Curr HIV/AIDS Rep (2015) 12:451–461
DOI 10.1007/s11904-015-0291-7

Recent Evidence for Emerging Digital Technologies to Support Global HIV Engagement in Care

Kate Jongbloed [1] · **Sunjit Parmar** [2] · **Mia van der Kop** [3,4] · **Patricia M. Spittal** [1] · **Richard T. Lester** [3]

Published online: 10 October 2015

Abstract Antiretroviral therapy is a powerful tool to reduce morbidity and mortality for the 35 million people living with HIV globally. However, availability of treatment alone is insufficient to meet new UNAIDS 90-90-90 targets calling for rapid scale-up of engagement in HIV care to end the epidemic in 2030. Digital technology interventions (mHealth, eHealth, and telehealth) are emerging as one approach to support lifelong engagement in HIV care. This review synthesizes recent reviews and primary studies published since January 2014 on digital technology interventions for engagement in HIV care after diagnosis. Technologies for health provide emerging and proven solutions to support achievement of the United Nations targets for the generalized HIV-affected population. Much of the existing evidence addresses antiretroviral therapy (ART) adherence; however, studies have begun to investigate programs to support linkage and retention in care as well as interventions to engage key populations facing extensive barriers to care.

Keywords Digital technology · mHealth · eHealth · Telehealth · HIV · Key populations · Engagement · Adherence · Retention

This article is part of the Topical Collection on *HIV and Technology*

✉ Kate Jongbloed
katejongbloed@gmail.com

Sunjit Parmar
sunjit17@gmail.com

Mia van der Kop
miavanderkop@gmail.com

Patricia M. Spittal
spittal@sm.hivnet.ubc.ca

Richard T. Lester
rlester@mail.ubc.ca

1 School of Population & Public Health, University of British Columbia, 2206 E Mall, Vancouver, BC V6T 1Z9, Canada

2 Faculty of Medicine, University of British Columbia, 2350 Health Sciences Mall, Vancouver, BC V6T 1Z3, Canada

3 Division of Infectious Diseases, Faculty of Medicine, University of British Columbia, 566-828 West 10th Avenue, Vancouver, BC V5Z 1L8, Canada

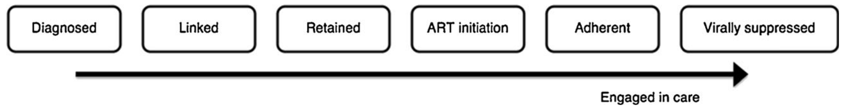
4 Department of Public Health Sciences, Karolinska Institutet, Tomtebodavagen 18a, Campus Solna, Stockholm, Sweden

Introduction

Antiretroviral therapy (ART) is a powerful tool to prevent illness and death for the 35 million people living with HIV globally, as well as to avert new infections [1]. However, availability of treatment alone is insufficient to end the HIV epidemic. Globally, 22 million people, or three out of five people living with HIV, are unable to access treatment [1, 2]. The new UNAIDS 90-90-90 goals aim to end the epidemic in 2030, with 90 % of all people living with HIV knowing their HIV status, 90 % of all those diagnosed with HIV receiving sustained ART, and 90 % of all people receiving ART virally suppressed by 2020 [2].

Digital technology interventions are emerging as one approach to support lifelong engagement in the HIV care continuum: linkage and retention in care, ART initiation and adherence, and viral suppression (Fig. 1) [3]. Approximately 25 million people living with HIV are in sub-Saharan Africa, accounting for nearly 71 % of all people living with HIV globally [1]. With significant proportions of people living with HIV in resource-limited settings, interventions that use technology to respond to the pandemic must be widely accessible or scalable in these contexts. In addition, specialized interventions are required for key populations facing significant

Fig. 1 HIV continuum of care



barriers to treatment—those who are most at risk of becoming the "10-10-10" who are unable to engage in care.

Mobile phones have had enormous reach in resource-limited settings, providing real potential for low-cost adoption to support engagement in HIV care. Accordingly, the majority of studies on HIV engagement technologies have used mobile devices (mHealth), often capitalizing on widely used and available text messaging, or short-message-service (SMS). Point-of-care (POC) diagnostics and other lower cost laboratory testing and monitoring services, together with wireless electronic informatics, provide additional opportunities to improve engagement in HIV care. Furthermore, a smaller but significant portion of the epidemic affects people with access to technologies such as broadband internet, smartphones, and/or social media; thus many innovations are using "Web 2.0" and other advancing technologies.

This review provides an update on evidence for digital technology interventions for engagement in HIV care after diagnosis. Digital technologies examined include mHealth, eHealth, and telehealth, which are not mutually exclusive (Table 1).

Methods

We searched Google Scholar and PubMed for articles published between 01/01/2014 and 05/31/2015 using the keywords HIV, smartphone, telemedicine, ICT, eHealth, and mHealth. Additional articles were identified through searches of technology-focused health journals for HIV-related articles. Articles published in peer-reviewed journals were included if they discussed digital technology interventions in the context of the HIV care continuum. Relevant articles included primary research (qualitative and quantitative), reviews, and commentaries. Conference abstracts, theses, grey literature, protocols, and book chapters were excluded. Articles focused on HIV prevention and HIV-related activism were also excluded. Articles were evaluated, summarized, and synthesized jointly by all authors.

Results

We identified 15 reviews that presented evidence of technology interventions for engagement in HIV care (Table 2). In addition, our search revealed 18 peer-reviewed articles describing new intervention studies (Table 3). Finally, 11 articles described technology use among key populations and feasibility/acceptability of technology interventions for engagement in HIV care (Table 4). Technologies evaluated ranged from simple text messaging via mobile phones to complex smartphone, internet-based interactive platforms, or informatics. Several studies investigated the use of SMS for appointment and medication reminders, while others examined bi-directional SMS programs that supported communication between patients and healthcare providers. Fewer studies investigated other types of healthcare technologies, for example, advances in POC laboratory testing and its role in patient engagement in the care continuum.

Review of Reviews

Linkage to and Retention in Care

Brennan et al. identified five randomized controlled trials (RCTs), two on linkage to care and three on retention in care [4] (Table 2). Only one included trial evaluated a technology intervention: telephone reminders decreased missed appointments from 11.4 to 7.8 % in primary care, and suggested an effect but was underpowered for a subgroup of HIV patients [4]. Overall, this review suggests significant opportunity for research into technology interventions to support linkage to and retention in HIV care.

