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Review Article

Challenges and opportunities for HIV screening with the support of health digital technology: A scoping review

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ABSTRACT

Background & Aim: HIV screening is a crucial step in the prevention and treatment of HIV/AIDS, but challenges related to accessibility, efficiency, and service quality in many regions. With the rise of digital technologies, digital health applications hold significant potential to address these challenges. This review evaluates the opportunities and challenges of applying digital technologies in HIV screening, focusing on accessibility, privacy, and healthcare quality.
Materials & Methods: A scoping review was conducted using the framework of Arksey & O'Malley (2005), as modified by Levac et al. (2010). Systematic searches were performed in PubMed, Scopus, DOAJ, Wiley Online Library, Cochrane Library, and EBSCOhost for studies published between 2015 and 2024. Relevant studies were selected based on criteria focused on technology accessibility, privacy, and infrastructure reliability. Data were extracted, mapped, and findings categorized by geographical context and key challenges.
Results: Ten studies involving over 3,500 participants were analysed, including randomized controlled trials, observational studies, and program evaluations. Major challenges identified included limited access to technology, particularly in low-resource areas, as well as privacy concerns and technology reliability. Despite these challenges, significant opportunities to improve healthcare services through digital technologies were noted, especially when adapted to local contexts and supported by user training.
Conclusion: Despite challenges in accessibility and privacy, digital technologies provide opportunities to enhance HIV screening, especially with contextual adaptations and user training. These findings suggest a path forward for integrating digital solutions in HIV care.

Introduction

Human Immunodeficiency Virus (HIV) screening is a crucial step in the prevention and treatment of HIV/AIDS. The incidence of HIV/AIDS is still a significant global health problem. According to data from UNAIDS (2024), about 38 million people worldwide live with HIV, and more than 1.5 million new cases are detected each year. Efforts to improve the accessibility, reliability, and efficiency of HIV testing are critical to controlling the spread of the virus (1).

Digital health technology has shown great potential in supporting various aspects of health services, including HIV screening. This technology includes a variety of tools and platforms, ranging from mobile applications, telemedicine, to electronic health information systems that can improve access, quality, and efficiency of healthcare services (2). However, the adoption of digital technology in HIV testing cannot be separated from significant challenges, ranging from accessibility issues, privacy to user skills.

Several previous studies have shown different aspects of digital technology in the context of HIV screening. Examples Syed et al. (3), highlight the impact of digital health technology on improving the speed and accuracy of HIV screening. Their research shows that digital technology can overcome

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limited access to health facilities and reduce social stigma related to HIV screening. However, they also note that the lack of digital literacy and privacy concerns are still major obstacles

Meanwhile, research by Popa et al. (4) Identify regulatory challenges and public trust as key obstacles to the adoption of digital technology for healthcare. They found that while this technology has great potential to improve the quality of services, there is still much that needs to be done to ensure compliance with health standards and build public trust in this technology

The urgency of this research is based on the urgent need to improve effective and efficient HIV testing methods. Digital technology can answer the challenges that exist in conventional HIV testing, such as limited access to health facilities, social stigma, and delays in test results. With the use of digital technology, HIV testing can be carried out faster, more accurately, and confidentially, so that it can reach a wider and higher-risk population (5).

The research focuses on the challenges and opportunities in the application of digital technology for HIV screening, which is a relatively new and growing field. Most of the existing literature discusses digital technology in general without specializing in HIV screening. Therefore, this scoping review aims to fill the knowledge gap by providing a comprehensive overview of how digital technologies can be optimized for HIV screening, as well as identifying existing barriers and opportunities. This study is expected to provide guidance for policymakers, health practitioners, and researchers in developing effective implementation strategies (6).

Thus, this research aims to provide insights into the role of digital technologies in HIV screening and how they might influence health policies and practices."

Methods

Research design

This study uses the scoping review method to explore challenges and opportunities in the application of digital technology in HIV screening. The scoping review method was chosen for its ability to comprehensively identify and map relevant research in an emerging field such as digital health in HIV services. The study follows the framework proposed by Arksey and O'Malley (7) , which includes five main stages: identification of research questions, identification of relevant studies, selection of studies, data collection, and presentation and reporting of results.

The consultation with stakeholders, which is considered an optional step in Arksey and O'Malley's framework, is not included in this study, following their methodology. On the other hand, Levac et al. (8) emphasize that stakeholder consultation is a necessary step in their updated version of the framework.

Research questions

The main research question guiding this research is: "What are the challenges and opportunities associated with the use of digital technology in HIV screening?"

Literature search strategy

Literature searches were conducted comprehensively in several major academic databases such as PubMed, Scopus, DOAJ, Wiley Online Library, Cochrane Library, and EBSCO. The search is focused on publications from 2015 to 2024, using a combination of keywords such as "HIV testing", "digital health", "telemedicine", "mobile health", and "digital technology" (Table 1). The inclusion criteria for this review involved studies published in English, involved studies published in English, in line with the research questions specifically addressing the application of digital technologies in HIV screening.

Only studies available in full text for further evaluation and published in accredited journals or reports from recognized health organizations were included. The time frame for the literature search was limited to this period to capture the most recent advancements in digital health technologies that have been applied to HIV testing, ensuring the relevance and timeliness of the findings.

Table 1. Search strategy for each database

Database	Search strategy
PubMed	("HIV testing"[MeSH Terms] OR "HIV testing"[All Fields] OR "HIV diagnosis"[All Fields] OR "HIV screening"[All Fields])
	("digital health"[MeSH Terms] OR "digital health"[All Fields] OR "e-health"[All Fields] OR "digital health interventions"[All Fields])
	("telemedicine"[MeSH Terms] OR "telemedicine"[All Fields] OR "telehealth"[All Fields] OR "remote healthcare"[All Fields])
	("mobile health"[MeSH Terms] OR "mobile health"[All Fields] OR "mHealth"[All Fields] OR "mobile health interventions"[All Fields])
Scopus	TITLE-ABS-KEY("HIV testing") AND TITLE-ABS-KEY("digital health")
	TITLE-ABS-KEY("HIV testing") AND TITLE-ABS-KEY("telemedicine")
	TITLE-ABS-KEY("HIV testing") AND TITLE-ABS-KEY("mobile health")
	TITLE-ABS-KEY("HIV testing") AND TITLE-ABS-KEY("digital technology")
DOAJ	("HIV testing") AND ("digital health")
	("HIV testing") AND ("telemedicine")
	("HIV testing") AND ("mobile health")
	("HIV testing") AND ("digital technology")
Wiley Online Library	("HIV testing") AND ("digital health")
	("HIV testing") AND ("telemedicine")
	("HIV testing") AND ("mobile health")
	("HIV testing") AND ("digital technology")
Cochrane Library	("HIV testing") AND ("digital health")
	("HIV testing") AND ("telemedicine")
	("HIV testing") AND ("mobile health")
	("HIV testing") AND ("digital technology")
EBSCO	("HIV testing") AND ("digital health")
	("HIV testing") AND ("telemedicine")
	("HIV testing") AND ("mobile health")
	("HIV testing") AND ("digital technology")

Study selection

Studies were selected based on pre-defined inclusion criteria, where only studies focused on the application of digital technology in the context of HIV screening were included. Exclusion criteria were applied to studies that were not published in the United Kingdom, did not fit the research question, were not available in full text, were not related to HIV testing supported by digital technology, or did not match the results of the study. The selection process involves several stages of screening, from reviewing titles and abstracts to evaluating the full text.

Data collection and analysis

Data from the selected studies were extracted and analysed using a thematic approach. This method allows for the identification of key patterns and themes related to the challenges and opportunities of digital technology in HIV screening. The extracted data included details about the following aspects:

- Author, year & country
- Research Design
- Number of samples size
- Challenges and opportunities related aspects (Including Accessibility, Privacy and Confidentiality, User Skills, Technology Reliability, Cost and Funding, Compliance and Regulation, Public Trust, Collaboration and Integration) (Table 2).

