–13].

We investigated the feasibility and usability of an app to support HIVST in youth aged 16–24 years in Zimbabwe, within a trial of a community-based integrated HIV and sexual and reproductive health service (CHIEDZA). Our aim was to understand the operational facilitators and challenges as well as contextual factors that influence implementation of a digitally supported HIVST intervention to inform future programming of HIVST for youth.

Methods

Study design and setting

We conducted a mixed-methods study using WHO guidance on evaluating digital health interventions [14], embedded within the CHIEDZA trial. CHIEDZA was a cluster randomised trial (trial registration number: NCT03719521) investigating the impact of provision of community-based HIV testing and treatment integrated with sexual and reproductive health services to youth aged 16–24 years on population-level HIV viral load [15].The trial was conducted in three provinces (Harare, Bulawayo, and Mashonaland East) with each having eight clusters in urban settings randomised 1:1 to the intervention or to the control arm (existing health services). Clusters were defined as a geographically demarcated area with a primary health care clinic and a community centre from where the intervention would be delivered. The trial protocol is reported elsewhere, but in brief, the CHIEDZA intervention package included HIV testing, treatment and adherence support, as well as risk-reduction counselling, condoms, contraception, menstrual health education and products, management of sexually transmitted infections, and general health counselling [15]. All services were delivered weekly from community centres in the intervention clusters and were offered free of charge to youth residents within the cluster.

Human immunodeficiency viruses testing within CHIEDZA

Those not known to be HIV positive and not having had an HIV test in the past 12 months were eligible for HIV testing. Clients could choose to have a provider-delivered blood-based rapid point-of-care HIV test, or HIVST. Clients opting for HIVST were encouraged to use the ITHAKA app. The present study, nested within the CHIEDZA trial, evaluated ITHAKA, which was used to support HIVST. In this study, an app was defined as a software application that could run on a variety of mobile platforms or be web-based but optimized for mobile devices and tablets.

HIVST was performed using an OraQuick OMT test. Those with a reactive OMT were able to access confirmatory blood-based HIV testing as per national guidelines, either on the same day (if testing on-site) or at a later date, either from the study sites or at routine primary health care facilities. If a client tested HIV-positive, they were offered the option of either linking to care at a public sector clinic or receiving HIV care through CHIEDZA, including antiretroviral therapy (ART) initiation according to national guidelines, ART refills, treatment monitoring, and adherence support. Further details are provided in the CHIEDZA protocol [15].

Human immunodeficiency viruses self-testing app

A population-based survey, undertaken as part of the formative work to inform the CHIEDZA intervention, showed high prevalence of mobile phone ownership among youth in study communities, which motivated the incorporation of an app to support HIVST [16].

An app called ITHAKA designed by Aviro Health (Cape Town, South Africa) was offered to clients to support HIVST. The app was designed to be accessed through a web browser on either smartphones or tablets. While an internet browser was required

