Electronic and other new media technology interventions for HIV care and prevention: a systematic review

Kevin M Maloney1,§, Anna Bratcher2, Ryan Wilkerson1 and Patrick S Sullivan1

§Corresponding author: Kevin M Maloney, 1520 Clifton Road, Atlanta, Georgia 30322, USA. Tel: 404-727-0483. (kevin.maloney@emory.edu)

Abstract

Introduction: Electronic and other new media technologies (eHealth) can facilitate large-scale dissemination of information and effective delivery of interventions for HIV care and prevention. There is a need to both monitor a rapidly changing pipeline of technology-based care and prevention methods and to assess whether the interventions are appropriately diversified. We systematically review and critically appraise the research pipeline of eHealth interventions for HIV care and prevention, including published studies and other funded projects.

Methods: Two peer-reviewed literature databases were searched for studies describing the development, trial testing or implementation of new technology interventions, published from September 2014 to September 2018. The National Institutes of Health database of grants was searched for interventions still in development. Interventions were included if eHealth was utilized and an outcome directly related to HIV treatment or prevention was targeted. We summarized each intervention including the stage of development, eHealth mode of delivery, target population and stage of the HIV care and prevention continua targeted.

Results and discussion: Of 2178 articles in the published literature, 113 were included with 84 unique interventions described. The interventions utilize a variety of eHealth technologies and target various points on the prevention and care continua, with greater emphasis on education, behaviour change and testing than linkage to medical care. There were a variety of interventions for HIV care support but none for PrEP care. Most interventions were developed for populations in high income countries. An additional 62 interventions with funding were found in the development pipeline, with greater emphasis on managing HIV and PrEP care.

Conclusions: Our systematic review found a robust collection of eHealth interventions in the published literature as well as unpublished interventions still in development. In the published literature, there is an imbalance of interventions favouring education and behaviour change over linkage to care, retention in care, and adherence, especially for PrEP. The next generation of interventions already in the pipeline might address these neglected areas of care and prevention, but the development process is slow. Researchers need new methods for more efficient and expedited intervention development so that current and future needs are addressed.

Keywords: eHealth; mobile applications; smartphones; social media; primary prevention; secondary prevention

Additional information may be found under the Supporting Information tab for this article.

Received 26 February 2019; Accepted 4 December 2019

Copyright © 2020 The Authors. Journal of the International AIDS Society published by John Wiley & Sons Ltd on behalf of the International AIDS Society. This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

1 | INTRODUCTION

Care and prevention interventions for HIV stand at the intersection of two important trends. First, the models of care for people living with HIV and those at risk for HIV have become increasingly reliant on biomedical interventions (HIV treatment and pre-exposure prophylaxis (PrEP)), and have converged on a conceptual framework of care continua (the HIV care continuum and the PrEP continuum) [1–4]. The care continua are tools to measure the proportion of the population aware of their HIV status and engaged in various stages of HIV or PrEP care, including linkage to care, initiation of treatment, retention in care, adherence, and suppression (for people living with HIV). Second, there has been a proliferation of technology-based delivery mechanisms for treatment and prevention, including electronic (eHealth) and mobile (mHealth) technology approaches. Mobile and other emerging electronic technologies, collectively referred to hereafter as eHealth, are attractive tools for health communication and innovation of traditional HIV interventions. These technologies can facilitate large-scale dissemination of information and effective delivery of tools to promote and maintain behavioural modification.
routine testing of HIV among uninfected individuals, and linkage to HIV treatment or PrEP. Examples include smartphone applications (apps) for locating HIV testing services, web-based modules to improve communication in sexual partnerships, and digital games to educate adolescents about substance use and HIV risk. A recent review of eHealth interventions related to HIV prevention and care through 2014 catalogued publications about interventions in development, and noted trends towards use of social networking sites, real-time assessment and feedback, and gamification [5].

At the crossroads of a maturing conception of serostatus-neutral HIV care and prevention and rapidly changing technology, there is a need to both monitor a rapidly changing pipeline of technology-based prevention methods, and to assess whether the research being conducted is appropriately distributed across the care and prevention continua. For example care and prevention indicators typically monitor distal phases of the continua (e.g. HIV viral suppression for people living with HIV; PrEP uptake for HIV-negative people at risk for HIV) [6,7]. In the United States, only 51% of people living with HIV aged ≥13 years are virally suppressed [8,9], and <5% of men who have sex with men (MSM) with PrEP indications have used PrEP [10]. But interventions might need to address more proximal aspects of the continua (e.g. linkage to care, increasing awareness of PrEP), and it is important to examine the adequacy of the pipeline of interventions addressing these proximal steps in the continua. To illustrate this, we present HIV care and prevention continua, combining elements of the HIV care and PrEP continua with traditional approaches to HIV prevention, including testing, education and behavioural change. We have provided an illustration of these continua and examples of interventions (Figure 1).

We conducted a systematic review of published literature and of public data on funded NIH grants to describe technology-based interventions for HIV care and prevention, and to assess the relative distribution of those interventions on the care and prevention continua.

2 | METHODS

We conducted a systematic review of published literature and publicly funded research, updating the methodology outlined by Muessig et al to assess what progress has been made since their systematic review of the literature within the framework of the prevention and care continua [5]. Briefly, we searched the PubMed and Web of Science databases using the dates 1 September 2014 to 1 September 2018 with the search term “HIV” in combination with any of the following: “mobile health”; “mHealth”; “mobile phone”; "cell phone"; "smartphone"; “social media”; “mobile application”; "app"; "eHealth"; “Internet”; or “game”. Article titles and abstracts were reviewed for relevance, and candidate articles were reviewed in full for final inclusion in the study.