One systematic review of 24 completed studies and 15 ongoing trials identified by Govindasamy et al. investigated interventions to improve linkage to care, retention in care, and ART initiation in low-income settings observed that the highest quality studies included those that tested POC CD4 testing, patient navigation, rapid ART initiation, and mHealth programs [5]. The rest were limited as they were observational with unclear risk of bias. The authors call for further high-quality studies with key populations, informed by existing evidence on barriers to care [5].

Muessig et al. identified 23 intervention and 32 pre-trial funded project publications assessing technologies that require services beyond text messaging, including eHealth, mHealth, and Web 2.0 social media interventions spanning HIV prevention and the continuum of care [6••]. Their findings suggest that significant gaps remain around linkage to care, retention in care, and ART initiation [6••].

Finally, Robustillo Cortes et al. conducted a review of smartphone apps related to HIV/AIDS and assessed each for quality and main strengths and weaknesses [7]. Of 41 apps developed before 2012, only 1 (*Practice HIV*) was of exceptional quality, and 50 % did not achieve minimum quality

Table 1 Types of digital technology interventions for engagement in HIV care

Term	Definition
mHealth	Use of mobile devices, including phones, smartphones, and tablets, for health.
eHealth	Use of internet for health, for example, electronic medical records (eMR) and Web 2.0 initiatives.
Telehealth	Use of electronic information and telecommunications technologies to support long-distance healthcare.

standards. Overall, quality of existing HIV-related smartphone apps is generally low.

ART Adherence

In this issue, interventions to support adherence have been comprehensively reviewed by Amico [8]. Briefly, we identified several reviews published on interventions to improve ART adherence with the use of technologies. These include a network meta-analysis [9••], a rapid systematic review [10], four meta-analyses [11, 12••, 13, 14], a descriptive narrative evaluation [15], and two systematic reviews [16, 17]. Overall, these reviews concluded that mHealth interventions, and those that used SMS in particular, improved adherence [9, 11, 12••, 16]. Taken together, the evidence supported weekly (versus daily) contact with patients [9, 11], and personalized, two-way interaction [11, 12]. The greater adherence benefit found with two-way text messaging may be explained by opportunity for social contact for otherwise isolated patients and improved communication between patients and care providers [12]. Despite the consistency of the findings, some authors called for rigorous, longer-term studies to gauge the efficacy of mHealth interventions on adherence over time [16].

Summary

Results from reviews demonstrate considerable evidence supporting mHealth for ART adherence. Several reviews revealed important distinctions in what works and what does not. Overall, programs that enhance communication between healthcare providers and patients have the greatest success in improving treatment adherence, and the evidence for text messaging is more developed than for more complex technologies. Significant gaps remain in development and testing of technology interventions for linkage, retention, and ART initiation.

Of note, there was substantial overlap in the HIV-related technology studies included in these reviews. Overall, study quality is an issue and bias remains a risk in interpreting the evidence. In a review seeking high-quality studies of interventions enhancing adherence to ART, only 10 of the 49 improved both ART adherence and a clinical outcome, and many had a high risk of bias [17]. Similarly, in Anglada-Martinez et al.'s review, only one trial [18] was considered to have low risk of bias [13] using the Cochrane Collaboration tool to assess risk of bias. Future assessments of ART adherence interventions should consider measuring clinical outcomes to determine the intervention's effect on patient health and investigators should ensure study designs minimize risk of bias. Furthermore, the HIV continuum of care is lifelong; subsequently, longer-term trials and cohorts are required to assess real-world effectiveness over time.

Although some reviews of engagement in care interventions focused on key populations, including young people [19] and African-American women [20], these reviews did not identify any technology interventions for these particular groups. There is a paucity of current research on tailored technological interventions to support key populations to engage in HIV care.

Recent Primary Studies

Linkage to Care

HIV testing often occurs at sites that do not automatically link into care, such as community voluntary counseling and testing sites and home-based testing. The period immediately after testing HIV-positive is a critical time. However, no studies were identified that evaluated technology interventions to improve linkage to care, suggesting that this is a key area requiring innovation (Table 3).

Retention in Care

Successful HIV treatment depends on sustained, lifelong engagement in care. As a result, researchers are increasingly interested in interventions that support people living with HIV to remain engaged over time. Nine articles measured the effect of a variety of technology interventions on retention in care [21–29]. mHealth appears to be the predominant mode for delivery as all but two of the retention in care studies tested mHealth interventions or an mHealth hybrid program.

A small RCT (n=52) among adults attending an HIV clinic in Durham, North Carolina found no difference in clinic attendance among those who received SMS appointment reminders, compared to controls (72 % versus 81 %, p=0.42) [21]. However, this study may be limited by small sample size and because 24 % of intervention participants did not receive reminders because of phone disconnection [21]. The authors

Table 2 Recent reviews that include studies of digital technologies for engagement in HIV care

Author, publication year	Years covered	No. studies included	Review design	Digital technology	HIV continuum stage	Key population or context
Anglada-Martinez et al. (2014) [13]	Up to March 2014	20 studies	Systematic review	mHealth (SMS or smartphone app)	Adherence (in general)	–
Brennan et al. (2014) [4]	1966 to present	5 RCTs	Systematic review	Interventions (in general)	Linkage, retention	–
Chaiyachati et al. (2014) [10]	2010 to 2012	124 RCTs	Rapid systematic review	Interventions (in general)	Adherence	–
Finitsis et al. (2014) [11]	1990 to 2013	8 RCTs	Meta-analysis	mHealth (SMS)	Adherence	–
Govindasamy et al. (2014) [5]	2004 to 2013	24 completed studies, 15 ongoing	Systematic review	Interventions (in general)	Linkage, retention, ART initiation	Low-income settings
Kannisto et al. (2014) [15]	2003 to 2013	60 studies	Descriptive narrative evaluation	mHealth (SMS reminders)	Adherence	–
Langebeek et al. (2015) [14]	1996 to 2014	13 RCTs	Meta-analysis	Electronic medication monitoring devices	Adherence	–
MacPherson et al. (2015) [19]	2001 to 2014	11 studies	Systematic review	Interventions (in general)	Linkage, retention and adherence	Young people
Mbuagbaw et al. (2015) [17]	Up to December 2013	49 RCTs	Systematic review	Interventions (in general)	Adherence	–
Mills et al. (2014) [9••]	Up to October 2014	14 RCTs	Network meta-analysis	Interventions (in general)	Adherence	Africa
Muessig et al. (2015) [6••]	2013 to 2014	23 completed studies, 32 ongoing	Systematic review	eHealth, mHealth, Web 2.0	Full continuum	–
Park et al. (2014) [16]	2002 to 2013	29 studies	Systematic review	mHealth (SMS)	Adherence	–
Robustillo Cortes et al. (2014) [7]	Up to December 2012	41 apps	Review	mHealth (smartphone apps)	Not specified	–
Tufts et al. (2015) [20]	1985 and 2013	0 RCTs, 14 ongoing trials	Systematic review	mHealth	Not specified	African-American women
Wald et al. (2015) [12••]	None specified	8 RCTs	Meta-analysis	mHealth (SMS)	Adherence	–