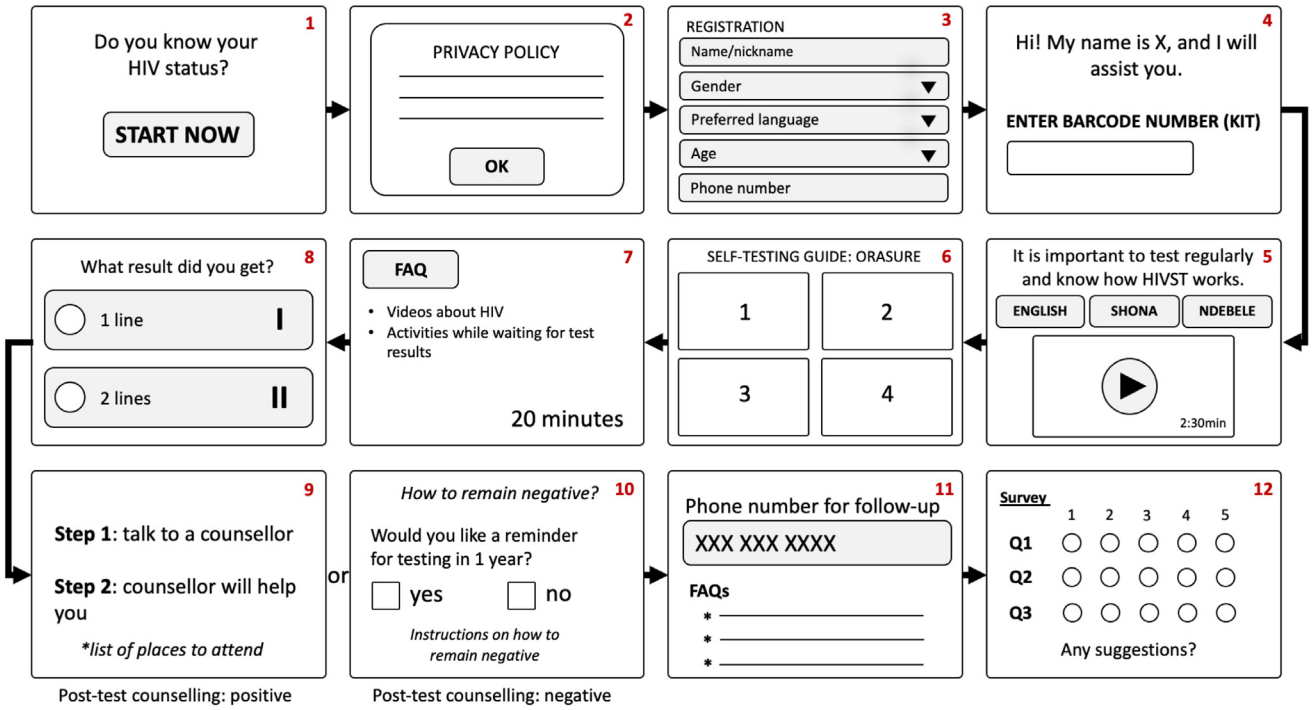

Figure 1. Storyboard of ITHAKA application journey.

to access ITHAKA, once loaded on a device, it could be used offline. A mobile signal and data were required to initially access the web app to load it on to the device and to submit the HIV test result. The app was customised for the local context over a four-month period following user design workshops and acceptability testing, generating a minimally viable product for the studies. Customization included educational videos in English as well as in the two local languages (Shona and Ndebele), mapping of local HIV prevention care and care services that were listed on the app (see below), building appropriate chat/phone support, building a system for covering clients' data consumption costs, and specific daily data downloads to track app use. The app was connected to the local mobile data networks (NetOne and Econet). The product was iteratively adapted following testing with users to check understanding of the information in the videos, the flow of content, and the user testing journey.

The platform supported multiple content formats, had interactive features for feedback, provided logins and data security, and included journey tracking with reminders and reporting. Figure 1 displays a storyboard detailing the journey. It included educational videos about HIV and HIV testing, a series of four short videos that provided a step-by-step guide to performing the OMT test (including a timed prompt and an SMS message to read the test result), and interpreting the test results. ITHAKA also included post-test counselling tailored to the result, including instructions to guide individuals on what to do if their OMT was reactive and details of providers they could access for confirmatory HIV testing. Those with nonreactive tests were given information on how to prevent HIV infection and asked whether or not they wanted to receive an SMS reminder for repeat testing in 12 months.

Clients could opt for HIVST either in a private booth at the community centre from where the CHIEDZA intervention was delivered (onsite HIVST) or off-site at a location of their choice. For clients testing on-site, a tablet with ITHAKA preinstalled was available in the booth. Clients who opted for off-site testing had ITHAKA installed on their own smartphones. Providers provided clients with written and verbal instruction and, if needed, assisted clients to install ITHAKA on their smartphones. A cellular network and data were required to install ITHAKA, and clients were given data bundles for either of the two network providers, restricted to the installation of ITHAKA and reporting of results.

Data collection and analysis

All OMT kits were labelled with a unique number, which was entered into ITHAKA by the client. This number was also entered on the study data form (which contained the client's ID number) by the provider so that the test results recorded on ITHAKA could be linked to the client's details. As CHIEDZA was designed to be a youth-friendly, convenient, and non-judgemental service, only client age and sex and the services taken were recorded on the study form.