We selected papers for which an intervention was clearly described, piloted or tested, including research and development protocols, with a primary or secondary outcome directly related to HIV treatment or prevention. We defined “intervention” broadly, to include any eHealth resource, tool or product which can be used to educate, motivate behaviour change, link users to external resources and/or support prevention activities. For example the included intervention may: educate users about risk factors for HIV transmission; help users implement behavioural changes to reduce their risk for HIV acquisition or transmission; link users to local sexual health clinics; or support medication adherence. In addition, we selected only those interventions which utilize new technology and have the potential to be scaled and reach a large population. We therefore excluded interventions which utilize text (email or SMS) or recorded voice messaging as the only component(s) of the intervention, as well as interventions which use an in-person component. We also excluded: conference proceedings; articles focused exclusively on formative information gathering (e.g. a paper describing focus group reactions to an intervention prototype would be included, but a focus group discussion of acceptability and preferences for a hypothetical intervention which has not yet been developed would not be included); and interventions for general health or generic support for managing any chronic disease.

From each article, we recorded intervention and study characteristics: the intervention name (if any), a brief description of the intervention, sample size, a brief description of the study, and study results. We also abstracted information about the target population for the intervention: HIV serostatus (HIV negative; HIV positive or both), age, gender, sexual orientation, race and ethnicity and substance use. We categorized each article (not mutually exclusive) based on the eHealth mode used (web-based; smartphone app; social media; and/or game), the stage of the HIV care or prevention continua that was targeted (testing; education; behaviour change; linkage to sexual healthcare if HIV negative; PrEP care support; linkage to HIV care if HIV positive; and/or HIV care support), and the publication stage (early developmental; trial protocol; intervention-only pilot trial; real-world evaluation; or randomized controlled trial (RCT)). For interventions described in more than one publication, we assigned one publication stage based on the most advanced study design, in order from early development to RCT. Examples of interventions and their placement within the HIV treatment and prevention continua are shown in Figure 1.

We also searched the National Institutes of Health Research Portfolio Online Reporting Tools (NIH-RePORT) for interventions still in the research pipeline. Our search, completed on 14 August 2018, included projects awarded funding in fiscal year(s) 2017 and/or 2018, as well as all other active projects. We used a more recent data range than the review of interventions in the published literature, in order to capture current trends in innovation by cataloguing projects with more recent funding. We used the same search strategy as used for peer-reviewed publications. Project titles and abstracts were reviewed using the same inclusion and exclusion criteria for interventions in the published literature. Because these studies are ongoing, the interventions were not described in detail; therefore, we looked for basic summary information (often only 1 to 2 sentences) which indicated that development or testing of an intervention is a project aim, the intervention will utilize relevant new technology, and no indication of the exclusion criteria. To exclude interventions which were found in the published literature review, projects identified in the NIH-RePORT were matched to the list of published interventions using the name of the intervention (if known), study author and project investigator names, project description, and any
Figure 1. Target points on the HIV care and prevention continua with examples of interventions.

Examples of eHealth interventions found in a systematic review of peer reviewed literature (2014–2018). †Denotes an unpublished intervention in the research pipeline.
The interventions are presented in Table 1, organized by services, describing 84 unique interventions for HIV prevention. We included 113 articles, describing 84 unique interventions for HIV prevention. The interventions are presented in Table 1, organized by eHealth mode of delivery and HIV serostatus population, with indication of the target point on the HIV care and prevention continua which the intervention addresses (additional intervention and study detail provided in Table S1).

We found 48 interventions (57%) designed solely for HIV-negative users and 24 (29%) for only HIV-positive users. Twelve (14%) additional interventions could be used by either HIV-negative or HIV-positive users. The distribution of the interventions along the care and prevention continua can be seen in Figure 2. Around one third of the interventions (n = 27; 32%) linked users to HIV testing services or served to adjutct home testing. Some of these testing interventions also provided the important bridge to HIV care for patients with positive results (n = 10; 37%) or to sexual health services for patients with negative results (n = 9; 33%). Among interventions for HIV-negative users, most included an educational component (n = 44; 73%) and/or direct support for behaviour change (n = 30; 50%). Fewer facilitated linkage to clinical care (n = 11; 18%), where individualized counselling, routine HIV and STI screening, and access to biomedical interventions, such as PrEP, can occur. We found no interventions that were designed to support PrEP adherence or persistence. The interventions for HIV-positive users were more evenly distributed along the prevention and care continua, including education (n = 21; 58%), behaviour change (n = 16; 44%), linkage to HIV care services (n = 15; 42%), and/or HIV care support (n = 18; 50%), including ART adherence.

The interventions were often designed for special populations, including MSM (n = 45; 54%), adolescents or young adults (n = 31; 37%), racial or ethnic minorities (n = 24; 29%), women (n = 7; 8%), transgender persons (n = 2; 2%), and/or persons who use drugs or alcohol (n = 8; 10%). Vulnerable or high-risk groups, with intersectional identities and risk behaviours, were targeted with tailored interventions. Among the interventions for MSM, 13 (29%) targeted youth and 13 (29%) were for racial and ethnic minorities; four interventions (9%) were for young MSM of colour. Similarly, the 24 interventions for racial or ethnic minority populations were tailored for youth (n = 10; 42%) and women (n = 5; 21%). The majority (n = 71; 85%) of interventions were developed for users in resource rich countries. The remaining (n = 13; 15%) were intended to address the unique cultural needs of specific communities in low- or middle-income countries.

Web-based products, including traditional websites, messaging boards and modular content (e.g. interactive videos and quizzes), were the most common medium used for delivery of the interventions (n = 46; 55%), followed by apps (n = 33; 39%). We found eight interventions (10%) that communicated information using interactive gaming, including both web- and app-based formats. Some of the interventions utilized existing social media platforms (n = 12; 14%) to reach large audiences with content, facilitate social support networks, and/or generate broad community discussion.