Table 3 New evidence of digital technologies for engagement in HIV care

Author (year)	Study design	Sample	Location	Digital technology	HIV continuum stage	Key population or context
Belzer et al. (2014) [37]	RCT	Young people living with HIV (n=37)	USA	mHealth and telehealth	Adherence and viral suppression	Young people
Bigna et al. (2014) [23••]	RCT	Carers of children infected with/exposed to HIV (n=242)	Cameroon	mHealth and telehealth	Retention	PMTCT
Côté et al. (2015) [33]	Quasi-experimental	People living with HIV (n=179)	Canada	eHealth	Adherence	–
Crouch et al. (2015) [32]	Cross-sectional	Veterans living with HIV (n=40)	USA	eHealth (ePHR)	Adherence and viral suppression	Veterans
Dryden-Peterson et al. (2015) [30••]	RCT	Pregnant women with HIV (n=366)	Botswana	mHealth (SMS)	ART initiation	PMTCT
Finocchario-Kessler et al. (2014) [25]	Observational pilot	Mother-infant pairs (n=843)	Kenya	mHealth and eHealth	Retention	PMTCT
Hao et al. (2015) [27]	Qualitative	Clinics (n=6)	Swaziland	mHealth	Retention	Laboratory
Jirawison et al. (2015) [29]	Observational	People living with HIV (n=103)	Thailand	Telehealth	Retention	POC screening
Moore et al. (2015) [38•]	RCT	People living with HIV w/ coexisting bipolar disorder (n=50)	USA	mHealth	Adherence	Co-morbidities
Norton et al. (2014) [21]	RCT	Adults living with HIV (n=52)	USA	mHealth (SMS appointment reminders)	Retention	–
Oluoch et al. (2014) [31]	Observational (population-level)	People living with HIV (n=7,298)	Kenya	eHealth (eMR)	ART initiation	Rural
Oluoch et al. (2015) [22]	Observational (population-level)	Patients recieving pre-ART care (n=18523)	Kenya	eHealth (eMR)	Retention	Rural
Perera et al. (2014) [34]	RCT	People living with HIV (n=28)	New Zealand	mHealth (smartphone app)	Adherence and viral suppression	–
Schwartz et al. (2015) [24]	Observational pilot	Pregnant women with HIV (n=50)	South Africa	mHealth	Retention	PMTCT
Shet et al. (2014) [35]	RCT	ART-naïve patients (n=631)	India	mHealth and telehealth	Adherence and viral suppression	Rural
Siedner et al. (2015) [28•]	RCT	People living with HIV (n=385)	Uganda	mHealth	Retention	Rural; Laboratory
Swendeman et al. (2015) [36]	Mixed-methods pilot	People living with HIV (n=46)	India	telehealth	Adherence	–
Young et al. (2014) [39]	Observational	Prisoners living with HIV (n=687)	USA	telehealth	Viral suppression	Prisoners

concluded that an effect was not observed due to "logistical challenges" in implementing reminders [21].

Oluoch et al. used a retrospective population-level study to determine changes in quality of pre-ART care before and after introduction of an eMR system in 17 rural HIV clinics in Kenya [22]. They found that among 18,523 patients receiving pre-ART care, those who received care using an eMR (n=3047) were significantly more likely to receive a CD4 test (OR 1.59, 95 % CI 1.49–1.69) [22].

Retention for HIV-Related Maternal and Child Health

Evaluating technology interventions for retention in care for prevention of mother-to-child transmission (PMTCT) is an important area of research as three out of ten pregnant women living with HIV do not receive ART, and one child becomes infected with HIV every two minutes [1]. Furthermore, only 24 % of 3.2 million children living with HIV globally are currently receiving HIV treatment [1]. Without treatment, approximately one third of children living with HIV die by their first birthday and half die by their second [1]. Three recent studies in sub-Saharan Africa used technology to improve retention in care for infants and caregivers.

An RCT of 242 carers of children infected with/exposed to HIV in Cameroon found that reminders sent via concomitant SMS and mobile phone call were most effective in improving appointment attendance (OR 7.5, 95 % CI 2.9–19.0; p<0.0001), although text messaging alone was more cost-effective (OR 2.9, 95 % CI 1.3–6.3; p=0.012) [23••].

Fifty HIV-positive pregnant women attending a clinic in Johannesburg, South Africa participated in a pilot study to test the potential of mobile phone case management to improve infant HIV testing and maternal retention in care [24]. Outcomes among pilot study participants were compared to 50 similar women attending the clinic in the period immediately preceding the intervention [24]. There were no differences in maternal retention in care between the two groups; however, infants were more likely to be tested for HIV in the pilot study group [24]. Furthermore, intervention participants reported that the emotional support, information, and reminders were helpful to them [24].

Mother-infant pairs attending two hospitals in Kenya were enrolled in an observational pilot study before (n=320) and during implementation (n=523) of the HIV infant tracking system (*HITSystem*), a hybrid Internet/SMS program to improve the flow of laboratory testing and alert mothers when results are ready [25]. Researchers observed an increase in the proportion of HIV-exposed infants retained in care as well as those initiated on ART during the intervention [25].

Clinical and Laboratory Interventions to Improve Retention in Care

With a worldwide push to build laboratory capacity toward global treatment goals, digital technology interventions to improve laboratory testing processes and notification are relevant [2]. Furthermore, point-of-care (POC) diagnostics are a developing area essential for preventing patient attrition from HIV care and ensuring opportunistic infections are promptly identified and addressed [26].