A client was considered to have completed the ITHAKA testing journey if they watched the educational videos, underwent HIVST, and reported the HIV test result on the web-app, and completed post-test counselling. If a client exited ITHAKA at any point prior to completing the post-test counselling, they were categorised as having an incomplete ITHAKA journey. Application data on ITHAKA was collected by the study team to ascertain the proportion of clients who completed the testing journey and the last journey stage the participants interacted with before exiting the app.

Five semi-structured interviews were conducted with the CHIEDZA service providers involved in different roles including a nurse (n = 1), a mobiliser (n = 1), community health workers

Table 1
Characteristics of clients in the CHIEDZA study

	CHIEDZA	
	HIV tested (n = 2,181)	HIVST with ITHAKA (n = 128)
Female	1,499 (68.7%)	79 (61.7%)
<19 years	1,291 (59.2%)	78 (60.9%)
20–21 years	380 (17.4%)	22 (17.2%)
>22 years	510 (23.4%)	28 (21.9%)
Last HIV test ≤ 6 months ago	13 (0.6%)	1 (0.8%)
Last HIV test > 6 months ago	1,169 (53.6%)	69 (53.9%)
Never tested	999 (45.8%)	58 (45.3%)

(n = 2), and a youth worker (n = 1), at the end of the ITHAKA study. The interviews were conducted in English by a single interviewer using topic guides developed jointly by the research team. These topic guides explored the providers' perceptions and experience of delivering ITHAKA to clients and elicited the feedback provided by the clients to the providers. A particular focus of the interviews was on the usability and the operability and the specific contextual challenges involved in implementing ITHAKA. The interviews were audio-recorded and transcribed by the interviewer, a researcher external to the study and respondents. A combination of iterative thematic intent and applied thematic analysis was used to explore emerging themes in the data. Emerging themes were coded initially by LL, LS, and RAF. Iterative thematic analysis was used to explore both deductive themes identified before interviews were conducted and inductive themes, which emerged from the qualitative data [17].

Ethical considerations

Ethical approval for the CHIEDZA study was given by Medical Research Council of Zimbabwe (MRCZ) (MRCZ/A/2387), the Biomedical Research and Training Institute Institutional Review Board (AP149/2018) and the London School of Hygiene and Tropical Medicine ethics committee (16,124). HIV testing was offered as part of a sexual reproductive health service, and the requirement for written consent was waived. All clients gave verbal consent for accessing HIV testing (and other services). Written informed consent was obtained from all interviewees.

Results

Between April 1st 2019 and September 30th 2019, 2,181 clients accessed HIV testing in the four CHIEDZA intervention clusters in Harare. The median age was 19.2 (IQR: 17.5 – 21.7) years, and 1,499 (68.7%) were female. Notably, only 128/2,181 (5.9%) opted for HIVST, the remainder (n = 2,053) opting for HIV testing performed by the provider. The age of those taking up HIV testing and HIVST was similar but proportionally more men took up HIVST than men who took up HIV testing overall (68.7% vs. 61.2%, Table 1). Of the 128 clients who took up HIVST, 19 (14.8%) opted to test at home, the remainder (n = 109) performing HIVST on-site.

Completion of the ITHAKA journey

Out of the 19 participants who took the HIV test off-site, 9 (47.4%) completed the ITHAKA journey, and all reported nonreactive test results. One of the clients who did not complete the journey exited the app at the results stage and reported a reactive test in person at the CHIEDZA centre. Of the remaining nine clients who did not complete the ITHAKA journey, 7/9 exited the process during the HIV testing instructions stage, and 2/9 exited at the post-test counselling stage for nonreactive results. Of the 109 clients who opted for HIVST on-site at the CHIEDZA centre in a booth, 108/109 (99.1%) completed the ITHAKA journey and reported the results (all nonreactive), both through the app and verbally to a CHIEDZA community health worker. The client who did not complete the journey exited at the testing stage and opted to be tested by a provider instead after watching the educational videos (Figure 2).