Most of the interventions (n = 58; 69%) were fully developed at the time of the most recent publication, with RCT (n = 28; 33%), intervention-only pilot trial (n = 20; 24%) or real-world evaluation (n = 10; 12%) results reported. The remaining interventions were still in early developmental stages (n = 10; 12%) or described in conjunction with a protocol for an ongoing or future RCT (n = 15; 18%). Among RCTs, the format for control or placebo conditions was widely variable. For example some studies used a standard-of-care or no-intervention control condition, whereas others implemented a control condition designed to isolate the effects of either the intervention content or the mode of delivery. In studies testing the effect of the intervention content, placebo or general health content was delivered with technology comparable to the intervention (e.g. a game designed to improve HIV knowledge was compared to a control game that provided no health content) [11]. Alternatively, to test the effects of new technologies, the control condition used traditional media formats to present content that was substantively the same or similar as the intervention (e.g. an individually tailored web intervention to connect users with relevant sexual health services was compared to a control condition that provided a simple sortable list of clinic locations) [12].

Using NIH-RePORT, we identified 422 projects with funding in the years 2017 or 2018 or continued active support awarded in prior years. We removed 152 duplicate entries (consecutive annual funding for ongoing work), leaving 270 unique projects eligible for review. Of these, 81 projects met inclusion criteria: 19 were matched to the published literature review and excluded, leaving 62 interventions in the research pipeline.

We found 41 interventions (66%) in the research pipeline focused on HIV-negative users and 28 (45%) for HIV-positive users; seven (11%) of the interventions had features for both populations. Overall, 19 (31%) of the projects aim to promote or facilitate HIV testing. Among potential future interventions for HIV-negative users, 14 (34%) will include educational content, 17 (41%) will promote behavioural modification, 9 (22%) will link users to clinical care, and 13 (29%) will support PrEP care. The interventions for HIV-positive users will include components for education (n = 4; 14%), behavioural modification (n = 10; 36%), linkage to care (n = 4; 14%) and HIV care support (n = 22; 79%). Figure 2 shows how these interventions would contribute to the existing collection of interventions represented in the published literature.

Our systematic review found a robust collection of eHealth interventions, spanning important populations at risk for HIV, a balance of interventions addressing the prevention and care continua, and a wide variety of eHealth platforms. A major finding is that, for interventions in both the prevention and care continua, there is a greater representation of studies addressing more proximal steps in the continua than the distal steps. Thus, our review illustrates the need for more
Table 1. eHealth interventions found in the published literature, 2014 to 2018, organized by eHealth mode of delivery and HIV serostatus population, and categorized by the targeted point on the HIV care and prevention continua