Table 2. Challenges and opportunities for HIV testing with digital health technology support

Author, year & country	Research design	Number of samples	Aspects	Challenge	Chance
(9), United Kingdom	The design of this study is a qualitative evaluation conducted in conjunction with a randomized controlled trial (RCT) of quantitative feasibility from the Men's Safer Sex website. Qualitative evaluations used three data sources: interviews with 11 RCT participants, free text comments from 46 RCT participants, and interviews with 9 clinic staff.	The sample size for the feasibility randomized trial was 159 participants, with 84 participants in the intervention group and 75 participants in the control group. In addition, 11 men were interviewed for a qualitative evaluation.	Accessibility	1) Technical issues with the software and Wi-Fi access 2) Difficulties engaging participants with online research procedures before accessing the intervention 3) Concerns from staff about consent and confidentiality	1) Offer digital interventions in the clinic waiting room to take advantage of waiting time before making an appointment. 2) Conducting digital interventions as a complement rather than replacing face-to-face health services, with clinic staff supporting and directing patients to digital resources. 3) Integrate digital interventions into routine clinic pathways and systems to increase engagement and trust.
			Privacy and confidentiality	1) Technical issues with the software and Wi-Fi access 2) Difficulties engaging participants with online research procedures before accessing the intervention 3) Concerns from staff about consent and confidentiality	1) The online environment poses a risk of data privacy and security breaches, for example, through unsecured email accounts and browsing history. 2) The security protocols implemented, e.g., complex passwords, create frustration for participants and make it difficult for them to access the study. 3) Participants were less concerned about consent and confidentiality, likely due to the partnership between the university and the NHS conducting the research, which increased their trust.
			User skills	1) Technical issues with the software and Wi-Fi access 2) Difficulties engaging participants with online research procedures before accessing the intervention 3) Concerns from staff about consent and confidentiality	This paper does not explicitly discuss "User Skills Opportunities" as a theme. However, the paper suggests that the Men's Safer Sex website can provide additional information and skills that are useful to users, if properly integrated into clinical care and supported by staff. This paper suggests that digital interventions should not replace direct care, but can play a complementary role in meeting users' healthcare needs.
			Technology reliability	1) Significant technical issues with trial software and the provision of reliable Wi-Fi access for patients in clinic waiting rooms reflect the wider digital infrastructure challenges in the NHS. 2) Lack of digital skills and confidence among clinic staff to solve technical problems, which demonstrates the need to build digital capabilities in the NHS workforce. 3) The tension between the principle of informed consent and the practical reality of the online research procedure creates barriers for participants.	1) Address the lack of reliable Wi-Fi access and technology infrastructure within the NHS to support digital health interventions. 2) Integrate digital sexual health interventions into existing NHS digital systems and clinical workflows to drive uptake and engagement, and increase patient trust through N support

Author, year & country	Research design	Number of samples	Aspects	Challenge	Chance
			Fees and funding	Not mentioned (this paper does not mention the "cost and funding challenges" associated with digital sexual health interventions or research studies)	Not mentioned (this paper does not provide any information on the costs or funding opportunities for digital sexual health interventions)
			Compliance and regulation	1) Competing priorities and a lack of adequate space in the clinic for research activities. 2) Substantial technical issues with software and unreliable Wi-Fi access in the clinic's waiting room, impacting recruitment, data collection, and access to interventions.	Not mentioned (this paper does not directly address "compliance and regulatory opportunities" for digital sexual health interventions)
			Public trust	1) Competition for clinical and research priorities that may be perceived as a burden on already limited resources. 2) Unreliable technical infrastructure, such as Wi-Fi access, that undermines the usability and reliability of digital interventions. 3) Lack of digital skills and confidence of NHS staff to effectively support and recommend digital interventions to patients	1) Digital interventions are supported by public health policies and have the potential for cost-effective sexual health promotion. 2) The support of clinic staff and the integration of digital resources into routine clinical systems can help build patient trust. 3) Integrating digital interventions into existing NHS clinical systems can further enhance patient confidence through NHS support.
			Collaboration and integration	1. Technical issues with unreliable software and internet access in the clinic environment. 2. Lack of digital skills and confidence among clinic staff to solve problems and support digital interventions. 3. The tension between digital interventions and the need for face-to-face clinical care, with concerns that digital interventions should not replace face-to-face services.	1) Integrate such health services into routine clinical systems and pathways. 2) Have NHS staff who support and direct patients to those health services. 3) Positioning these health services as complements, not substitutes, to face-to-face health services.
(10), Canada	The design of this study was a longitudinal multi-method study, which combined qualitative interviews and quantitative surveys conducted for one year or more with participants.	The sample size for this study was 25 participants.	Accessibility	1) Receiving an HIV-positive diagnosis by phone, either formally or informally, which poses difficulties for some participants in terms of emotional distress, uncertainty about the meaning of the results, and challenges in handling the diagnosis in the right environment. 2) Inconsistent practices around the delivery of HIV test results, with some participants receiving results by phone even though it is not standard practice, so there are proposals for the results delivery system to be reviewed and standardized.	Not mentioned (abstract does not mention any "accessibility opportunities" related to the diagnostic technology discussed)
			Privacy and confidentiality	1) Receiving an HIV-positive diagnosis by phone, either formally or informally, which poses difficulties for some participants in terms of emotional distress, uncertainty about the meaning of the results, and challenges in handling the diagnosis in the right environment. 2) Inconsistent practices around the delivery of HIV test results, with some participants receiving results by phone even though it is not standard practice, so there are proposals for the results delivery system to be reviewed and standardized.	Not mentioned (abstract does not mention anything about the "privacy and confidentiality opportunities" associated with the diagnostic technology discussed)
			User skills	1) Receiving an HIV-positive diagnosis by phone, either formally or informally, which poses difficulties for some participants in terms of	The "User Skills Opportunity" in this study is an opportunity for clients and practitioners to develop

Author, year & country	Research design	Number of samples	Aspects	Challenge	Chance
				emotional distress, uncertainty about the meaning of the results, and challenges in handling the diagnosis in the right environment. 2) Inconsistent practices around the delivery of HIV test results, with some participants receiving results by phone even though it is not standard practice, so there are proposals for the results delivery system to be reviewed and standardized.	skills in interpreting and translating new diagnostic technologies and categories to be meaningful and support public health goals.
			Technology reliability	Not mentioned (abstract does not mention "technology reliability challenges" related to diagnostic technologies used to detect acute or recent HIV infection)	1) New diagnostic technologies for acute and current HIV infection provide an opportunity to improve the health of individuals and populations by detecting infection early. 2) The new diagnostic categories created by this technology require careful interpretation and communication to patients to be meaningful, reduce uncertainty, and support public health goals. 3) This study examines how new diagnostic technologies interact with and are used by patients and healthcare providers in clinical practice.
			Fees and funding	Not mentioned (abstract does not mention anything about the "cost and funding challenges" related to the diagnostic technology discussed in the study)	Not mentioned (abstract does not mention anything about the costs or funding opportunities associated with the diagnostic technology discussed in the study)
			Compliance and regulation	Not mentioned (abstract does not address any "compliance and regulatory challenges" related to the described diagnostic technology)	Not mentioned (abstract does not mention anything about the "compliance and regulatory opportunities" related to the diagnostic technology discussed)
			Public trust	Not mentioned (abstract does not directly mention the "public trust challenge" associated with the diagnostic technology discussed)	Not mentioned (abstract does not directly mention the "public trust opportunity" related to the diagnostic technology discussed)
			Collaboration and integration	Not mentioned (abstract does not mention any "collaboration and integration challenges" related to the diagnostic technology discussed)	Not mentioned (abstract does not mention specific "collaboration and integration opportunities" related to the diagnostic technology discussed)
(21), South Africa	The design of this study is a randomized controlled trial (RCT).	The planned sample size for this study is 1000 participants in each group, for a total of 2000 participants. However, the number of participants recruited and randomized was	Accessibility	1) Many participants do not have Android smartphones, which is the platform of choice for the app. 2) Even among Android users, many do not have the necessary version of Android or enough RAM to run the app. 3) The app also does not work on some Android tablet devices owned by some participants.	1) Expanding the intervention to reach those who do not have access to mobile phones, which excludes a large portion of the target population. 2) Ensure the app is compatible with various operating systems and phone models, including older/underpowered phones, to maximize accessibility. 3) Consider alternative methods beyond mobile apps to reach those who don't have access to smartphones.
			Privacy and confidentiality	1) Many participants do not have Android smartphones, which is the platform of choice for the app. 2) Even among Android users, many do	1) Password and PIN system to prevent unauthorized access to applications and confidential information.