The median time between start and finish of the ITHAKA journey among off-site testers (n = 9) was 91 (IQR: 65–277) minutes. The corresponding period for on-site testers (n = 108) was 24 (IQR: 22–26) minutes.

Experience with ITHAKA

Each interview with CHIEDZA staff lasted between 25 and 45 minutes. Five main themes emerged that influenced the feasibility and operability of digitally supported HIVST in community-based settings: i) low levels of literacy (defined as difficulty reading and interpreting written text) and digital literacy (defined as difficulty interacting with digital tools), ii) lack of self-agency and/or ii) technical challenges, iii) lack of a private physical space or dedicated phone ownership, and v) the desire for provider support for HIV testing. These issues pertained to the use of a digital app to support HIVST and/or to the process of HIVST itself. Quotes supporting these themes are detailed in Table 2.

Low literacy

Providers reported that the uptake and use of ITHAKA was challenged by the low overall literacy and digital literacy among clients attending CHIEDZA services. Written information was provided in English and Shona or Ndebele (the local languages) on how to use the app, but many clients had difficulties understanding the instructions and would ask providers for more detailed explanations.

Some clients did not understand the concept of the app and how to navigate ITHAKA correctly. Thus, some clients prematurely dropped out of the ITHAKA journey and instead chose to access provider-performed testing. Several clients who were HIV self-testing in the booth using ITHAKA preloaded on a tablet, did have providers nearby, and were only able to complete their testing journey with help of providers, and thus providers did not perceive this as an HIV self-testing process.

Lack of a private digital or physical space

Providers reported that clients, particularly younger clients, often shared ownership of their phones with family members or friends. Clients were concerned that the presence of an app on the smartphone would prompt questions by family and/or friends about the nature of the app and inadvertently disclose that they had accessed HIV testing. Even among those who had their own smartphones, providers said that clients would opt for testing on-site due to lack of privacy at home.

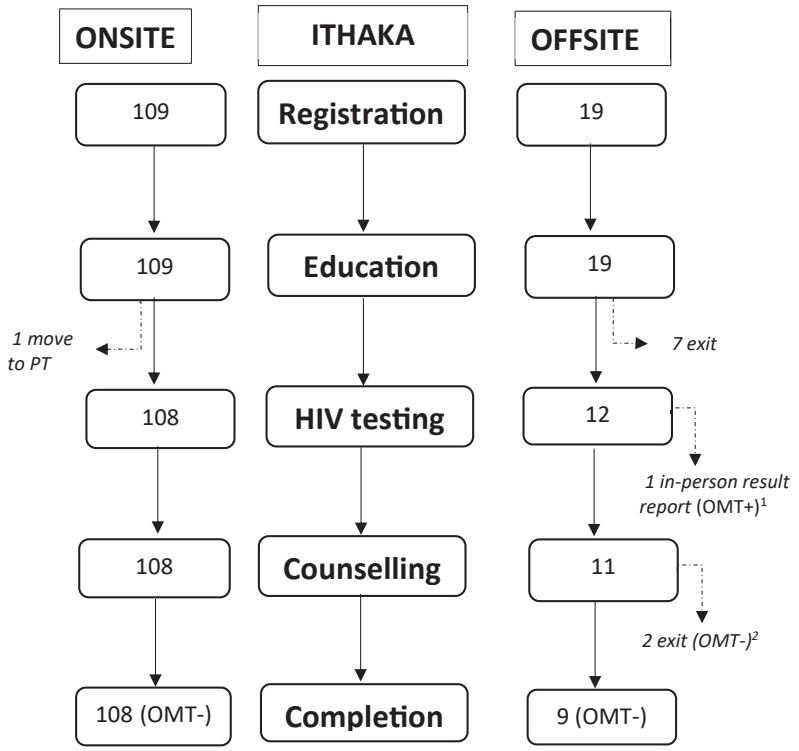

Figure 2. ITHAKA journey and steps in mobile application where clients from studies dropped off. Testing included watching a 4-step guide to performing an OMT and reporting the result. Counselling is post-test counselling with content differing depending on HIV test result. Finish defined as someone who has completed the ITHAKA HIVST journey by testing, reporting result and completing post-test counselling. OMT-: Non-reactive HIV test; OMT+: Reactive HIV test; PT: Provider Testing. [1]Did not report result in ITHAKA; [2]Exited before completing post-test counselling.