| Mode       | Population        | Citations                                                                 | Intervention Name          | Education | Behaviour | Testing | Linkage | Support |
|------------|-------------------|---------------------------------------------------------------------------|---------------------------|-----------|-----------|---------|---------|---------|
| App        | HIV--             | Browne et al. [20]                                                        | mHealth Young Women's CoOp (YWC) | •         | •         |         |         |         |
|            |                   | Cordova et al. [21]                                                       | Storytelling 4 Empowerment | •         |           |         |         |         |
|            |                   | Besoain et al. [22]                                                       |                           |           |           |         |         |         |
|            |                   | Scott et al. [24]                                                         |                           |           |           |         |         |         |
|            |                   | Goldenberg et al. [25]                                                    | HealthMindr               | •         |           |         |         |         |
|            |                   | Goldenberg et al. [26]                                                    |                           |           |           |         |         |         |
|            |                   | Sullivan et al. [27]                                                      |                           |           |           |         |         |         |
|            |                   | Winskel et al. [28]                                                       | Tumaini                   | •         |           |         |         |         |
|            |                   | Wray et al. [29]                                                          | cTEST                     |           |           |         |         |         |
|            |                   | Bauermeister et al. [12]                                                  | Get Connected!            | •         |           |         |         |         |
|            |                   | Bauermeister et al. [30]                                                  |                           |           |           |         |         |         |
|            |                   | Horvath et al. [31]                                                       |                           |           |           |         |         |         |
|            | HIV+              | Yan et al. [32]                                                           |                           | •         |           |         | •       |         |
|            |                   | Yang et al. [33]                                                          | emocha                    | •         |           |         | •       |         |
|            |                   | Flickinger et al. [34]                                                    | PositiveLinks             | •         |           |         | •       |         |
|            |                   | Flickinger et al. [35]                                                    |                           |           |           |         | •       |         |
|            |                   | Flickinger et al. [36]                                                    |                           |           |           |         | •       |         |
|            |                   | Flickinger et al. [37]                                                    |                           |           |           |         | •       |         |
|            |                   | Dworkin et al. [38]                                                       |                           |           |           |         |         |         |
|            |                   | Himelhoch et al. [39]                                                     | Heart2HAART               |           |           |         |         |         |
|            |                   | Jacobs et al. [40]                                                        |                           |           |           |         |         |         |
|            |                   | Martin et al. [41]                                                        | Care4Today                |           |           |         |         |         |
|            |                   | Perera et al. [42]                                                        |                           |           |           |         |         |         |
|            |                   | Swendeman et al. [43]                                                     |                           |           |           |         |         |         |
|            | HIV-- or HIV+     | Venter et al. [44]                                                        | SmartLink                 |           |           |         |         |         |
|            |                   | Westergard et al. [45]                                                    | mPeer2Peer                |           |           |         |         |         |
|            |                   | Levy et al. [46]                                                          |                           |           |           | •       |         |         |
|            |                   | Osbahr et al. [47]                                                        | HIV/Hepatitis Education   |           |           |         |         | •       |
|            |                   | Reback et al. [48]                                                        | Getting Off: Methamphetamine |           |           |         |         | •       |
|            |                   | Steinberg et al. [49]                                                     | Teens in NYC              |           |           |         |         | •       |
| Mode                  | Population | Citations | Intervention Name | Education | Behaviour | Testing | Linkage | Support |
|----------------------|------------|-----------|-------------------|-----------|-----------|---------|---------|---------|
| Web-based HIV–       |            |           | Ahmed-Little et al. [50] | RUClear   |           |         |         |         |
|                      |            |           | Bauermeister et al. [51] | myDEX     |           |         |         |         |
|                      |            |           | Billings et al. [52] | Safe Sistah |           |         |         |         |
|                      |            |           | Brady et al. [53] | TeensTalkHealth |           |         |         |         |
|                      |            |           | Danielson et al. [54] | SIHLEWeb   |           |         |         |         |
|                      |            |           | Fernandez et al. [55] | POWER     |           |         |         |         |
|                      |            |           | Greene et al. [56] | Keep It Up! |           |         |         |         |
|                      |            |           | Motley et al. [57] |           |           |         |         |         |
|                      |            |           | Mustanski et al. [58] |           |           |         |         |         |
|                      |            |           | Mustanski et al. [59] |           |           |         |         |         |
|                      |            |           | Manavi et al. [60] | Umbrella Health |         |         |         |         |
|                      |            |           | Jones et al. [61] | Guide-Enhanced Love, Sex, and Choices |         |         |         |         |
|                      |            |           | Kasatpibal et al. [62] | rakplodpai.com |           |         |         |         |
|                      |            |           | Klein et al. [63] | Sexual Awareness for Everyone (C-SAFE) |         |         |         |         |
|                      |            |           | Maksut et al. [64] |           |           |         |         |         |
|                      |            |           | Mustanski et al. [65] | Queer Sex Ed |         |         |         |         |
|                      |            |           | Platteau et al. [66] | Swab2Know |         |         |         |         |
|                      |            |           | Loos et al. [67] |           |           |         |         |         |
|                      |            |           | Widman et al. [68] | ProjectHeartforGirls.com |         |         |         |         |
|                      |            |           | Wilson et al. [59] | Sexual Health 24 (SH24) |         |         |         |         |
|                      |            |           | Wilson et al. [70] |           |           |         |         |         |
| HIV+                 |            |           | Yarra et al. [71] | CyberSenga |         |         |         |         |
|                      |            |           | Cote et al. [72] | VIH-TAVIE |         |         |         |         |
|                      |            |           | Cruess et al. [73] | HINTS |         |         |         |         |
|                      |            |           | Green et al. [74] | HR-VG |         |         |         |         |
|                      |            |           | Hirshfield et al. [75] | Sex Positive! |         |         |         |         |
|                      |            |           | Horvath et al. [76] | Thrive With Me |         |         |         |         |
|                      |            |           | Mi et al. [77] |           |           |         |         |         |
|                      |            |           | Milam et al. [78] | Positive Outlook |         |         |         |         |
|                      |            |           | Millard et al. [79] |           |           |         |         |         |
|                      |            |           | Millard et al. [80] |           |           |         |         |         |
| HIV– or HIV+         |            |           | Miranda et al. [81] | Condom-HIM |         |         |         |         |
|                      |            |           | Peterson et al. [82] | CARE+ Corrections |         |         |         |         |
|                      |            |           | Anand et al. [83] | Adams’ Love |         |         |         |         |
|                      |            |           | Anand et al. [84] |           |           |         |         |         |
|                      |            |           | Haas et al. [85] | KNOW*NOW |         |         |         |         |
|                      |            |           | Klein et al. [86] | Real Talk |         |         |         |         |
|                      |            |           | Lau et al. [87] |           |           |         |         |         |
|                      |            |           | March et al. [88] | Therapeutic Education System (TES) |         |         |         |         |
|                      |            |           | Mitchell et al. [89] | MCAP |         |         |         |         |
|                      |            |           | Stephenson et al. [90] | Project Nexus |         |         |         |         |
|                      |            |           | Van den Berg et al. [91] | Men2MenRI |         |         |         |         |
|                      |            |           | de Boni et al. [92] | A Hora É Agora |         |         |         |         |
|                      |            |           | Dolwick Grieb et al. [93] | ¡Sólo Se Vive Una Vez! |         |         |         |         |
|                      |            |           | Dolwick Grieb et al. [94] |           |         |         |         |         |
|                      |            |           | Stephenson et al. [95] | Project Moxie |         |         |         |         |
| App & Web-based HIV– |            |           | Cho et al. [96] | mobile Video Information Provider (mVIP) |         |         |         |         |
|                      |            |           | Cho et al. [97] |           |           |         |         |         |
|                      |            |           | Schnall et al. [98] |           |           |         |         |         |

(* indicates the presence of each feature; blank indicates absence.)
| Mode            | Population | Citations | Intervention Name | Educationa | Behavioura | Testinga | Linkagea | Supporta |
|-----------------|------------|-----------|-------------------|------------|------------|----------|----------|----------|
| Social media    | HIV−       |           |                   |            |            |          |          |          |
|                 |            |           | Chu et al. [99]   |            |            |          |          |          |
|                 |            |           | Carett et al. [100]|            |            |          |          |          |
|                 |            |           | Young et al. [101]|            |            |          |          |          |
|                 |            |           | Young et al. [102]|            |            |          |          |          |
|                 |            |           | Young et al. [103]|            |            |          |          |          |
|                 |            |           | Young et al. [104]|            |            |          |          |          |
|                 |            |           | Alarcon Gutierrez et al. [105]| |            |          |          |          |
|                 |            |           | Bauermeister et al. [106]| |            |          |          |          |
|                 |            |           | Huang et al. [107]|         |            |          |          |          |
|                 |            |           | Jenkins et al. [108]| |            |          |          |          |
|                 |            |           | Lampkin et al. [109]| |            |          |          |          |
|                 |            |           | Lelutiu-Weinberger et al. [110]| |            |          |          |          |
|                 |            |           | Patel et al. [111]|          |            |          |          |          |
|                 |            |           | Rhodes et al. [112]| |            |          |          |          |
|                 |            |           | Sun et al. [113]|          |            |          |          |          |
|                 |            |           | Sun et al. [114]|          |            |          |          |          |
|                 |            |           | Tucker at al. [115]| |            |          |          |          |
|                 |            |           | Tang et al. [116]|          |            |          |          |          |
|                 |            |           | Washington et al. [117]| |            |          |          |          |
|                 | HIV+       |           |                   |            |            |          |          |          |
|                 |            |           | Tancer et al. [118]| |            |          |          |          |
|                 | HIV− or HIV+|         |                   |            |            |          |          |          |
|                 |            |           | Baltiera et al. [119]| |            |          |          |          |
|                 |            |           | Bauermeister et al. [120]| |            |          |          |          |
|                 |            |           | Hightow-Weidman et al. [121]| |            |          |          |          |
|                 |            |           | Hightow-Weidman et al. [122]| |            |          |          |          |
| Game, app-based | HIV+       |           |                   |            |            |          |          |          |
|                 |            |           | Hightow-Weidman et al. [123]| |            |          |          |          |
|                 |            |           | LeGrand et al. [124]| |            |          |          |          |
|                 |            |           | LeGrand et al. [125]| |            |          |          |          |
| Game, web-based | HIV−       |           |                   |            |            |          |          |          |
|                 |            |           | Shegog et al. [127]| |            |          |          |          |
|                 |            |           | Schonnesson et al. [128]| |            |          |          |          |
|                 |            |           | Fiellin et al. [111]| |            |          |          |          |
|                 |            |           | Montanaro et al. [129]| |            |          |          |          |
|                 |            |           | Fiellin et al. [130]| |            |          |          |          |
|                 |            |           | Lukhele et al. [131]| |            |          |          |          |
|                 |            |           | Enah et al. [132]|          |            |          |          |          |