Author, year & country	Research design	Number of samples	Aspects	Challenge	Chance
		actually 353, which is much lower than the planned sample size.		not have the necessary version of Android or enough RAM to run the app. 3) The app also does not work on some Android tablet devices owned by some participants.	2) Manual verification of participant identities and restriction of access to NHLS databases to authorized personnel. 3) Restricting applications to be downloaded only by individuals who are confirmed HIV positive, rather than making them publicly available.
			User skills	1) Many participants do not have Android smartphones, which is the platform of choice for the app. 2) Even among Android users, many do not have the necessary version of Android or enough RAM to run the app. 3) The app also does not work on some Android tablet devices owned by some participants.	1) Ensure the software development team has sufficient expertise and understanding of the needs of the target population 2) Conduct rapid trials with the target group to identify and address issues 3) Have independent technical experts who assess software development and provide support 4) Ensure the software can run on older and underpowered phones commonly used in the target environment
			Technology reliability	1) The inability to distribute the app through the Google Play Store, requiring manual updates on each phone. 2) Minimum RAM requirements that exclude a large number of participants with low-end Android phones. 3) Incompatibility with some Android tablet devices. 4) Problems with the application successfully receiving and displaying lab results for a large number of participants.	1) The Android platform provides essential functionality for app interventions, such as secure data transmission and push notifications. 2) However, the app requires a relatively recent version of Android that is not supported by more than a third of the participants' phones, thus limiting eligibility. 3) Many of the participants' phones also do not have sufficient RAM to support the app, especially the cheaper smartphone models. 4) The app also unexpectedly had problems working on some Android tablet devices, further limiting recruitment.
			Fees and funding	Not mentioned (the paper does not provide specific details about the overall cost and challenges of research funding)	Not mentioned (this paper does not provide specific information regarding the overall cost of developing and implementing mobile phone application interventions, or potential funding opportunities explored or secured for the project)
			Compliance and regulation	1) The need to maintain the confidentiality of the HIV-positive status of app users, which causes the app to be unavailable to the public on the Google Play Store and requires manual updates. 2) Absence of unique patient identifiers across databases and systems, which makes it difficult to correlate patient data and maintain data quality. 3) Inability to achieve full interoperability between the application, NHLS database, and participant devices, resulting in some participants not receiving their lab results through the application as intended.	1) Develop a unique clinic ID that links the application to a laboratory database to overcome the challenge of linking patient data across multiple systems. 2) Educate patients on the need to carry a form of ID, such as a photo ID, for any mHealth intervention that requires verification of the patient's identity. 3) Expand the use of apps beyond early HIV testing and links to care, in line with the national mHealth strategy, to support other aspects of chronic

Author, year & country	Research design	Number of samples	Aspects	Challenge	Chance
					disease management such as treatment adherence and appointment scheduling.
			Public trust	1) The requirement to have a photo ID card as a form of identity verification is a significant obstacle in registration because many patients do not have this identity card. 2) Researchers must implement additional manual processes to verify patient identities and protect the confidentiality of lab results, which adds complexity to their implementation. 3) Failure of the application to consistently provide lab results to participants weakens the ability to appropriately evaluate the effectiveness of the intervention.	Not mentioned (this paper does not explicitly mention "public trust opportunities")
			Collaboration and integration	1) Lack of full interoperability between the various systems and devices involved, which leads to many participants not receiving their lab results through the app. 2) Lack of unique patient identifiers across different databases, making it very difficult to correlate patient information and lab results. 3) Lack of expertise in the project team in app development, especially for the Android platform, which leads to many technical challenges.	1) Expand the use of the app beyond HIV testing and its relevance to treatment, to also communicate the results of routine monitoring, follow-up measures, and drug availability for patients undergoing ART. 2) Expand services to TB and diabetes patients and improve the functionality of the app to enable healthcare providers to send messages to individual patients about unexpected lab results. 3) Using the app to support study participants, enabling communication between the study site and participants, and potentially enabling the assessment of self-test devices used by patients to monitor their own chronic conditions.
(22), South Africa	The design of the study involved two phases: 1) focused group discussions with rural South Africa youth aged 18-24 years, and 2) direct observation of participants who completed oral HIVST kits and/or blood-based HIVST kits, with sub-phases in which participants could choose which kits to use.	Not mentioned (abstract does not clearly state the total number of samples for this study)	Accessibility	1. Lack of emotional support when undergoing self-tests 2. Cost of HIVST test kits	1) Provide emotional support and counselling in conjunction with HIVST to address issues in self-handling outcomes 2) Ensure the validity and accuracy of HIVST kits to build trust 3) Make HIVST kits affordable and accessible through existing testing campaigns
			Privacy and confidentiality	1) Concerns about the accuracy of HIVST (false positive/negative) results and the ability to emotionally handle results while undergoing the test alone without support. 2) The need for HIVST to be accompanied by emotional support, rather than undergoing testing entirely alone, to address privacy and confidentiality concerns.	1) Ability to perform the test privately and discreetly without having to go to a clinic or test site. 2) Potential increase in test scores due to the privacy and confidentiality provided by HIVST. However, participants also raised concerns about the accuracy of HIVST and the ability to handle the results themselves, suggesting that they wanted HIVST privacy but also support from someone present when they took the test.

Author, year & country	Research design	Number of samples	Aspects	Challenge	Chance
			User skills	1) Concerns about the accuracy of HIVST results and the ability to receive results emotionally 2) A preference for HIVST with emotional support from others 3) More challenges experienced with blood-based HIVST compared to oral HIVST	Not mentioned (abstract does not mention anything about "user skills opportunities" related to HIV self-testing)
			Technology reliability	1) Concerns about the accuracy of HIVST results, including potential false positives and false-negative results 2) Concerns about the emotional impact of receiving HIVST results without any support or counselling.	1) Improve the accuracy and reliability of HIVST results to address concerns about false positive and negative results 2) Provide emotional support and counselling in conjunction with HIVST to help individuals cope with the testing process and results. 3) Ensure that HIVST kits are affordable and accessible to South Africa's youth target population
			Fees and Funding	Not mentioned (abstract does not provide specific details on the "cost and funding challenges" associated with HIVST in South Africa)	Not mentioned (abstract does not provide any information about the cost or funding opportunities for self-contained HIV test kits)
			Compliance and regulation	Not mentioned (abstract does not mention any "compliance and regulatory challenges" associated with HIV self-testing)	Not mentioned (abstract does not mention anything about the "compliance and regulatory opportunities" associated with HIV self-testing)
			Public trust	The main challenges to HIVST-related public trust among South African youth are: 1) concerns about the accuracy and reliability of HIVST, including the potential for false positive and negative results, 2) concerns about individuals' ability to accept their test results without any emotional support, and 3) concerns about the cost of HIVST test kits.	1. Address issues about the validity and reliability of HIVST test results, including the potential for false positive and negative results. 2. Provide emotional support and guidance when using the HIVST test kit, to help individuals cope with the results and feel supported during the testing process. 3. Address the cost of HIVST test kits to ensure they are accessible to target populations.
			Collaboration and integration	Not mentioned (abstract does not mention any "collaboration and integration challenges" associated with HIV self-testing)	Not mentioned (abstract does not mention "collaboration and integration opportunities" related to HIV self-testing)
(23), France and Australia	The design of this research is observational and iterative, using an agile development process and qualitative research methods. This research was carried out in two stages: 1) making and testing prototypes, and 2) conducting pilot studies. The researchers	Not mentioned (the paper does not provide an overall sample size for the entire study)	Accessibility	1. Older doctors and patients have greater difficulty understanding and navigating the app's visual interface compared to younger users. 2. Patients with higher levels of anxiety and stress are more concerned about the confidentiality of apps, which can be an accessibility issue for those with specific mental health needs.	1. Using an iterative, user-centric design approach to ensure the software is accessible and meets the needs of different patient populations. 2. Designed the software to be intuitive and easy to use, without redundant instructions, so that it can be accessed by a wide range of patients. 3. Ensured the software is secure and confidential, which is important for patients with stigmatized conditions such as HIV.
			Privacy and confidentiality	1) Huge concerns about data security and confidentiality among France patients, especially those with migrant backgrounds, who fear their information could be misused or exposed. 2) Increased concerns about	1. Addressing the safety and confidentiality issues of patients, especially those from migrant backgrounds. 2. Ensure the app can be used privately, such as on a