Limited self-efficacy and/or agency

Providers stated that clients were "used to getting things done for them." While some of this may have been related to a client's low literacy and self-perceived and/or actual inability to navigate the app, providers stated that some young people wanted the provider to tell and show them how to test for HIV, even if they felt they had understood the information provided through ITHAKA. This went against the concept of HIVST with digital support, which was meant to promote autonomy and required clients to watch the video to get information and instructions, perform HIVST independently, and report the results.

Fear of testing and need for provider support

Providers felt that clients were anxious and afraid of HIV testing. According to providers, the information, education, and counselling and the instructions in ITHAKA did not sufficiently address young people's anxiety. Support from friendly, non-judgemental providers was perceived to be an essential component of HIV testing to cater to the emotional needs of young people undergoing HIV testing.

Technical challenges

Providers cited several technical challenges to operationalizing ITHAKA. Some phones, even if they resembled smartphones, had limited functionality and did not support connections to websites or downloadable apps. The functionality of the phone could only be assessed by downloading ITHAKA on-site. Clients were provided with a free data bundle specifically to access ITHAKA, but on occasion, access was slow or failed completely. Providers attributed these challenges to poor network coverage and/or network unavailability due to frequent power cuts both in the areas where CHIEDZA services were offered and in the clients' residential areas. According to providers this was one reason why clients prematurely terminated their ITHAKA journey. Notably, the client on-site who terminated their ITHAKA journey before the testing stage did switch to provider testing.

Providers spent significant amounts of time helping clients load and/or use ITHAKA, which they perceived as "not really qualifying as HIVST." Also resolving technical issues sometimes took longer than performing blood-based HIV testing. With increasing experience of ITHAKA, providers became more and more concerned that clients who opted for HIVST off-site might not be able to access the HIVST guidance either due to limited smartphone functionality or erratic network availability. As a result, they promoted provider-based testing and advocated for ITHAKA to be discontinued within the CHIEDZA service.

Discussion

Our study found low acceptability and preference among youth for an app supporting HIVST in community-based settings and significant challenges to implementation, which resulted in the discontinuation of its use. Notably, proportionally more males than females accessed HIV testing using ITHAKA, which may possibly reflect higher levels of internet access and