*Target points on the HIV and care and prevention continuums: Education; Behaviour change; Testing; Linkage to Care; Care Support.
Interventions exist to address adherence to HIV treatment. A recent review of peer-reviewed literature identified 11 PrEP interventions already available for download, including five with features for improving adherence, but quality was variable and none were found in the peer-reviewed literature [16]. These apps could be important stopgap tools, but a rigorous and scientific process is needed so that users and stakeholders can be confident that the tools work. Researchers can expedite the process with more efficient development, modification and testing protocols that do not always reinvent the wheel. A sustainable eHealth intervention will need to be flexible to meet new challenges in HIV care and prevention and transferrable to rapidly evolving eHealth technologies. One way to achieve this is to isolate and test the effects of individual components of an intervention thereby allowing future innovations to recycle and build upon effective strategies.

The overwhelming majority of interventions we found were designed for use in high-income countries, where smartphones and high-speed Internet are ubiquitous. It is important to note that our review excluded eHealth interventions that use only SMS or voice messaging. A recent systematic review of SMS and voice call interventions for HIV-positive subjects found that a majority were for individuals in low- and middle-income countries, contrasting the findings of this review [17]. Limited access to new technologies in these settings has likely discouraged researchers from developing interventions that utilize these platforms. Consequently, innovative approaches to HIV prevention will not reach areas with the greatest global need. New technology interventions are not necessarily better than text and voice messaging interventions, and there remains a need for these interventions in geographies with poor technology infrastructure and in populations with low technology literacy. However, as technology becomes available to more people, equitable access to new technology interventions, if indeed superior, must be ensured. Comprehensive and country-specific strategies should be implemented to maximize the benefit of currently available technologies and plan for future availability of others [18].

Our study has limitations typical of systematic reviews. We are limited in our electronic search to published articles, and there may be publication biases that lead to under-representation of studies that have not been found to be efficacious; our analysis did not summarize efficacy, but we might have failed to enumerate studies for which the authors chose not to publish results or presented findings at a conference. We only searched two databases of published articles and our search terms, while selected to be comprehensive, may not be exhaustive. We have also missed early phase studies not yet published and funded through sources that would not appear in NIH-ResearchPort – for example studies funded through foundational sources or through government health departments. Finally, our study excluded eHealth interventions that include other components (i.e. face-to-face counselling that is “boosted” by an app) which means we missed some interventions that fall within the new tech landscape. However, we chose to limit the scope of the review to interventions that can have broad impact.

We believe that there is value in periodically summarizing or updating the research pipeline based on the care and prevention continua and their elements. For example the Global HIV Vaccine Enterprise maintains a “pipeline project” with an updated description of the state of the vaccine field, from...
early concepts through randomized studies [19]. Descriptions such as ours and the Global HIV Vaccine Enterprise document, allow funders and researchers to develop an understanding of relatively under-investigated areas of study, and propose or fund projects to address important but understudied steps in the prevention and care continua.

4 | CONCLUSIONS

The emergence of eHealth technologies has created opportunities for large-scale dissemination of effective prevention interventions. This review provides an overview of recently published interventions as well as the next generation of interventions that are still in development. The research pipeline of eHealth interventions is robust, with a wide variety of knowledge, behavioural and care needs addressed. There is continued need for interventions to address adherence and retention in care for therapies, especially PrEP, service to key populations in low- and middle-income countries, and development of more efficient and expedited processes for intervention research and development.

AUTHORS’ AFFILIATIONS
1Department of Epidemiology, Emory University, Atlanta, GA, USA; 2Department of Epidemiology, University of California, Los Angeles, CA, USA

COMPETING INTERESTS
KMM, AB, RW and PSS have no competing interests to declare.

AUTHORS’ CONTRIBUTIONS
KMM and PSS designed the study. KMM, AB and RW completed data collection and organized the data. All authors assisted with interpretation of results. KMM and PSS drafted the manuscript. All authors reviewed and agreed to submit the manuscript.

ABBREVIATIONS
apps, smartphone applications; eHealth, mobile and other electronic technologies; MSM, men who have sex with men; NIH-REPORT, National Institutes of Health Research Portfolio Online Reporting Tools; PrEP, pre-exposure prophylaxis; RCT, randomized control trial; SMS, short message service; TW, transgender women.

ACKNOWLEDGEMENTS
None declared.

FUNDING
This work was supported by the Center for AIDS Research at Emory University (P30AI050409).