Author, year & country	Research design	Number of samples	Aspects	Challenge	Chance
	used a user-centered design approach and involved patients and clinicians in the design and development process.			confidentiality among Australia patients with higher levels of stress and anxiety when actually using the app, compared to a hypothetical scenario. 3) Patients experience greater privacy when using apps on home computers than mobile devices in public, although people with diseases that are considered bad may be more likely to use online communication with doctors. 4) Doctors in both countries are worried about data security, with French doctors emphasising the issue more compared to Australian doctors.	home computer rather than on a mobile device in a public place. 3. Provide clear information about data security and privacy protection to build patient trust.
			User skills	1. Older patients have greater difficulty understanding the visual interface and navigating the software, which indicates age-related challenges in using digital health apps. 2. Concerns about confidentiality are common, especially among patients with higher levels of anxiety and stress, suggesting that a user's mental health status can affect their perception and acceptance of digital health devices.	1. Younger doctors are more open to using mHealth apps and digital clinical support tools, compared to older doctors. 2. Physicians need training on how to use and interpret the PRO data generated by the app, in order to effectively incorporate it into patient care. 3. Doctors have concerns around data security and confidentiality, including risks associated with data storage and transmission, that need to be addressed.
			Technology reliability	Not mentioned (this paper does not directly address the "challenges of technology reliability" as the main theme)	1. Ensure the confidentiality and security of patient data, especially for those who have high levels of anxiety and stress. 2. Provide adequate user training to prevent communication interruptions. 3. Responding to doctors' concerns about data storage, transmission, and security in the RUMA system
			Fees and funding	Not mentioned (this paper does not mention the "cost and funding challenges" associated with pro software application development)	Not mentioned (the paper does not mention any information about the "costs and funding opportunities" for the software application)
			Compliance and regulation	Not mentioned (this paper does not explicitly address "compliance and regulatory challenges" as the main theme)	1) Data security and confidentiality for patients 2) User training and expectations management for patients and clinicians 3) Integration with existing clinical workflows and IT systems
			Public trust	1) Concerns about data confidentiality and security, especially among France patients and doctors 2) Patients with higher levels of stress and anxiety tend to be more concerned about confidentiality when actually using the software 3) Patients feel greater privacy when using the software on a personal computer at home compared to a mobile device in public	Not mentioned (this paper does not mention the existence of "public trust opportunities")
			Collaboration and integration	1) Synthesizing large amounts of data generated by PRO questionnaires 2) Collecting data between patient visits 3) Integrating PRO results into clinical decision-making 4) Organizational barriers to integrating PRO	1. Integration with medical practice software to allow patients to enter data that can be reviewed by doctors during consultations. 2. Allows the use of validated PRO measures outside of the hospital environment

Author, year & country	Research design	Number of samples	Aspects	Challenge	Chance
				measurements in real-life settings 5) Over-information and complexity of PRO data for physicians to interpret and integrate into consultations	and between patient visits, which are increasingly common in chronic disease management. 3. Potential to integrate a variety of PRO instruments outside just HIV, such as to monitor side effects and treatment adherence.
(12), Tanzania	The design of this study is a three-arm, parallel group randomized controlled trial (RCT).	Not mentioned (the paper does not explicitly state the overall sample size for the study, but provides some information about the number of participants screened and followed up)	Accessibility	1. Poor network coverage and power outages that prevent the proper functioning of mHealth devices. 2. Privacy concerns and fear of accidental disclosure of HIV status. 3. The need for participants to use reminders other than the mHealth intervention.	Not mentioned (this paper does not directly address "accessibility opportunities" as a key topic)
			Privacy and confidentiality	1) Concerns about undesirable disclosure of their HIV status to others if they use mHealth interventions, especially RTMM devices that can disclose their HIV status to the public. 2) Participants who have not disclosed their HIV status to friends/family are hesitant to use the intervention for fear of being accidentally exposed. 3) Participants wanted a neutral message that did not refer to HIV or treatment, to avoid potential disclosure.	1. Using neutral messages that do not refer to topics related to disease or treatment to avoid unwanted disclosure of HIV status. 2. Allow participants to delete SMS text messages after responding to them to prevent others from accessing the message and knowing their HIV status. 3. Consider the privacy concerns of participants who have not disclosed their HIV status to others, as monitoring interventions could potentially reveal their status.
			User skills	1) Difficulty using SMS text messaging interventions correctly, with many participants failing to respond to messages as expected. 2) Difficulty relying on mHealth interventions alone to remember taking medication, which led participants to use additional cues and reminders. 3) Disruption of participants' existing strategies for remembering to take medications, leading to reduced adherence when using mHealth interventions.	Not mentioned (this paper does not directly address "user skills opportunities" as a topic)
			Technology reliability	1) Poor network coverage 2) Power outages 3) Lack of interoperability between network providers. These technical issues resulted in problems in the delivery and functioning of mHealth interventions (SMS text messages and real-time monitoring of medications), resulting in discrepancies between self-reported compliance and compliance recorded by digital tools.	1. Ensure adequate network coverage in participants' homes before implementation 2. Using neutral messages to avoid unwanted disclosure of HIV status 3. Advise participants to continue using the reminder cues they are used to
			Fees and funding	Not mentioned (this paper does not address the "cost and funding challenges" associated with the mhealth interventions used in this study)	Not mentioned (the paper does not mention any information about the "costs and funding opportunities" for the study)
			Compliance and regulation	1) Psychosocial constraints, including fear of disclosing HIV status and lack of social support, leading to low adherence to ART and compliance monitoring tools. 2) Participants continued to rely on their own reminder cues rather than the mHealth interventions provided, which	1) Ensure stable network connectivity in participants' homes prior to implementation 2) Use neutral messages to avoid unwanted disclosure of HIV status 3) Allow participants to continue using their usual

Author, year & country	Research design	Number of samples	Aspects	Challenge	Chance
				showed that the interventions were not fully integrated with their existing compliance strategies.	compliance strategies 4) Develop a triage system to assess patient readiness for mHealth interventions
			Public trust	The main challenges of public trust identified in this paper are concerns about the potential for unwanted disclosure of HIV status and privacy violations related to the use of mHealth technology to monitor ART compliance. Participants expressed concerns that SMS reminders or RTMM devices could reveal their HIV status to family, friends, or community members, undermining their trust in the intervention.	Not mentioned (this paper does not mention the existence of "public trust opportunities")
			Collaboration and integration	1) Differentiate between adherence to the use of digital monitoring tools and adherence to actual medication 2) Integrate mHealth interventions with existing strategies in participants to remember taking their medications 3) Address psychosocial barriers, such as mental health issues and stigma concerns, that may hinder the effective use of mHealth tools	Not mentioned (this paper does not explicitly address "collaboration and integration opportunities")
(13), United States	The design of this research is qualitative research using semi-structured interviews.	- Initial RCT sample: 396 women - Final randomized sample: 71 participants (36 interventions, 35 controls) - Qualitative interview sample: 21 participants	Accessibility	1) Reliable and high-speed internet access and the technology needed (e.g., computers, tablets) can be a major barrier for low-income communities living with HIV. 2) Ensuring secure internet transmission, providing technical assistance for varying hardware/software, and maintaining privacy through additional features are additional challenges for home-based interventions. 3) Accessing interventions from public locations with potentially poor or insecure internet connections can interfere with content delivery and threaten confidentiality.	1) Provide a private, dedicated space with the technology needed in the CBO to improve the experience and accessibility for participants. 2) Improve access for hard-to-reach populations, such as people with disabilities or those living in remote/rural areas, by reducing barriers related to travel through home delivery. 3) Reduce stigma by limiting the need to go to a CBO, which can lead to the disclosure of a person's HIV status to the public.
			Privacy and confidentiality	The main privacy and confidentiality challenges in the delivery of HR-VG interventions at home include: 1) lack of privacy when others are staying at home, 2) concerns about inadvertently disclosing HIV status to others in the home, especially children, and 3) various disturbances in the home environment that can interfere with the privacy and confidentiality of the intervention.	- Accessing interventions at CBOs is seen as an advantage because it has a dedicated private space, which increases attention and safety. - Accessing interventions at home is seen as a disadvantage due to a lack of privacy, especially when there are other people living in the home. - Accessing interventions in CBOs may be a challenge for some WLHs due to the burden of travel, particularly for those living in remote or rural areas. - Accessing interventions at home may also increase the risk of accidentally revealing HIV status to others at home, which is a concern for some participants.
			User skills	1) Reliable and high-speed internet access and the required technology (computers, tablets, etc.) can be a major obstacle for low-income people living with HIV (PLH) to access home-based internet interventions due	Not mentioned (this paper does not directly address "user skills opportunities" as a theme)