In Swaziland, six clinics were provided with mobile phones equipped to receive patient lab test results via SMS. A qualitative study observed improved turn-around time as compared to the standard paper report delivery system [27].

Siedner et al.'s trial to evaluate the efficacy of an SMS application to notify people living with HIV (n=385) of laboratory results in rural Uganda found that those with concerning results and higher literacy were more likely return to clinic (OR 3.81, 95 % CI 1.61–9.03, p=0.002) [28•]. Literacy at enrollment was strongly associated with response to SMS notifications [28•].

Jirawison et al. tested telemedicine to improve POC screening of a common HIV-related opportunistic infection, Cytomegalovirus (CMV) retinitis, among 103 patients attending an HIV clinic in Thailand [29]. Compared to gold standard diagnostic tests, the digital screening program was less sensitive but may present an opportunity to more rapidly identify severe retinitis that poses an immediate threat to vision [29].

In summary, recent evidence on technology interventions for retention in HIV care, including those for PMTCT and laboratory processes and notification, is promising. However, several studies were small pilot studies or used observational and qualitative study designs. Larger, longer-term RCTs are needed. Furthermore, a majority of studies were set in sub-Saharan Africa; as barriers to retention in care may be quite different in other contexts, additional research is required.

Antiretroviral Initiation and Adherence

Despite recommendations for earlier initiation of ART, time to initiation and adherence remain a challenge. Ten papers published since January 2014 provide new evidence on technology interventions for ART initiation and adherence.

Dryden-Peterson et al. conducted a stepped-wedge cluster RCT to test the effect of an automated SMS platform to relay CD4 results for 366 pregnant women with HIV attending 20 antenatal clinics in Botswana [30••]. Time-to-delivery of CD4 results from lab to clinic was reduced from 16 to 6 days (p<0.001) [30••]. However, ART initiation was still low among intervention participants (36.4 %) and not significantly different from the control group (OR 1.06, 95 % CI 0.53–2.13, p=0.87) [30••].

Oluoch et al. conducted a second study, this time to determine efficacy of an eMR on ART initiation among 7298 patients from 17 Kenyan clinics [31]. Patients in the eMR group had a 22 % increase in odds of initiating ART, compared to patients in a paper-based system (OR 1.22, 95 % CI 1.12–1.33) [31]. However, one limitation in eMR deployment in many clinical settings in Africa is that data is often not entered or accessible real-time during patient visits, and instead functions as records for monitoring and evaluation rather than enhanced clinical care.

eMRs may also present an opportunity for patient engagement by making personal health information available online. A cross-sectional study examined *My HealtheVet*, an electronic personal health record (ePHR), to engage veterans living with HIV in San Francisco, USA. Greater patient activation and satisfaction, viral suppression, and awareness of current health status were observed among those using ePHR (n=20) compared to controls (n=20) [32]. No differences between groups were observed in terms of CD4 count, provider satisfaction, healthcare empowerment score, or ART adherence [32]. In addition, Côté et al. in Montreal, Canada tested a virtual nursing intervention for HIV self-management (*VIH-TAVIE*) using a quasi-experimental design (n=179); however, adherence among patients receiving online follow-up was no different than among controls [33].

Perera et al. evaluated a smartphone application to send graphical representations of plasma ART concentrations and viral load using an RCT in Auckland, New Zealand (n=28). Intervention participants had lower viral load (p=0.023) and improved adherence (p=0.03) at 3 months [34].

In an RCT among 631 ART-naïve patients in rural South India, Shet et al. found no difference in time to virological failure (HR 0.98, 95 % CI 0.67–1.47, p=0.95) or adherence (IRR 1.24, 95 % CI 0.93–1.65) between participants receiving customized, interactive, automated voice reminders, plus a weekly pictorial message, compared to participants receiving standard of care [35].

Swendeman et al. conducted a mixed-method pilot study (n=46) of an automated twice-daily interactive voice response intervention to support ART adherence in Kolkata, India [36]. A pre-post design showed significant increases in self-reported adherence at 1 month (p=0.05) and a longer-term randomized trial is now underway [36].

Citing mobile phones as a convenient, culturally relevant means of communicating with youth, Belzer et al. performed a six-month RCT involving 37 young people living with HIV 15–24 in five US cities. Intervention participants (n=19), who received daily mobile phone calls to confirm medication adherence plus problem solving support, reported greater adherence (p=0.007) and reduced viral load (p=0.043), compared to controls [37]. However, findings should be considered carefully as seven of 19 intervention participants were removed from the study after missing more than 20 % of calls, going off medication for ≥14 consecutive days, or missing calls for 10 consecutive days [37]. This punitive approach may exclude the very participants struggling the most to engage in care.

In a 30-day RCT involving 50 people living with HIV with coexisting bipolar disorder in San Diego, USA, Moore et al. found that those receiving individualized two-way, medication SMS reminders (*iTAB*) had similar adherence to controls for both psychotropic and antiretroviral medications, but took medication closer to intended dosing time (p=0.02) [38•].

Young et al. compared the efficacy of subspecialty HIV care via telemedicine to on-site management by a correctional physician in an Illinois, USA prison [39]. The observational study (n=687) demonstrated improved odds of virologic suppression in the telemedicine group despite the same number of visits (OR 7.0, 95 % CI 5.1–9.8, p<0.001) [39]. Despite the relatively low quality of evidence provided by this study, it is an important contribution [40, 41]. Globally, 10 million people are incarcerated at any point in time and 30 million spend time in prison each year [1]. In addition, people with HIV are over-represented in prisons due to criminalization of many HIV risk behaviors, including same-sex sex, intravenous drug use, and sex work. Prisoners are at risk of HIV treatment interruption and face considerable unmet healthcare needs [1]. As a result, Young et al.'s study is a critical starting point to understand how technology interventions can support engagement in HIV care for prisoners and ensure continuity of care upon release.