REFERENCES
1. 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(6):793–800.
2. Medland NA, McMahon JH, Chow EP, Elliott JH, Hoy JF, Fairley CK. The HIV care cascade: a systematic review of data sources, methodology and comparability. J Int AIDS Soc. 2015;18:20634.
3. Kelley CF, Kahle E, Siegler A, Sanchez T, Del Rio C, Sullivan PS, et al. Applying a PrEP continuum of care for men who have sex with men in Atlanta, Georgia. Clin Infect Dis. 2015;61(10):1590–7.
4. Nunn AS, Brinkley-Rubinstein L, Oldenburg CE, Mayer KH, Mimiga M, Patel R, et al. Defining the HIV pre-exposure prophylaxis care continuum. AIDS. 2015;29(5):731–4.
5. 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(1):173–90.
6. Carnicer-Pont D, Barbera-Gracia MJ, Fernandez-Davila P, de Ollalla PG, Munoz R, Jacques-Avino C, et al. Use of new technologies to notify possible contagion of sexually-transmitted infections among men. Gac Sanit. 2015;29(2):96–7.
7. Chan PA, Towey C, Poceta J, Rose J, Bertrand T, Kantor R, et al. Online hookup sites for meeting sexual partners among men who have sex with men in Rhode Island, 2013: a call for public health action. Public Health Rep. 2016;131(2):264–71.
8. Centers for Disease Control and Prevention. Estimated HIV incidence and prevalence in the United States, 2010–2015. HIV Surveillance Supplemental Report. 2018. Available from: https://www.cdc.gov/hiv/pdf/library/reports/surveillance/cdc-hiv-surveillance-supplemental-report-vol-23-1pdf
9. Centers for Disease Control and Prevention. Monitoring selected national HIV prevention and care objectives by using HIV surveillance data—United States and 6 dependent areas, 2016. HIV Surveillance Supplemental Report; 2018. Available from: https://www.cdc.gov/hiv/pdf/library/reports/surveillance/cdc-hiv-surveillance-supplemental-report-vol-23-1pdf
10. Hoots BE, Finlayson T, Nerland L, Puz-Bailey G. Willingness to take, use of, and indications for pre-exposure prophylaxis among men who have sex with men-20 US cities, 2014. Clin Infect Dis. 2016;63(5):672–7.
11. Fiellin LE, Hieftje KD, Pendergrass TM, Kyriakides TC, Duncan LR, Dzirua JD, et al. Video game intervention for sexual risk reduction in minority adolescents: randomized controlled trial. J Med Internet Res. 2017;19:e314.
12. Bauermeister JA, Pingel ES, Jadwin-Cakmak L, Harper GW, Horvath K, Weiss G, et al. Acceptability and preliminary efficacy of a tailored online HIV/STI testing intervention for young men who have sex with men: the Get Connected! program. AIDS Behav. 2015;19(10):1860–74.
13. Anderson PL, Glidden DV, Liu A, Buchbinder S, Lama JR, Guarina JV, et al. Emtricitabine-tenofovir concentrations and pre-exposure prophylaxis efficacy in men who have sex with men. Sci Transl Med. 2012;4(151):151ra25.
14. Van Damme L, Corneli A, Ahmed K, Agot K, Lombaard J, Kapiga S, et al. Preexposure prophylaxis for HIV infection among African women. N Engl J Med. 2012;367(5):411–22.
15. Marrazzo J, Ramjee G, Nair G, Palanee T, Mkhize B, Nakabilito C, et al. Pre-exposure prophylaxis for HIV in women: daily oral tenofovir, oral tenofovir/entricitabine, or vaginal tenofovir gel in the VOICE Study (MTN 003). 20th Conference on Retroviruses and Opportunistic Infections; March 3–6, 2013; Atlanta, GA.
16. Sharpe JD, Kamara MT. A systematic evaluation of mobile apps to improve the uptake of and adherence to HIV pre-exposure prophylaxis. Sex Health. 2016;13(6):587.
17. Amankwaa I, Boateng D, Quansah DY, Akuoko CP, Evans C. Effectiveness of short message services and voice call interventions for antiretroviral therapy adherence and other outcomes: a systematic review and meta-analysis. PLoS ONE. 2018;13:e0204091.
18. Scott RE, Mars M. Principles and framework for eHealth strategy development. J Med Internet Res. 2013;15:e155.
19. Drozd F, Skeie LG, Kraft P, Kvale D. A web-based intervention trial for depressive symptoms and subjective well-being in patients with chronic HIV infection. AIDS Care. 2014;26(9):1080–9.
20. Browne FA, Wechsberg WM, Kizakevich PN, Zule WA, Bonner CP, Madison AN, et al. mHealth versus face-to-face: study protocol for a randomized trial to test a gender-focused intervention for young African American women at risk for HIV in North Carolina. BMC Public Health. 2018;18(1):492.
21. Cordova D, Aleres-Rojas F, Lua FM, Bauermeister J, Nurenberg R, Ovadje L, et al. The usability and acceptability of an adolescent mHealth HIV/STI and drug abuse preventive intervention in primary care. Behav Med. 2018;44:36–47.
22. Cordova D, Bauermeister JA, Fessler K, Delva J, Nelson A, Nurenberg R, et al. A community-engaged approach to developing an mHealth HIV/STI and drug abuse preventive intervention in primary care. Behav Med. 2018;44:36–47.
23. Besoain F, Perez-Navaora A, Cayla JA, Avino CJ, de Ollalla PG. Prevention of sexually transmitted infections using mobile devices and ubiquitous computing. Int J Health Geogr. 2015;14:18.
24. Scott CK, Dennis ML, Gustafson DH. Using smartphones to decrease substance use via self-monitoring and recovery support: study protocol for a randomized control trial. Trials. 2017;18(1):374.
25. Goldenberg T, McDougal SJ, Sullivan PS, Stekler JD, Stephenson R. Preferences for a mobile HIV prevention app for men who have sex with men. JMIR Mhealth Uhealth. 2014;2:e47.
26. Goldenberg T, McDougal SJ, Sullivan PS, Stekler JD, Stephenson R. Building a mobile HIV prevention app for men who have sex with men: an iterative and community-driven process. JMIR Public Health Surveill. 2015;1:e18.
27. Sullivan PS, Driggers R, Stekler JD, Siegler A, Goldenberg T, McDougal SJ, et al. Usability and acceptability of a mobile comprehensive HIV prevention app for men who have sex with men: a pilot study. JMIR Mhealth Uhealth. 2017;5:e2.
28. Winskell K, Sabben G, Akelo V, Ondeng’e K, Obong’o C, Stephenson R, et al. A smartphone game-based intervention (Tumaini) to prevent HIV among young africans: pilot randomized controlled trial. JMIR Mhealth Uhealth. 2018;6:e10482.
29. Wray T, Chan PA, Simpanen E, Operario D. eTEST: developing a smart home HIV testing kit that enables active, real-time follow-up and referral after testing. JMIR Mhealth Uhealth. 2017;5:e2.
30. Bauermeister JA, Golinkoff JM, Horvath KJ, Hightow-Weidman LB, Sullivan PS, Stephenson R. A Multilevel tailored web app-based intervention for linking young men who have sex with men to quality care (get connected); protocol for a randomized controlled trial. JMIR Res Protoc. 2018;7:e10444.
31. Horvath KJ, Bauermeister JA. eHealth literacy and intervention tailoring impacts the acceptability of a HIV/STI testing intervention and sexual decision making among young gay and bisexual men. AIDS Educ Prev. 2017;29(1):14-23.
32. Yan J, Zhang A, Zhou L, Huang Z, Zhang Y, Pang Y. Development and effectiveness of a mobile phone application conducting health behavioral intervention among men who have sex with men, a randomized controlled trial: study protocol. BMC Public Health. 2017;17(1):355.
33. Yang C, Linas D, Kirk G, Bollinger R, Chang L, Chander G, et al. Feasibility and acceptability of smartphone-based ecological momentary assessment of alcohol use among African American men who have sex with men in Baltimore. JMIR Mhealth Uhealth. 2015;3(2):e67.