Author, year & country	Research design	Number of samples	Aspects	Challenge	Chance
				to the cost involved. 2) A quality internet connection is essential for the proper delivery of internet-based interventions, but internet coverage in rural areas may be inadequate. 3) While the problems of technology access and internet quality can be overcome, there are still other challenges, such as ensuring secure internet transmission, providing technical assistance for hardware/software/internet speed variability, and maintaining privacy through additional features.	
			Technology reliability	1) Consistent, reliable, and high-speed internet access, which can be a major obstacle for low-income PLH. 2) A quality internet connection to ensure adequate delivery and sustainability of the program, which may be lacking in rural areas. 3) Ensure secure internet transmission, provide technical assistance for varying hardware/software/internet, and maintain privacy through additional features.	1) Ensure reliable and high-speed internet access and the necessary technology (computers, tablets, etc.) for low-income communities living with HIV, which can be a major barrier to accessing home-based internet interventions. 2) Provide quality internet connections that can support the adequate provision of internet-based interventions, especially in rural areas where coverage may be inadequate. 3) Addressing the challenges associated with ensuring secure internet transmission, providing technical assistance for various hardware/software, and maintaining privacy through additional features such as chat, headphones, or screen filters.
			Fees and funding	1) Transportation costs for participants to access CBO-based interventions 2) Costs of necessary technology (computers, tablets, high-speed Internet) for home-based interventions, which may not be feasible for low-income PLHs 3) Quality and reliability of Internet connections, especially in rural areas, which are important for the effective delivery of home-based interventions	Not mentioned (this paper does not directly address the "costs and funding opportunities" for HR-VG interventions)
			Compliance and regulation	1) Ensure low-income communities living with HIV have access to the necessary technology (computers, tablets, high-speed internet) to participate. 2) Maintain a high-quality and reliable internet connection to provide effective interventions, especially in rural areas. 3) Ensure secure internet transmission, provide technical assistance for participants' hardware/software variability, and maintain privacy through additional features such as chat, headphones, or screen filters.	Not mentioned (this paper does not address the "compliance and regulatory opportunities" associated with internet-based HIV/AIDS interventions)
			Public trust	Not mentioned (this paper does not address the "public trust challenges" associated with internet-based HIV/AIDS interventions)	Not mentioned (this paper does not mention anything about "public trust opportunities")
			Collaboration and integration	Not mentioned (this paper does not discuss "collaboration and integration challenges" as a theme)	Not mentioned (this paper does not specifically address "collaboration and integration opportunities" as a separate theme or section)

Author, year & country	Research design	Number of samples	Aspects	Challenge	Chance
(14), Dutch	The research design of this study is a mixed-methods pilot study that aims to explore the feasibility and acceptability of social network testing (SNT) using HIV self-testing among men who have sex with men with non-Western migration backgrounds (MSM-NW) in the Netherlands. The study will recruit 50-60 peer recruiters who will distribute 4-5 HIV self-tests each to reach a total of 200 network peers (NAs). Quantitative and qualitative data will be collected from peers and NAs to assess the feasibility and acceptance of the intervention.	The target sample size for the PREVENT study is 200 network associates (NAs) who will receive HIV self-tests, and 50-60 peers who will distribute the tests.	Accessibility	1) Difficulty in collecting accurate data regarding test results, because participants may not report the results or undergo tests outside the study site. 2) Participants may not use the website as they should, resulting in data loss. 3) Language barriers, as the material is only available in 3 languages, although peers may be able to help.	1) Provide free HIV self-testing to hard-to-reach populations such as MSM-NW through their peers, with very low thresholds. 2) Encourage conversations about HIV risk, testing, and barriers in social networks, which can help promote the normalization of HIV testing. 3) Enable anonymous relationships between peers and NAs through integrated online data collection, which allows tracking of HIV self-tests distributed and used.
			Privacy and confidentiality	1) Reliance on self-reported test results by NAs and only collecting data from participating clinics can lead to loss of information regarding test results. 2) NAs may use paper manuals instead of websites, which means their epidemiological data and test results will not be captured. 3) Language barriers can be challenging, as the website and materials are only available in 3 languages.	1) Participants give informed consent before any data is collected. 2) Basic questionnaires only collect limited personal information. 3) Providing an email address for follow-up is voluntary, and refusal does not affect participation.
			User skills	1. Difficulty in gathering accurate data about test results, as NAs may not report their results or conduct tests outside of the study site. 2. NA may not use the website as it should and instead rely on paper manuals, which leads to data loss. 3. Language barriers, as materials are only available in three languages, although peers may be able to help NA overcome this.	1. Ability to explain HIV transmission routes and how self-test HIV works. 2. Motivation to prioritize reaching out to friends/contacts who have never been tested for HIV, have a non-Western migration background, and/or are at high sexual risk. 3. Ability to start a conversation about HIV testing with their network mates.
			Technology reliability	1) Difficulty in collecting test result data accurately, as participants may not report their results or may be tested at a site outside the study. 2) Participants may use paper manuals instead of websites, which leads to a loss of data about their epidemiological information and test results. 3) Language barriers, as the website and materials are only available in three languages, although peers may be able to help bridge these barriers.	This paper shows that the HIV self-test used in the PREVENT pilot study is a reliable technology, with high sensitivity and specificity as reported in previous studies. The study also provides clear instructions and support for peers and NAs on how to use the self-test, including information on window periods and the need for confirmatory testing. Overall, this paper shows that HIV self-testing is a reliable and well-supported technology for the web-based social network testing approach used in the PREVENT trial.
			Fees and funding	Not mentioned (this paper does not mention the existence of "cost and funding challenges" for the prevention pilot study)	Not mentioned (the paper does not mention any details about the cost or funding opportunities for the prevention pilot study)
			Compliance and regulation	Not mentioned (this paper does not specifically address the "compliance and regulatory challenges" faced by prevention studies)	Not mentioned (this paper does not mention the "compliance and regulatory opportunities" associated with the prevention pilot study)

Author, year & country	Research design	Number of samples	Aspects	Challenge	Chance
			Public trust	Not mentioned (this paper does not address the "public trust challenges" faced by prevention studies)	Not mentioned (this paper does not mention anything about "public trust opportunities")
			Collaboration and integration	1) Recruit and retain motivated and willing peer recruiters to contribute to HIV testing in their communities, which is critical to the success of the SNT approach. 2) Reach the target population consisting of 50-60 peers and 200 network peers within a period of 12-18 months, considering the diversity of the population that is difficult to reach. 3) Collect accurate data on test results, as participants may not report their results or conduct testing outside of participating clinics. 4) Ensure NA uses the website as it should, rather than relying solely on paper manuals, to obtain complete epidemiological data.	1) If the PREVENT trial is successful, the approach can be adopted by other clinics or adapted for use in other high-risk populations. 2) The researchers plan to collaborate with participating clinics to promote the trial and engage prospective peer recruiters. 3) The researchers will use the results of the trial to identify opportunities to improve the intervention and its implementation.
(24), Not mentioned (country not mentioned in the abstract)	The design of this study is a pilot study or a concept test study, with the aim of determining the feasibility of self-conducted home HIV testing with video chat-based peer counselling.	The sample size for this study was 20 participants.	Accessibility	1) Logistical barriers to accessing face-to-face testing sites 2) Stigma and concerns about recognition at face-to-face testing sites	The "Accessibility Opportunities" in this study are intended to overcome logistical and emotional barriers to HIV testing for MSIs, particularly BMSMs, through the use of self-administered at-home HIV testing with web-based peer counselling via video chat.
			Privacy and confidentiality	Not mentioned (abstract does not explicitly mention the "privacy and confidentiality challenges" associated with home HIV testing with web-based peer counselling)	1) Address concerns about stigmatization or recognition at the in-person testing site 2) Provide a more private and confidential testing experience compared to clinic-based testing, as evidenced by the majority of participants who prefer an in-home approach 3) Reduce logistical and emotional barriers to testing that can affect privacy and confidentiality
			User skills	Not mentioned (abstract does not mention any "user skills challenges" related to self-conducted home HIV testing with web-based peer counselling)	Not mentioned (abstract doesn't mention anything about "user skill opportunities")
			Technology reliability	Not mentioned (abstract does not mention any "technology reliability challenges" related to self-conducted at-home HIV testing with web-based peer counselling via video chat)	The "Technology Reliability Opportunity" in this study is the feasibility and satisfaction of using home-based HIV testing with web-based peer counselling via video chat for men who have sex with men (MSMS), specifically Black/African-American (BMSM) MSIs.
			Fees and funding	Not mentioned (abstract does not mention anything about the cost or funding challenges of home HIV testing with web-based peer counselling interventions)	Not mentioned (abstract does not provide any information about the cost or funding opportunities for this study)
			Compliance and regulation	Not mentioned (abstract does not mention any "compliance and regulatory challenges" associated with the study)	Not mentioned (abstract does not mention anything about "compliance and regulatory opportunities" related to the research)