Emerging Research

Of note, several research teams investigated mobile phone and Internet use patterns among key populations and in varied settings, suggesting that intervention studies may follow (Table 4). Preliminary work on technology interventions for engagement in HIV care for mothers and infants is underway in both Cameroon [42] and South Africa [43]. Researchers in Kampala, Uganda presented pre-trial findings on acceptability of an mHealth intervention among adolescents living with HIV [44], as well as prevalence and correlates of mobile phone use among youth living in slum areas [45]. One Latin American study assessed feasibility of mHealth among transgender women and men who have sex with men living with HIV in Lima, Peru [46]. Two American studies published early results on technology use patterns and feasibility of technology interventions for HIV care and support among women in the Bronx, New York [47, 48]. Also in New York, researchers performed a content analysis of online interactions in a Facebook group for young people aged 16–25 living with HIV, observing that group participants frequently sought out social support in this context [49]. Notably, these American studies explicitly discussed the potential for digital technologies to provide social support, a shift from much of the existing

Table 4 Emerging research on the feasibility of digital technologies for engagement in HIV care

Author (year)	Study design	Sample	Location	Assessment	Key population or context
Bigna et al. (2014) [42]	Cross-sectional	Adult caregivers of HIV-exposed/ infected children (n=301)	Cameroon	Literacy; phone ownership; mHealth acceptance	PMTCT
Blackstock et al. (2014) [48]	Qualitative	Women living with HIV (n=27)	USA	Potential for online peer group for social support	Women
Blackstock et al. (2015) [47]	Cross-sectional	Women living with HIV (n=103)	USA	Internet use patterns	Women
Clouse et al. (2015) [43]	Cross-sectional	Pregnant women with HIV (n=50)	South Africa	Mobile phone, Internet, and email use	PMTCT
Gaysynsky et al. (2014) [49]	Qualitative	Participants in private Facebook group for HIV-positive young people (16–25) (n=43)	USA	Evaluate a Facebook group for HIV clinic young adult program	Young people
Krishnan et al. (2014) [46]	Cross-sectional	MSM and TGW living with HIV (n=359)	Peru	Communication technology access/utilization; mHealth acceptance	MSM; transgender women
Madhvani et al. (2015) [50]	Cross-sectional	People living with HIV receiving ART (n=883)	South Africa	Correlates of use of mobile phones for reminders	–
Rana et al. (2015) [44]	Qualitative	Young people (15–24) living with HIV (n=39)	Uganda	Barriers to mHealth; perceived mechanisms of mHealth	Young people
Reid et al. (2014) [52]	Cross-sectional	Adults living with HIV enrolled in an mHealth RCT (n=83)	Botswana	Opinions and attitudes to SMS reminders	–
Smillie et al. (2014) [51]	Qualitative	People living with HIV (n=15) and healthcare providers (n=5)	Kenya	Use of mobile phones; perceptions of communicating via text message with healthcare providers	–
Swahn et al. (2014) [45]	Cross-sectional	Young people (14–24) living on the streets or in slums (n=457)	Uganda	Prevalence and correlates of mobile phone ownership and use	Young people
Xiao et al. (2014) [53]	Cross-sectional	Adults living with HIV (n=801)	China	Acceptability and factors associated with willingness to receive mHealth	–

evidence that has focused on reminders [44]. Finally, related stage-setting work is also being done with adults living with HIV in Soweto, South Africa [50], Nairobi, Kenya [51], Gaborone, Botswana [52], and Anhui, China [53]. Overall, these feasibility and acceptability findings indicate that mobile phones remain the most ubiquitous digital technology especially in low-income settings. However, it is important to consider unique barriers to access in different contexts.

Discussion

Established and emerging evidence on digital technology interventions to support people living with HIV sustain lifelong engagement in care indicate that these are critical tools to help achieve the UNAIDS 90-90-90 targets. However, evidence also demonstrates that not all technological interventions are equally effective. So far, the evidence suggests that weekly, two-way interactive text messaging is likely the most effective intervention, and has the advantage to reach millions of people living with HIV, primarily in sub-Saharan Africa where the HIV burden is highest and basic cellular coverage is nearing ubiquity. Now is the time to scale up programs that are evidence-based, while continuing to innovate for specialized settings and key populations.

Much of the new evidence related to technology interventions for engagement in HIV care has focused on mHealth to support ART adherence. However, several important studies have investigated new areas and applications, such as providing timely laboratory results and supporting retention in care. It is exciting to note that some studies are bringing technology-driven interventions to key populations, including maternal and child health, young people, prisoners, and veterans. Furthermore, although many studies continue to take place in sub-Saharan Africa, recent work in North America, Asia, and Oceania suggests that digital technologies are emerging for engagement in HIV care globally.

Despite these important contributions, notably missing from the evidence are technology interventions that support engagement in care for Indigenous people, migrants, displaced people, people who use drugs, men who have sex with men, transgender women, and sex workers [1, 2]. These are key populations who face significant and complex barriers to HIV care and treatment, including stigma and discrimination in healthcare settings [54–57]. Criminalization of several key populations through laws against sex work, drug use, and same-sex sex further marginalize these groups from care and services [1, 2]. Furthermore, the four million young people aged 15–24 living with HIV globally have been identified as a critical group experiencing multiple barriers to engagement in care, but for whom few targeted interventions are being developed and evaluated [1, 19]. In reaching for the 90-90-90 targets, relegating these key populations to the “10-10-10”, those who are left behind, is a risk. There is a clear need to adapt digital technology interventions to meet the specific needs of these key populations and empower them to engage in lifelong care.

Technology-driven interventions may be powerful tools to reach hard-to-engage groups, if targeted to these key populations. Recent research has shown that by facilitating communication between patients and health services, and supporting connection with peers [48], two-way communication technology is a formidable vehicle for psychosocial support [44, 51, 58, 59]. Others have begun to discuss the power of community input and ownership to develop technology interventions that are valued and acceptable in diverse communities [36, 60–63]. Furthermore, new studies have taken a "whole-person" approach to technological engagement in care interventions that acknowledge and support multiple health needs and priorities, such as co-morbidities and substance use [38•, 60, 61].

Careful consideration of the barriers to technology—which may be the same barriers that prevent people from fully engaging in HIV care—are also vital. For programs to be accessible, clients must either have access to or be provided with the technology at study initiation. Several studies reviewed here observed below-average mobile phone and Internet access within target populations [64]. Digital illiteracy may also be a significant obstacle, including among the elderly. In response, some have provided mobile phones as part of mHealth studies to reach clients that may not have had the opportunity to enroll otherwise [37, 58]. However, struggles with phone loss and participant non-adherence remain a challenge [37, 58]. Furthermore, programs that embrace technologies that are already a part of peoples' daily lives may be more successful than those that require learning new skills or creating new digital habits.