34. Dillingham R, Ingersoll K, Flickinger TE, Waldman AL, Grabowski M, Laurence C, et al. PositiveLinks: a mobile health intervention for retention in HIV care and clinical outcomes with 12-month follow-up. AIDS Patient Care STDS. 2018;32(6):241-50.
35. Flickinger TE, DeBolt C, Waldman AL, Reynolds G, Cohn WF, Beach MC, et al. Social support in a virtual community: analysis of a clinic-affiliated online support group for persons living with HIV/AIDS. AIDS Behav. 2017;21(11):3087-99.
36. Flickinger TE, DeBolt C, Wispelwey E, Laurence C, Plews-Ogan E, Waldman AL, et al. Content analysis and user characteristics of a smartphone-based online support group for people living with HIV. Telemed J E Health. 2016;22(9):746-54.
37. Flickinger TE, DeBolt C, Xie A, Kosmacki A, Grabowski M, Waldman AL, et al. Addressing stigma through a virtual community for people living with HIV: a mixed methods study of the positiveslinks mobile Health intervention. AIDS Behav. 2018;22(10):3395-406.
38. Dworink M, Chakraborty A, Lee S, Monahan C, Hightow-Weidman L, Garofalo R, et al. Linking human embodied asking phone intervention to promote HIV medication adherence and retention in care in young HIV-positive african american men who have sex with men: qualitative study. JMIR Mhealth Uhealth. 2018;6:e10211.
39. Himelech S, Kreyenbuhl J, Palmer-Bacon J, Chu M, Brown C, Potts W. Pilot feasibility study of Heart2HAART: a smartphone application to assist with adherence among substance users living with HIV. AIDS Care. 2017;29(7):898-904.
40. 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 Inform Decis Mak. 2014;14:103.
41. Martin CA, Upwall MJ. A mobile phone HIV medication adherence intervention: acceptability and feasibility study. J Assoc Nurses AIDS Care. 2016;27(6):804-16.
42. Perera Al, 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(11):579-86.
43. Svendem D, Ramanathan N, Baetscher L, Medich M, Scheffler A, Comulada WS, et al. Smartphone self-monitoring to support self-management among people living with HIV: perceived benefits and theory of change from a mixed-methods randomized pilot study. J Acquir Immune Defic Syndr. 2015;69 Suppl 1:S180-91.
44. Venter W, Coleman J, Chan VL, Shubber Z, Phatsoane M, Gorgens M, et al. Improving linkage to HIV care through mobile phone apps: randomized controlled trial. JMIR Mhealth Uhealth. 2018;6:e155.
45. Westergaard RP, Genz A, Panico K, Surkan PJ, Keruly J, Hutton HE, et al. Acceptability of a mobile health intervention to enhance HIV care coordination for people with substance use disorders. Addict Sci Pract. 2017;12(1):11.
46. Levy ME, Watson CC, Wilton L, Criss V, Kuo I, Glick SN, et al. Acceptability of a mobile smartphone application intervention to improve access to HIV prevention and care services for black men who have sex with men in the district of Columbia. Digit Cult Educ. 2015;7(2):169-91.
47. Ochalek TA, Hell SH, Higgins ST, Badger GJ, Sigmon SC. A novel mHealth application for improving HIV and Hepatitis C knowledge in individuals with opiate use disorder: A pilot study. Drug Alcohol Depend. 2019;190:224-8.
48. Reback CJ, Ruenger D, Fletcher JB, Swendeman D. Ecological momentary assessments for self-monitoring and counseling to optimize methamphetamine treatment and sexual risk reduction outcomes among gay and bisexual men. J Subst Abuse Treat. 2018;92:17-26.
49. Steinberg A, Griffin-Tomas M, Abu-Odeh D, Whitten A. Evaluation of a mobile phone app for providing adolescents with sexual and reproductive health information, New York City, 2013–2016. Public Health Rep. 2018;133(3):234-9.
50. Ahmed-Little Y, Bothra V, Cordwell D, Freeman Powell D, Ellis L, Klapper P, et al. Attitudes towards HIV testing via home-sampling kits ordered online (RUClear pilots 2011–12). J Public Health. 2016;38(3):585–90.
51. Bauermeister JA, Tingler RC, Demers M, Harper GW. Development of a tailored HIV prevention intervention for single young men who have sex with men who meet partners online: protocol for the myDject project. JMIR Res Protoc. 2017;4:e141.
52. Billings DW, Leaf SL, Spencer J, Crenshaw T, Brockington S, Dalal RS. A randomized trial to evaluate the efficacy of a web-based HIV behavioral intervention for high-risk African American women. AIDS Behav. 2015;19(7):1263-74.
53. Brady SS, Sieving RE, Terween LG, Rosser BRS, Kodet AJ, Rothberg VD. An interactive website to reduce sexual risk behavior: process evaluation of TeensTalkHealth. JMIR Res Protoc. 2015:e106.
54. Danielson CK, McCauley JL, Gros KS, Jones AM, Barr SC, Borkan AL, et al. Development and usability testing of an evidence-based HIV prevention website for female African-American adolescents. Health Inform J. 2016;22(12):194-206.
55. Fernandez MI, Hosek SG, Hotton AL, Gaylord SE, Hernandez N, Alfonso SV, et al. A Randomized controlled trial of POWER: an internet-based HIV prevention intervention for black bisexual men. AIDS Behav. 2016;20(9):1951-60.
56. Greene GJ, Madkins K, Andrews K, Dispenza J, Mustanski B. Implementation and evaluation of the keep it up! online HIV prevention intervention in a community-based setting. AIDS Educ Prev. 2016;28(3):231-45.
57. Motley DN, Hammond S, Mustanski B. Strategies chosen by YMSM during goal setting to reduce risk for HIV and other sexually transmitted infections: results from the keep it up! 2.0 prevention trial. AIDS Educ Prev. 2017;29(1):1-13.
58. Mustanski B, Madkins K, Greene GJ, Parsons JT, Johnson BA, Sullivan P, et al. Internet-based HIV prevention with at-home sexually transmitted infection testing among young men having sex with men: study protocol of a randomized controlled trial of keep it up! 2.0. JMIR Res Protoc. 2017:6:e1.
59. Mustanski B, Parsons JT, Sullivan PS, Madkins K, Rosenberg E, Swann G. Biomedical and behavioral outcomes of keep it up!: an eHealth HIV prevention program RCT. Am J Prev Med. 2018;55(2):151-8.
60. Manavi K, Hodson J. Observational study of factors associated with return of home sampling kits for sexually transmitted infections requested online in the UK. BJM Open. 2017;7(10):e017792.
61. Jones R, Lacroix JL, Nolte K. “Is Your Man Stepping Out?” An online pilot study to evaluate acceptability of a guide-enhanced HIV prevention soap opera video series and feasibility of recruitment by Facebook advertising. J Assoc Nurses AIDS Care. 2015;26(4):368-86.
62. Kasapis N, Viseskul N, Srikantha W, Fonjkaew W, Surapagdee N, Grimes RM. Effects of Internet-based instruction on HIV prevention knowledge and practices among men who have sex with men. Nurs Health Sci. 2014;16(4):514-20.
63. Klein CH, Kuhn T, Altamirano M, Lomonaco C. C-SAFE: a computer-delivered sexual health promotion program for Latinas. Health Prom Prac. 2017;18(4):516-25.
64. Makus JL, Eaton LA, Siembida EJ, Driffin DD, Baldwin R. A test of concept study of the same, self-administered HIV testing with web-based peer counseling via video chat for men who have sex with men. JMIR Public Health Surveill. 2016;2:e170.
65. Mustanski B, Greene GJ, Ryan D, Whitten SW. Feasibility, acceptability, and initial efficacy of an online sexual health promotion program for LGBT youth: the queer sex ed intervention. J Sex Res. 2015;52(2):220-30.
66. Platteau T, Fransen K, Apers L, Kenyon C, Albers L, Vermeosens T, et al. Swab2know: an HIV-testing strategy using oral fluid samples and online communication for test results for men who have sex with men in Belgium. J Med Internet Res. 2015;17:e213.