Author, year & country	Research design	Number of samples	Aspects	Challenge	Chance
			Public trust	Not mentioned (abstract does not mention any "public trust challenges" associated with the research)	Not mentioned (the abstract doesn't mention anything about "public trust opportunities")
			Collaboration and integration	Not mentioned (the abstract does not mention any "collaboration and integration challenges" related to the study)	Not mentioned (abstract does not mention "collaboration and integration opportunities")
(25), China	The design of this study is a two-arm randomized controlled trial (RCT).	The total sample size for this study was 500 participants, with 250 participants in the intervention group and 250 participants in the control group.	Accessibility	Not mentioned (the paper does not explicitly mention any "accessibility challenges" faced in the study)	1) Recruiting participants through the popular social networking app MSM (Blued) 2) Providing an HIV self-test component through the widely used WeChat messaging app 3) Providing free HIV self-test kits that can be ordered and returned via WeChat
			Privacy and confidentiality	1) The nature of self-reported data, which may be susceptible to bias. 2) The researcher's efforts to validate the self-reported data by linking it to CDC surveillance data and implementing a rigorous review process to identify and exclude participants with multiple logical errors. 3) Use of city-level administrators and triangulation with CDC surveillance data to further validate self-reported data.	Not mentioned (this paper does not explicitly address "privacy and confidentiality opportunities" as a separate section or topic)
			User skills	Not mentioned (the paper does not mention the existence of a "user skills challenge" as part of the study design or intervention)	Not mentioned (the paper doesn't mention anything about "user skills opportunities")
			Technology reliability	Not mentioned (this paper does not mention any "technology reliability challenges" associated with digital crowdsourcing interventions)	Not mentioned (the paper doesn't mention anything about "user skills opportunities"
			Fees and funding	Not mentioned (the paper does not mention the "cost and funding challenges" associated with the research)	Not mentioned (the paper does not mention any details about the cost or funding of the crowdsourced intervention)
			Compliance and regulation	Not mentioned (this paper does not mention any "compliance and regulatory challenges" faced in this study)	Not mentioned (the paper doesn't mention anything about "compliance and regulatory opportunities")
			Public trust	Not mentioned (the paper does not explicitly mention the "public trust challenge" faced by this study)	Not mentioned (this paper makes no mention of anything about "public trust opportunities
			Collaboration and integration	Not mentioned (the paper does not mention any "collaboration and integration challenges" faced in the research)	1) Integrate various crowdsourced components (images, self-testing platforms, local story contests) into a comprehensive intervention. 2) Involve a diverse steering committee consisting of public health professionals, communicators, civil society members, and designers in evaluating crowdsourced strategies. 3) Co-organize a local story contest between the local CDC and the MSM CBO to promote community engagement.

The selection of these aspects was based on a framework derived from previous studies on digital health technologies, which have identified these categories as crucial factors influencing the success and adoption of digital solutions in healthcare. These categories were chosen to reflect the key areas where digital technologies in HIV screening might face challenges or offer opportunities for improvement. The results were then synthesized to provide a comprehensive narrative description of the current state of digital technologies in HIV screening, highlighting key challenges, opportunities, and recommendations for future implementation.

Ethical considerations

The research adheres to ethical principles, ensuring respect for intellectual property rights and transparency in the data selection and analysis process. All data sources are properly cited, and the findings of the study are validated by experts in the field to ensure reliability and validity.

Results

Research overview

Of the 412 articles identified from various databases, 256 articles were screened for relevance to the research question. A total of 166 articles were excluded for the following reasons: they were not published in English (n=59) or did not match the research question (n=107). Among the remaining 122 full-text articles, an additional 134 were excluded because full-text was available (n=72) or irrelevant to HIV testing supported by digital technology. Ultimately, 10 articles met the inclusion criteria for the final review (Figure 1).

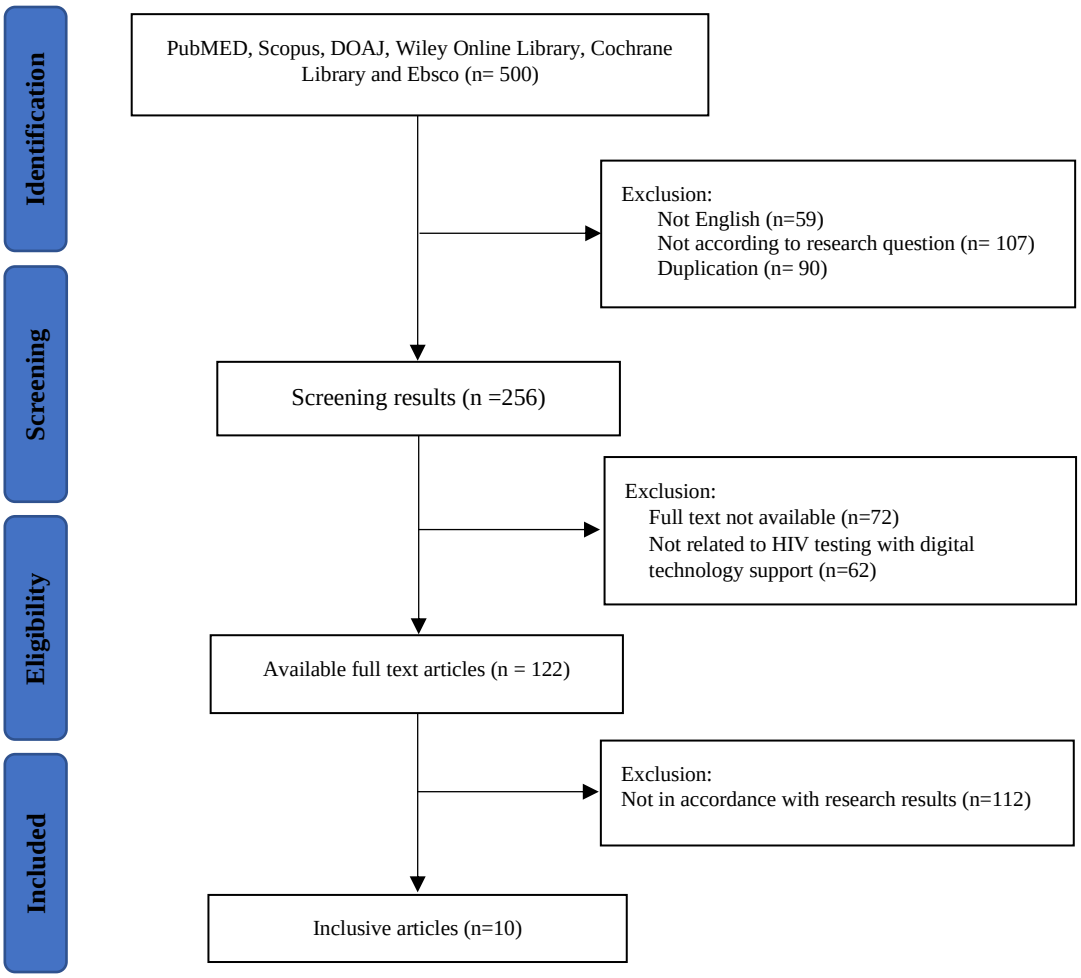

Figure 1. Flowchart for inclusion and exclusion studies

The studies included in this review were conducted in various regions, with the majority originating from the United Kingdom (n= 9, 28.1%) and the United States (n= 7, 21.9%). Research from regions such as South Africa, Canada, and Tanzania was also included, albeit in smaller numbers (Figure 2). The research designs varied and included randomized controlled trials (RCTs), digital intervention trials, case studies, proof of concept studies, and program evaluation or impact assessment. We identified three key themes among the included studies:

1. Technical challenges in the application of digital technologies.
2. The impact of digital technologies on patient engagement.
3. The effectiveness of digital technologies as an aid in HIV screening in various healthcare contexts.

Regional challenges and opportunities for the application of digital technology for HIV testing

Research in different regions shows unique challenges and opportunities in the application of digital technology for HIV testing. In the United Kingdom, technical challenges such as software issues, Wi-Fi access, and limited digital skills among clinic staff are a major concern. However, the integration of digital interventions into routine clinic lines offers significant opportunities to improve patient engagement (9). In Canada, telephone HIV diagnoses are emotionally distressing for patients, but the development of better communication skills can be an effective solution (10). In South Africa, the accessibility of HIVST apps is limited due to incompatible devices, but expanding app compatibility can help address this issue (11). In Tanzania, poor network coverage and power outages affect the functioning of mHealth devices, but the use of neutral messages and the option to delete messages can improve user privacy and security (12). In the United States, the main challenge is technology accessibility and reliable internet connections, but providing private spaces in CBOs and reducing stigma through home-based access offer opportunities to expand the reach of services (13). In the Netherlands, language barriers and accurate data collection are challenges, but the distribution of free HIV tests through social networks and the normalization of conversations about HIV risk can increase public awareness and acceptance of HIV testing (14) (Figure 3). These challenges and opportunities reflect the need for an approach tailored to the local context to maximize the effectiveness of digital technologies in HIV testing.