Conclusion

Reaching the UNAIDS 90-90-90 target has the potential to reduce 90 % of new infections and 80 % of HIV-related mortality by 2030. For these goals to be met, substantial improvements in reducing gaps in care for children, adolescents, and key populations are critical [2]. Technologies for health provide emerging and proven solutions to support achievement of these targets for engagement in HIV care, particularly among the generalized HIV-affected population in sub-Saharan Africa. Simple two-way interactive text messaging, to provide support rather than as a medication reminder, is an evidence-based technological intervention for engagement in care that is able to reach the majority of people with HIV. Opportunities for more complex technological interventions exist in resource-rich settings, and are emerging in resource-limited settings, but current evidence of their effectiveness remains weaker. Additional research is required for tailored technology innovations to support key populations.

Compliance with Ethics Guidelines

Conflict of Interest Ms. Jongbloed, Mr. Parmar, Ms. Van der Kop, and Dr. Spittal declare that they have no conflict of interest. Dr. Lester reports personal fees and other from WelTel International mHealth Society, grants from Grand Challenges Canada, grants from US National Institutes of Health Research, grants from Canadian Institutes of Health Research, and grants from Canadian HIV Clinical Trials Network, outside the submitted work.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

1. UNAIDS. The gap report. Geneva: Joint United Nations Programme on HIV/AIDS (UNAIDS). 2014.
2. UNAIDS. 90-90-90: an ambitious treatment target to help end the AIDS epidemic. Geneva: Joint United Nations Programme on HIV/AIDS (UNAIDS). 2014.
3. Gardner EM, McLees MP, Steiner JF, del Rio C, Burman WJ. The spectrum of engagement in HIV care and its relevance to test-and-treat strategies for prevention of HIV infection. Clin Infect Dis. 2011;52:793–800.
4. Brennan A, Browne JP, Horgan M. A systematic review of health service interventions to improve linkage with or retention in HIV care. AIDS Care. 2014;26:804–12.
5. Govindasamy D, Meghij J, Negussi EK, Baggaley RC, Ford N, Kranzer K. Interventions to improve or facilitate linkage to or retention in pre-ART (HIV) care and initiation of ART in low-and middle-income settings–a systematic review. J Int AIDS Soc. 2014;17:19032. doi:10.7448/IAS.17.1.19032.
6. •• Muessig KE, Nekkanti M, Bauermeister J, Bull S, Hightow-Weidman LB. A systematic review of recent smartphone, Internet and Web 2.0 interventions to address the HIV continuum of care. Curr HIV/AIDS Rep. 2015;12:173–90. **This article is a comprehensive review of digital technologies excluding SMS for engagement in HIV care along the continuum from primary prevention through to secondary prevention.**
7. Robustillo Cortés MDLA, Cantudo Cuenca MR, Morillo Verdugo R, Calvo Cidoncha E. High quantity but limited quality in healthcare applications intended for HIV-infected patients. Telemed e-Health. 2014;20:729–35.
8. Amico KR. Evidence for Technology Interventions to Promote ART Adherence in Adult Populations: a Review of the Literature 2012–2015. Curr HIV/AIDS Rep. 2015. doi:10.1007/s11904-015-0286-4.
9. •• Mills, E. J., Lester, R., Thorlund, K., Lorenzi, M., Muldoon, K., Kanters, S., Linnemayr, S., Gross, R., Calderon, Y., Amico, K. R., & others. Interventions to promote adherence to antiretroviral therapy in Africa: a network meta-analysis. The Lancet HIV. 2014;1:

e104–e111. **This review is a comprehensive evaluation of interventions for ART adherence in Africa, paying important attention to nuances of programs (ie, SMS reminders versus supportive texting) to provide a clear picture of what works and what does not in the context of the generalized epidemic of sub-Saharan Africa**.