Table 2
Quotes supporting themes from qualitative interviews

Theme	Quote
Low general and digital literacy	*"Also when you look at literacy of the people that we're dealing with, can they really interpret even though we are giving them the language they prefer? It's not that they're not good at speaking it, but are they capable of reading? Interpreting? Can they do it on their own? You know in our society at times people are shy telling the truth that they can't. Because it's hard."* (**Nurse**) *"In the process of trying, they'll come back to the booth and knock: "This isn't working what do I do" or "I am not understanding this", so I end up going back to that booth and explaining the thing to them"* (**CHW**) *"We had some that opted for an OMT in a booth but it almost always ended up as a provider test. One would come out of the booth and try and get help from the providers so at the end of the day it's not really a self-test because you have to go and assist. They call you in and say "Yes I have seen the video, but how do you do it?"* (**YW**) *"At CHIEDZA we advocated for a friendly environment so at the end of the day when you talk to them about ITHAKA they take it up but when they are out there can they really use it? At times they would be shy to tell you that they can't really use it. Can you imagine having to tell someone that you can't really read?"* (**Nurse**)
Limited self-efficacy and/or agency	*"I know this is our culture, our African culture: people just don't like to read. They are only used to getting things done for them. They come to the clinic, and I tell them "Do this, do that". To get them to do it themselves might be a challenge of course it depends on the person, but you never know the type of people you meet."* (**Nurse**) *"I could give you a self-test hoping that you would do it yourself. You have three pamphlets of instructions in your own native language, in English, in Ndebele but still you don't want to read the instructions. You would come back to me and whether I have a client and ask what to do. But then again if you meet a client that's comfortable that's a lot easier. It's 50/50."* (**Nurse**) *"The video was sort of explaining how we do the test. Someone would stop the video and say, "can you stop the video please just explain this to me?". So, we would turn down the volume on the video and just explain. "The video is boring, please explain". They feel like you should be the one giving the instructions and not a video."* (**Nurse**)
Fear of testing and need for provider support	*"Some people may have taken up ITHAKA just because they had fear and didn't want to get the test done. And then when they went home they just threw it away and said "why bother, now I'm free" (…). They would take it up and then run away. It's a way of running away! You know, you're in a friendly environment, the providers are passionate, you get so engaged with them, to tell them that you don't want to be tested is not something that you would want."* (**Nurse**) *"From my experience, in a time where people need to cry, you allow them to cry, you allow them to talk about it. It's different from watching a video and interpreting your own results and going through the process of grieving and accepting your results on your own. It's a bit challenging. It requires someone who is prepared to do that, but how many people are ready to do that?* (**Nurse**)
Lack of a private digital or physical space	*"Most young people in these areas can't afford a smartphone and if they do, they share their phones with their brothers and sisters, they have very little privacy at home"* (**Nurse**) *"People take the test home and then don't do it. Maybe it's for fear of their family. They often don't have privacy in their own home and share rooms."* (**CHW**)
Technical Issues	*"Many would come back with issues, maybe the videos didn't load, or the data didn't work. (…) data doesn't work everywhere"* (**CHW**) *"We had some that opted for an OMT in a booth but it almost always ended up as a provider test. One would come out of the booth and try and get help from the providers so at the end of the day it's not really a self-test because you have to go and assist. They call you in and say "Yes I have seen the video, but how do you do it?"* (**Nurse**) *"We faced many challenges. I remember every meeting we faced a new challenge from ITHAKA and to the point where we said - let's drop it. (…) It was a disaster"* (**CHW**)

confidence in using the internet among males than females. In our survey investigating access to mobile technology, the odds of having internet access were two times higher in males than females [16].

Digital tools are increasingly being evaluated and, in some instances, integrated at scale into health systems globally to improve access to health interventions [18]. One area where digitally supported interventions have particularly gained traction is in improving the efficiency and impact of HIVST. In 2019, WHO updated its guidance on HIV testing to include HIVST as one of the HIV testing approaches and has called for evidence for innovative HIVST models that expand access and reach [5]. A systematic review of 46 studies conducted in Asia, North America, Europe, South America, and Africa showed that HIVST with digital supports was feasible, acceptable, and increased uptake, particularly among hard-to-reach populations such as youth, in contrast to our finding [9].

In this study, we evaluated an app designed to support an individual to undertake HIVST. The app included age-appropriate information about HIV in an attractive format, guidance, and a visual demonstration on how to perform HIVST with a prompt to read the result once the test was done, a channel to report results to a provider, and instructions on how to respond to a reactive or non-reactive test result. Young people are generally a healthy population and infrequent users of health care facilities, and we hypothesized that the provision of digitally supported HIVST would provide autonomy, convenience, and added confidentiality, avoid inadvertent coercion to test, as well as potentially reduce stigma by shifting the educational and reporting aspects to a digital system [13].

The integration of an app to support HIVST was informed by extensive formative research and contextualised to the setting. Previous studies in Africa have shown high uptake and acceptability of HIVST among youth in diverse settings [19–22]. In participatory workshops that we held with youth, there was strong support for HIVST [23]. Following user design workshops, information videos were developed in local languages and pilot tested with users and providers. We also conducted a population-based survey among young people which showed high mobile phone penetration, with the majority of phones being smartphones [16]. However, only two-thirds reported access to the internet in the survey. Hence, free data bundles were provided to clients to facilitate access to ITHAKA.