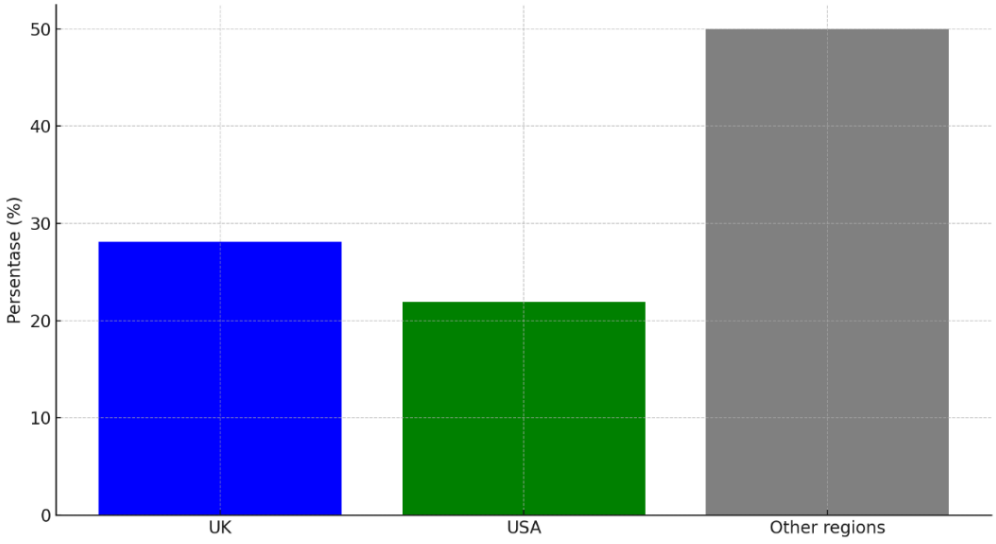

Figure 2. Distribution of research by region

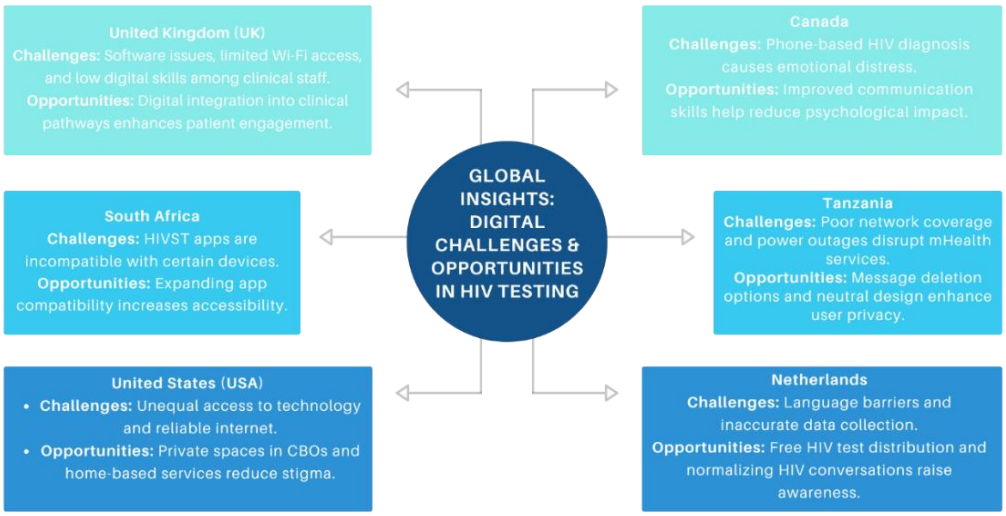

Figure 3. Global analysis: Digital transformation in HIV testing

Challenges and opportunities based on accessibility

Research Bailey et al. (9) found great challenges in the accessibility of digital technologies for HIV testing, mainly due to unstable software and poor Wi-Fi. Clinic staff also face difficulties in directing patients to digital resources, which hinders the adoption of this technology. However, there is an opportunity to improve the situation by integrating digital interventions into routine clinic lines, which can facilitate access and increase patient engagement.

In the study, Grace et al. (10) highlighting the emotional challenges that patients face when receiving an HIV diagnosis over the phone. This indicates an urgent need for improved communication skills among healthcare workers, which can improve the patient experience and support their emotional well-being.

In the study by Azelton et al. (11) focus on the technical challenges faced by HIVST app users, especially since many participants do not have compatible Android devices. While this hinders accessibility, there is a great opportunity to expand app compatibility to more devices and operating systems, which could expand the reach of the HIVST program.

From Tanzania, Ngowi et al. (12) encountered infrastructure challenges such as poor network coverage and power outages, which hindered the use of mHealth devices. However, opportunities to improve user privacy and security can arise through the use of neutral messages and message deletion options, as depicted in Figure 4. This figure highlights the key barriers and potential solutions identified across various studies, including those focused on accessibility, privacy, and infrastructure. The findings from Tanzania are illustrated here, but similar challenges were identified in other regions as well, as detailed in the text. The study by Green et al. (13) identified accessibility challenges in the United States, particularly related to access to technology and the internet among low-income communities. Opportunities to overcome these barriers include providing private spaces in Community-Based Organizations (CBOs), which can improve accessibility and reduce stigma related to HIV testing.

In the Netherlands, the study by De Coul et al. (14) noted challenges related to language barriers and difficulties in data collection, but opportunities arise through the distribution of self-administered HIV tests and the normalization of conversations about HIV risk in the community, which can increase the acceptance and use of these technologies.

Overall, while the challenges of digital technology accessibility for HIV testing are still numerous, the opportunities for improvement and innovation are enormous, especially with

approaches tailored to local needs and improved infrastructure, and better training.

Challenges and opportunities based on privacy and confidentiality

Research related to privacy and confidentiality in digital technologies for HIV testing reveals major challenges, but also opens up opportunities to improve user protection. Bailey et al. (9) noted privacy concerns in the use of digital interventions in clinics, especially if sensitive information is processed over insecure Wi-Fi. The implementation of stronger security protocols can increase user trust. Grace et al. (10) highlighting the emotional distress of patients when receiving an HIV diagnosis over the phone, which can be addressed by ensuring communication is done in a safe place and training healthcare workers to be more sensitive to privacy. Ngowi et al. (12) found that in Tanzania, participants were worried that mHealth devices could inadvertently reveal their HIV status. Software development with neutral messages and message deletion features can reduce this risk. Green et al. (13) noted that in the United States, privacy concerns are a barrier to the use of technology, especially among low-income people. Providing private spaces in CBOs can address this issue and protect user privacy. Although these privacy challenges are complex, there is a great opportunity to improve protection through technological adaptation and awareness-raising, which can strengthen the use of digital technologies in HIV testing.

User skills challenges and opportunities

The challenges of user skills in digital technologies for HIV testing need to be addressed to ensure the adoption and effectiveness of the technology. Bailey et al.(9) noted that the limited digital skills of clinic staff hinder the adoption of this technology, but training can improve staff competence and intervention effectiveness. Grace et al. (10) highlighting the importance of communication skills in delivering test results and remote support, where specialized training can help reduce miscommunication and emotional distress in patients. Azelton et al. (11) shows that the limitations of users' technical skills in using HIVST applications indicate the need for a more intuitive interface and better technical support. Ngowi et al. (12) noted the challenges in Tanzania, where low digital skills hinder the adoption of mHealth technology, but training programs tailored to local needs can help. Overall, this challenge emphasizes the need to invest in training and education, with a great opportunity to upskill through targeted programs and user-friendly interfaces, thereby increasing the adoption and effectiveness of technology in HIV testing.

Challenges and opportunities based on technology reliability

The challenges of technological reliability in HIV testing have greatly impacted its adoption and effectiveness. Bailey et al.(9) showed that in the United Kingdom, unstable software and inconsistent Wi-Fi hindered the use of technology in clinics. Opportunities arise with the improvement of digital infrastructure and more stable software. Ngowi et al. (12) noted a similar problem in Tanzania, where poor networks and power outages made mHealth devices unreliable. Solutions can include technology that functions in minimal infrastructure conditions. Azelton et al. (11) highlighting the challenges in South Africa with HIVST applications often incompatible or crashing, which can be overcome with better testing and software updates. In the United States, Green et al. (13) found that limited internet access affects the reliability of technology, especially among low-income communities. Opportunities include the development of offline options and increased access to affordable internet. By strengthening infrastructure and developing more reliable technologies, these challenges can be overcome, making digital technologies more effective in HIV testing.

Challenges and opportunities based on cost and funding

Research by Bailey et al.(9) highlighting the high-cost challenges for

hardware, software, and training, but looking at opportunities in funding from public health programs and collaborations with governments or international donors. Grace et al. (10) noted the difficulty of maintaining the sustainability of digital technology due to maintenance costs, but proposed sustainable business models such as SaaS to manage costs. Azelton et al. (11) acknowledged the challenges in developing compatible HIVST applications, but saw partnerships with technology companies as a solution to share costs and expand reach. Ngowi et al. (12) highlighted budget constraints in Tanzania, but saw funding opportunities from international programs to support mHealth infrastructure. Green et al. (13) noted cost as a bottleneck in low-income communities in the U.S., but opportunities exist in funding that supports technology in CBOs. De Coul et al.(14) acknowledged the cost challenges in the distribution of self-contained HIV tests in the Netherlands, but saw opportunities in national funding to support broad distribution. Overall, while cost and funding are challenging, there are great opportunities through innovative funding strategies and partnerships.