10. Chaiyachati KH, Ogbuoji O, Price M, Suthar AB, Negussie EK, Bärnighausen T. Interventions to improve adherence to antiretroviral therapy: a rapid systematic review. AIDS. 2014;28:S187–204.
11. Finitsis DJ, Pellowski JA, Johnson BT. Text message intervention designs to promote adherence to antiretroviral therapy (ART): a meta-analysis of randomized controlled trials. PLoS One. 2014. doi:10.1371/journal.pone.0088166.
12.•• Wald DS, Butt S, Bestwick JP. One-way versus two-way text messaging on improving medication adherence: meta-analysis of randomized trials. Am J Med. 2015. doi:10.1016/j.amjmed.2015.05.035. **This review article used a meta-analysis to evaluate differences in the impact of mHealth SMS programs that provide one-way versus two-way texting, providing insight the specifics of mHealth success**.
13. Anglada-Martinez H, Riu-Viladoms G, Martin-Conde M, Rovira-Illamola M, Sotoca-Momblona J, & Codina-Jane C. Does mHealth increase adherence to medication? Results of a systematic review. Int J Clin Pract. 2015. doi:10.1111/ijcp.12582.13.
14. Langebeek N, Nieuwkerk P. Electronic medication monitoring-informed counseling to improve adherence to combination antiretroviral therapy and virologic treatment outcomes: a meta-analysis. Front Public Health. 2015. doi:10.3389/fpubh.2015.00139.
15. Kannisto KA, Koivunen MH, Välimäki MA. Use of mobile phone text message reminders in health care services: a narrative literature review. J Med Internet Res. 2014. doi:10.2196/jmir.3442.
16. Park LG, Howie-Esquivel J, Dracup K. A quantitative systematic review of the efficacy of mobile phone interventions to improve medication adherence. J Adv Nurs. 2014;70:1932–53.
17. Mbuagbaw L, Sivaramalingam B, Navarro T, Hobson N, Keepanasseril A, Wilczynski NJ, et al. Interventions for enhancing adherence to antiretroviral therapy (ART): a systematic review of high quality studies. AIDS Patient Care STDs. 2015;29:248–66.
18. Lester RT, Ritvo P, Mills EJ, Kariri A, Karanja S, Chung MH, et al. Effects of a mobile phone short message service on antiretroviral treatment adherence in Kenya (WelTel Kenya1): a randomised trial. Lancet. 2010;376:1838–45.
19. MacPherson P, Munthali C, Ferguson J, Armstrong A, Kranzer K, Ferrand RA, et al. Service delivery interventions to improve adolescents' linkage, retention and adherence to antiretroviral therapy and HIV care. Tropical Med Int Health. 2015;20:1015–32.
20. Tufts KA, Johnson KF, Shepherd JG, Lee J-Y, Ajzoon MSB, Mahan LB, et al. Novel interventions for HIV self-management in African American women: a systematic review of mHealth interventions. J Assoc Nurses AIDS Care. 2015;26:139–50.
21. Norton BL, Person AK, Castillo C, Pastrana C, Subramanian M, Stout JE. Barriers to using text message appointment reminders in an HIV clinic. Telemed e-health. 2014;20:86–9.
22. Oluoch T, Kwaro D, Ssempijja V, Katana A, Langat P, Okeyo N, et al. Better adherence to pre-antiretroviral therapy guidelines after implementing an electronic medical record system in rural Kenyan HIV clinics: a multicenter pre–post study. Int J Infect Dis. 2015;33:109–13.
23.•• Bigna JJR, Noubiap JJN, Kouanfack C, Plottel CS, Koulla-Shiro S. Effect of mobile phone reminders on follow-up medical care of children exposed to or infected with HIV in Cameroon (MORE CARE): a multicentre, single-blind, factorial, randomised controlled trial. Lancet Infect Dis. 2014;14:600–8. **One of the larger randomized controlled trials to evaluate the potential for mHealth for retention in care for mothers and prevention of mother-to-child transmission**.
24. Schwartz SR, Clouse K, Yende N, Van Rie A, Bassett J, Ratshefola M, et al. Acceptability and feasibility of a mobile phone-based case management intervention to retain mothers and infants from an option B+ program in postpartum HIV care. Matern Child Health J. 2015;19:2029–37.
25. Finocchario-Kessler S, Gautney BJ, Khamadi S, Okoth V, Goggin K, Spinler JK, et al. If you text them, they will come: using the HIV infant tracking system to improve early infant diagnosis quality and retention in Kenya. AIDS. 2014;28:S313–21.
26. Alemnji G, Fonjungo P, Van Der Pol B, Peter T, Kantor R, Nkengasong J. The centrality of laboratory services in the HIV treatment and prevention cascade: The need for effective linkages and referrals in resource-limited settings. AIDS Patient Care STDs. 2014;28:268–73.
27. Hao W-R, Hsu Y-H, Chen K-C, Li H-C, Iqbal U, Nguyen P-A, et al. LabPush: a pilot study of providing remote clinics with laboratory results via short message service (SMS) in Swaziland, Africa—a qualitative study. Comput Methods Prog Biomed. 2015;118:77–83.
28.• Siedner MJ, Haberer JE, Bangsberg DR. Know your audience: predictors of success for a patient-centered texting app to augment linkage to HIV care in rural Uganda. J Med Internet Res. 2015. doi:10.2196/jmir.3859. **One of the first trials to evaluate efficacy of an SMS intervention to provide laboratory results. Observed that those notified of abnormal results with high literacy were more likely to return to hospital**.
29. Jirawison C, Yen M, Leenasirimakul P, Chen J, Guadanant S, Kunavisarut P, et al. Telemedicine screening for cytomegalovirus retinitis at the point of care for human immunodeficiency virus infection. JAMA Ophthalmol. 2015;133:198–205.
30.•• Dryden-Peterson S, Bennett K, Hughes MD, Veres A, John O, Pradhananga R, et al. An augmented SMS intervention to improve access to antenatal CD4 testing and ART initiation in HIV-infected pregnant women: a cluster randomized trial. PLoS One. 2015. doi:10.1371/journal.pone.0117181. **This article described a randomized trial to improve ART initiation via SMS-enabled relaying of CD4 count results from lab to clinic. While time to delivery of results was significantly reduced, ART initiation remained low and was no different in intervention arm compared to control**.
31. Oluoch T, Katana A, Ssempijja V, Kwaro D, Langat P, Kimanga D, et al. Electronic medical record systems are associated with appropriate placement of HIV patients on antiretroviral therapy in rural health facilities in Kenya: a retrospective pre-post study. J Am Med Inform Assoc. 2014;21:1009–14.
32. Crouch P-CB, Rose CD, Johnson M, Janson SL. A pilot study to evaluate the magnitude of association of the use of electronic personal health records with patient activation and empowerment in HIV-infected veterans. Peer J. 2015. doi:10.7717/peerj.852.
33. Côté J, Godin G, Ramirez-Garcia P, Rouleau G, Bourbonnais A, Guéhéneuc Y-G, et al. Virtual intervention to support self-management of antiretroviral therapy among people living with HIV. J Med Internet Res. 2015. doi:10.2196/jmir.3264.
34. Perera AI, Thomas MG, Moore JO, Faasse K, Petrie KJ. Effect of a smartphone application incorporating personalized health-related imagery on adherence to antiretroviral therapy: a randomized clinical trial. AIDS Patient Care STDs. 2014;28:579–86.
35. Shet A, De Costa A, Kumarasamy N, Rodrigues R, Rewari BB, Ashorn P, et al. Effect of mobile telephone reminders on treatment outcome in HIV: evidence from a randomised controlled trial in India. BMJ. 2014. doi:10.1136/bmj.g5978.
36. Swendeman D, Jana S, Ray P, Mindry D, Das M, Bhakta B. Development and pilot testing of daily interactive voice response (IVR) calls to support antiretroviral adherence in India: a mixed-methods pilot study. AIDS Behav. 2015;19:142–55.
37. Belzer, M. E., Naar-King, S., Olson, J., Sarr, M., Thornton, S., Kahana, S. Y., Gaur, A. H., Clark, L. F., for HIV/AIDS

Interventions, A. M. T. N., & et al. The use of cell phone support for non-adherent HIV-infected youth and young adults: an initial randomized and controlled intervention trial. AIDS Behav. 2014;18: 686–696.

38.• Moore DJ, Poquette A, Casaletto KB, Gouaux B, Montoya JL, Posada C, et al. Individualized texting for adherence building (iTAB): improving antiretroviral dose timing among HIV-infected persons with co-occurring bipolar disorder. AIDS Behav. 2015;19: 459–71. **This article presents findings from a small randomized controlled trial of two-way SMS medication reminders for people living with HIV and bi-polar disorder. While the small study did not observe an effect, it is important as it presents a new area of mHealth interventions that treats the patient as a whole person with multiple simultaneous health needs**.