The low uptake and usage of ITHAKA was partly explained by operational challenges. Network coverage was patchy even in Harare, the capital of Zimbabwe. In addition, there were frequent and lengthy power cuts, and as a result, Econet Wireless, the country's largest mobile operator, struggled to maintain its network [24]. Power cuts interfered with downloading ITHAKA and completing the testing journey. An unanticipated finding was that many mobile phones owned by CHIEDZA clients that appeared identical to smartphones had restricted "smart"

options such as WhatsApp messaging services but no web capabilities. These technical challenges required busy CHIEDZA providers to frequently troubleshoot app-related issues, which was time-consuming and added to the workload, resulting in poor acceptability by providers and likely serving as a disincentive to promote the app. Providers reported low digital literacy levels among CHIEDZA clients, which may have contributed to incorrect use of the app and premature termination of the testing journey. Within CHIEDZA services, the proportion who completed their test journey was much higher for those who used ITHAKA on-site than those who used it off-site, which was likely due to having providers available on-site to help clients use the app. Interestingly, the time taken to complete the testing journey was much longer for off-site testers than onsite testers. This may have been due to off-site testers either stopping and restarting their journey or having problems navigating the journey and having no providers to help troubleshoot. On-site users were in the booth specifically to test and had providers available to help with any issues with the app.

ITHAKA was designed to give clients autonomy and facilitate self-management of their testing journey. This included receiving information on HIVST, testing themselves (with the help of clear instructions and prompts regarding when to read the result), and getting post-test counselling and instructions on how to respond to the test result without a provider. In addition to literacy issues, limited self-efficacy and agency may have resulted in low preference for the app and indeed low uptake of HIVST. According to social cognitive theory, self-efficacy is one's *perceived* ability to deal with a task or situation, and agency is one's *actual* ability to deal with a task or situation [25]. As well as literacy, factors that contribute to this include autonomy-supportive education,parenting and culture [26]. Structural elements such as resource deprivation, geopolitical histories of structural adjustment policies, and cultural/historical norms also influence how people interact with health services [27]. Providers commented on prevailing norms whereby providers tell clients what to do and specifically commented that the process of navigating the app was much easier for clients who had agency.

Some clients feared not being able to perform the test proficiently, and also the consequences of a positive test. We have previously shown that *where available*, young people want the support of and counselling from providers when undergoing HIV testing [28]. The one CHIEDZA client who opted to use ITHAKA off-site and had a reactive test reported the HIV test result in person rather than on the app, to providers. It is notable that where youth had the choice of accessing either provider-delivered or HIVST, the majority opted for the latter, mostly on-site. Both CHIEDZA clients [28], and providers in this study, also highlighted the lack of privacy at home as a reason for not opting for testing at home. In addition, shared phone ownership among CHIEDZA clients was a further barrier to using ITHAKA to support HIVST.

The strengths of the study were the large quantitative sample size and the fact that the study was being conducted in real-life conditions, facilitating an understanding of the operational challenges of implementing digital technology. The study incorporated different options for HIV testing (HIVST and provider-delivered testing) as well as on-site and off-site HIVST testing. The app allowed tracking of a client's progress through the ITHAKA journey. We acknowledge several limitations to the study. No socio-demographic data were available on clients who accessed the CHIEDZA intervention except for age and sex, which meant that an analysis of factors associated with the uptake of ITHAKA was not possible. Collection of detailed individual-level data would not have catered for the ethos of a convenient, confidential service. Clients who used ITHAKA were not interviewed, and the reports about clients' experiences were ascertained through interviews with health providers only, who related the feedback that had been provided to them by clients. The interviews with CHIEDZA providers were held after the implementation of ITHAKA had been discontinued, and therefore the findings are subject to recall bias.

Our results add to a growing repertoire of evidence on digitally supported HIVST interventions. While digitally supported HIVST has been recommended as an approach to improving access to HIV testing in hard-to-reach groups such as young people, the feasibility of implementation and selection of target groups needs to be carefully considered and assessed [29]. There is a global move toward the use of digital, mobile, and wireless technologies to increase access to and efficiency of service delivery. While these interventions hold much promise in facilitating achievement of public health objectives, it is critical that they take into account the context in which they are to be delivered, including availability of relevant infrastructure to support delivery and maintenance of technologies, digital literacy, and whether digital rather than personal interaction with users is most appropriate. Failure to do so may make digital interventions into a barrier rather than a facilitator to achieving their underlying objective and actually increase health inequities [30].

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