Challenges and opportunities based on regulatory compliance

Research shows that compliance and regulation are significant challenges in the application of digital technology for HIV testing. Bailey et al.(9) highlighting that strict regulations, especially regarding data privacy and security, often hinder the adoption of technology in clinic environments. However, there is an opportunity to tailor regulations to be more flexible and support innovation without sacrificing patient protection.

Grace et al. (10) underscore the importance of healthcare workers' compliance with protocols when using technology for test results or remote support. Non-compliance can negatively impact patients, but opportunities arise through ongoing training and clearer regulatory guidance.

Azelton et al. (11) discusses regulatory challenges in the development of HIVST applications, where accuracy and security standards must be met. While this can slow down the rollout of apps, working with regulatory bodies can speed up the approval process without sacrificing quality.

Ngowi et al. (12)shows that in Tanzania, regulatory limitations lead to inconsistent adoption of the technology. Opportunities exist in developing strong local regulatory frameworks to support the ethical and effective use of technology.

Green et al. (13) noted that different regulations in each state in the U.S. could hinder widespread adoption of the technology. Harmonization of regulations at the national level can facilitate faster and consistent adoption.

De Coul et al**.** (14) highlighting the importance of regulations that ensure the distribution of self-contained HIV tests according to health standards. While these regulations are important for maintaining quality, there is an opportunity to update them to accommodate new technologies and expand access.

Overall, while compliance and regulation are challenging, there is an opportunity to accelerate technology adoption through regulatory adjustments, training, and collaboration with regulatory bodies to support innovation and patient protection.

Challenges and opportunities based on public trust

Public trust in digital technologies for HIV testing faces significant challenges, especially when it comes to data privacy and security concerns, as noted by Bailey et al. (9). However, opportunities arise with increased transparency and education that can build this trust. Grace et al. (10) emphasize the importance of using empathic technology in delivering test results to reduce stigma and build trust. Azelton et al. (11) noted that the compatibility and reliability of HIVST applications also affect public trust, with the opportunity lying in the development of more user-friendly applications.

Ngowi et al. (12) identified social stigma in Tanzania as a barrier to trust in

mHealth technology, but opportunities exist in designing technology that safeguards privacy and gives users more control. Green et al.(13) see that lack of access and knowledge hinders trust in low-income communities in the U.S., but education and technical support at the community level can increase trust. De Coul et al. (14) highlighted that in the Netherlands, trust can be increased through a wider distribution of self-test HIV tests and the normalization of conversations about HIV.

Overall, despite the challenges, the opportunities to increase public trust through education, transparency, and better technology design are enormous.

Challenges and opportunities based on collaboration and integration

Collaboration and integration of digital technologies for HIV testing face significant challenges, but also offer great opportunities. Bailey et al. (9) emphasizing the importance of partnerships between clinics, governments, and technology providers to facilitate adoption, the opportunity lies in strengthening these collaborations. Grace et al. (10) highlighting the need for the integration of technology into daily clinical practice to ensure optimal use. Azelton et al. (11) see the challenges in integrating HIVST applications with health services, but opportunities exist in developing applications that are connected to the health system.

Ngowi et al. (12) pointed to the lack of integration of mHealth technology in Tanzania as an obstacle to adoption, with opportunities in strengthening cooperation between stakeholders. Green et al. (13) noted the importance of collaboration between CBOs and technology providers in the U.S. to expand access, especially in low-income communities. De Coul et al.(14) emphasized the need for cooperation in the distribution of self-contained HIV tests in the Netherlands, with the integration of technology into existing public health programs as a key opportunity.

Overall, despite the challenges, strengthening collaboration and integration can improve the adoption and effectiveness of digital technologies in HIV testing.

Discussion

In this study, the application of digital technology in HIV testing shows that there are diverse challenges in various regions. The main challenges identified include technology accessibility, privacy, and the reliability of digital infrastructure. However, there is also a great opportunity to improve access, efficiency, and quality of HIV health services through the integration of these technologies.

In regions such as Tanzania and South Africa, technological accessibility remains a major obstacle. In Tanzania, for example, poor network coverage and frequent power outages hinder the adoption of mHealth technology for HIV testing (12). In South Africa, device compatibility limitations have prevented many participants from using the HIVST app (11). Previous research has also highlighted the importance of reliable access to technology to improve health outcomes, especially in areas with limited infrastructure (15). This finding is reinforced by the results of the study Al-Worafi (16), highlighting that inadequate technology infrastructure is often a major obstacle to the adoption of digital health technologies in developing countries.

Concerns regarding privacy and confidentiality have emerged as significant challenges in the implementation of digital technologies. In Tanzania, participants were concerned that the use of mHealth devices could inadvertently reveal their HIV status to others (12). This is in line with the findings of Siddiquee et al. (15), which show that privacy protection is one of the main concerns in the adoption of digital technologies in the healthcare sector. The study also found that software development with message-neutral and message deletion features can reduce the risk of privacy breaches. Further, Alzahrani et al. (17) emphasized that the implementation of stricter digital security standards is necessary to ensure that patient privacy is well protected, especially in the context of healthcare that uses advanced technology.

Technology reliability is also a major challenge, especially in areas with inadequate infrastructure. Research in South Africa and

Tanzania shows that unstable software and unreliable networks hinder the effectiveness of technology in HIV testing (12). These results are consistent with previous studies that emphasized the importance of software stability and reliable access to achieve optimal health outcomes (18). Moreover, Saurin et al. (19) noted that the development of software that is resilient and resistant to infrastructure disruptions is the key to success in the application of digital health technologies, especially in areas with limited resources.

However, while these challenges are significant, the study also identifies a huge opportunity for improved HIV health services through digital technology. In the United Kingdom, for example, the integration of digital interventions into routine clinic lines offers a significant opportunity to increase patient engagement (9). In the United States, the provision of private spaces in Community-Based Organizations (CBOs) can improve accessibility and reduce stigma related to HIV testing (13). These findings emphasize the importance of a locally context-tailored approach to maximizing the effectiveness of digital technology in HIV testing. Moreover, Mumtaz et al. (20) shows that community involvement in the development and implementation of health technology can increase the acceptance and success of digital health programs.

This research has several limitations that need to be considered. First, limited geographic coverage may affect the generalization of the findings, as the main focus of the study is on specific regions such as Tanzania, South Africa, the United Kingdom, and the United States. Second, variations in study design and sample size across studies, which are inherent in scoping reviews, do not affect the goal of this review, which is to explore the broad knowledge available on the topic. As such, these variations are considered part of the diversity of the studies reviewed, rather than a limitation. Additionally, a lack of quality assessment of the studies analysed can lead to bias in conclusions. Third, this study does not delve into the interaction between technology and socio-cultural factors that may affect the acceptance of technology in various regions. Finally, the long-term impact of implementing digital technology in HIV testing has not been fully explored, representing a research gap that warrants further investigation. These findings make a significant contribution to understanding how digital technologies can be effectively integrated into HIV healthcare services. The research supports the theory that adopting new technologies requires adaptation to the local context and enhancing user skills to achieve optimal outcomes. Furthermore, as emphasized in the introduction, the practical application of these findings in practice and policy is crucial. The study offers valuable insights for policymakers and healthcare professionals in designing and implementing digital technology-based HIV testing programs. It highlights the need for approaches tailored to local conditions, ensuring that challenges and opportunities specific to each healthcare setting are addressed, and that the technology is applied effectively for long-term sustainability and impact.

Conclusion

The conclusions of this study show that the application of digital technology in HIV testing offers significant challenges and opportunities. While there are barriers to technology accessibility, privacy, and infrastructure reliability in different regions, these findings also underscore the great potential of digital technologies to improve access, efficiency, and quality of HIV health services. This research not only contributes to the scientific understanding of digital technologies in HIV screening but also offers practical insights that can be implemented in health policies and practices. The integration of digital technology in HIV screening has the potential to transform healthcare delivery, making it more inclusive and responsive to patient needs. The importance of adapting to the local context, improving user skills, and developing adequate infrastructure is key to the successful adoption of this technology. However, to achieve long-term effectiveness,

more research is needed to overcome existing limitations and ensure that digital technologies can be sustainably integrated into healthcare in various contexts.

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Conflict of interest

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