39. Young JD, Patel M, Badowski M, Mackesy-Amiti ME, Vaughn P, Shicker L, et al. Improved virologic suppression with HIV subspecialty care in a large prison system using telemedicine: an observational study with historical controls. Clin Infect Dis. 2014;59:123–6.

40. Patel MC, Young JD. Delivering HIV subspecialty care in prisons utilizing telemedicine. Dis Mon. 2014;60:196–200.

41. Young JD, Patel M. HIV subspecialty care in correctional facilities using telemedicine. J Correct Health Care. 2015;21:177–85.

42. Bigna JJ, Noubiap JJ, Plottel CS, Kouanfack C, Koulla-Shiro S. Barriers to the implementation of mobile phone reminders in pediatric HIV care: a pre-trial analysis of the Cameroonian MORE CARE study. BMC Health Serv Res. 2014. doi:10.1186/s12913-014-0523-3.

43. Clouse K, Schwartz SR, Van Rie A, Bassett J, Vermund SH, Pettifor AE. High mobile phone ownership, but low Internet and email usage among pregnant, HIV-infected women attending antenatal care in Johannesburg. J Telemed Telecare. 2015;21:104–7.

44. Rana Y, Haberer J, Huang H, Kambugu A, Mukasa B, Thirumurthy H, et al. Short message service (SMS)-based intervention to improve treatment adherence among HIV-positive youth in Uganda: focus group findings. PLoS One. 2015. doi:10.1371/journal.pone.0125187.

45. Swahn MH, Braunstein S, Kasirye R. Demographic and psychosocial characteristics of mobile phone ownership and usage among youth living in the slums of Kampala, Urganda. West J Emerg Med. 2014;15:600–3.

46. Krishnan A, Ferro EG, Weikum D, Vagenas P, Lama JR, Sanchez J, et al. Communication technology use and mHealth acceptance among HIV-infected men who have sex with men in Peru: implications for HIV prevention and treatment. AIDS Care. 2015;27:273–82.

47. Blackstock OJ, Haughton LJ, Garner RY, Horvath KJ, Norwood C, Cunningham CO. General and health-related Internet use among an urban, community-based sample of HIV-positive women: implications for intervention development. AIDS Care. 2015;27:536–44.

48. Blackstock OJ, Shah PA, Haughton LJ, Horvath KJ, Cunningham CO. HIV-infected women's perspectives on the use of the internet for social support: a potential role for online group-based interventions. J Assoc Nurses AIDS Care. 2014;26:411–9.

49. Gaysynsky A, Romansky-Poulin K, Arpadi S. "My YAP Family": analysis of a Facebook group for young adults living with HIV. AIDS Behav. 2014;19:947–62.

50. Madhvani N, Longinetti E, Santacatterina M, Forsberg BC, El-Khatib Z. Correlates of mobile phone use in HIV care: results from a cross-sectional study in South Africa. Prev Med Rep. 2015;2: 512–6.

51. Smillie K, Borek NV, Kop MLVD, Lukhwaro A, Li N, Karanja S, et al. Mobile health for early retention in HIV care: a qualitative study in Kenya (WelTel Retain). Afr J AIDS Res. 2014;13:331–8.

52. Reid MJ, Dhar SI, Mark C, Liang P, Thompson J, Gabaitiri L, et al. Opinions and attitudes of participants in a RCT examining the efficacy of SMS reminders to enhance antiretroviral adherence: a cross sectional survey. J Acquir Immune Defic Syndr. 2014;65:e86–8.

53. Xiao Y, Ji G, Tian C, Li H, Biao W, Hu Z. Acceptability and factors associated with willingness to receive short messages for improving antiretroviral therapy adherence in China. AIDS Care. 2014;26: 952–8.

54. Allan B, Smylie J. First Peoples, second class treatment: The role of racism in the health and well-being of Indigenous peoples in Canada. Toronto: Wellesley Institute; 2015.

55. Wolfe D, Carrieri MP, Shepard D. Treatment and care for injecting drug users with HIV infection: a review of barriers and ways forward. Lancet. 2010;376:355–66.

56. Milloy M-J, Montaner J, Wood E. Barriers to HIV treatment among people who use injection drugs: implications for 'treatment as prevention'. Curr Opin HIV AIDS. 2012;7:332–8.

57. Goldenberg, S. M., Montaner, J., Duff, P., Nguyen, P., Dobrer, S., Guillemi, S., & Shannon, K. Structural Barriers to Antiretroviral Therapy Among Sex Workers Living with HIV: Findings of a Longitudinal Study in Vancouver, Canada. AIDS Behav. 2015.

58. Smillie K, Van Borek N, Abaki J, Pick N, Maan EJ, Friesen K, et al. A qualitative study investigating the use of a mobile phone short message service designed to improve HIV adherence and retention in care in Canada (WelTel BC1). J Assoc Nurses AIDS Care. 2014;25:614–25.

59. Mahal D, van der Kop M, Murray M, Jongbloed K, Patel A, Momin Kazi M, et al. Mobile health: an update on BC projects that use WelTel to enhance patient care. BC Med J. 2014;56:90.

60. Ingersoll K, Dillingham R, Reynolds G, Hettema J, Freeman J, Hosseinbor S, et al. Development of a personalized bidirectional text messaging tool for HIV adherence assessment and intervention among substance abusers. J Subst Abus Treat. 2014;46:66–73.

61. Montoya JL, Georges S, Poquette A, Depp CA, Atkinson JH, Moore DJ. Refining a personalized mHealth intervention to promote medication adherence among HIV+ methamphetamine users. AIDS Care. 2014;26:1477–81.

62. Jacobs RJ, Caballero J, Ownby RL, Kane MN. Development of a culturally appropriate computer-delivered tailored internet-based health literacy intervention for spanish-dominant hispanics living with HIV. BMC Med Inf Decis Making. 2014;14:103.

63. Mbuagbaw L, Bonono-Momnougui R-C, Thabane L, Kouanfack C, Smieja M, Ongolo-Zogo P. A framework for community ownership of a text messaging programme to improve adherence to antiretroviral therapy and client-provider communication: a mixed methods study. BMC Health Serv Res. 2014;14:441.

64. Rose CD, Cuca YP, Kamitani E, Eng S, Zepf R, Draughon J, et al. Using interactive web-based screening, brief intervention and referral to treatment in an urban, safety-Net HIV clinic. AIDS Behav. 2015;19:186–93.