67. Loos J, Manirankunda L, Platteau T, Albers L, Fransen K, Vermeosens T, et al. Acceptability of a community-based outreach HIV-testing intervention using oral fluid collection devices and web-based HIV test result collection among sub-Saharan African migrants: a mixed-method study. JIMR Public Health Surveill. 2016;2:e32.

68. Widman L, Golin CE, Noar SM, Massey J, Prinstein MJ. Projectheartfor-girls.com: development of a web-based HIV/STD prevention program for adolescent girls emphasizing sexual communication skills. AIDS Educ Prev. 2016;28(5):365–77.

69. Wilson E, Free C, Morris TP, Kenward MG, Syred J, Baraitser P. Can Internet-based sexual health services increase diagnoses of sexually transmitted infections (STI)? Protocol for a randomized evaluation of an internet-based STI testing and results service. JIMR Res Protoc. 2016;5:e5.

70. Wilson E, Free C, Morris TP, Syred J, Aheamed I, Monen-Johansson AS, et al. Internet-accessed sexually transmitted infection (e-STI) testing and results service: a randomised, single-blind, controlled trial. PLoS Med. 2017;14:e1002479.

71. Ybarra ML, Korchmaros JD, Prescott TL, Binaghi R. A randomized controlled trial to increase HIV preventive information, motivation, and behavioral skills in Ugandan adolescents. Ann Behav Med. 2015;49(3):473–85.

72. Cote J, Godin G, Ramirez-Garcia P, Rouleau G, Bourbonsais A, Queenehu YG, et al. Virtual intervention to support self-management of antiretroviral therapy among people living with HIV. J Med Internet Res. 2015;17:e6.

73. Cruess DG, Burnham KE, Finitisi DJ, Gohe BM, Strangie L, Kalichm M, et al. A randomized clinical trial of a brief internet-based group intervention to reduce sexual risk behavior among HIV-positive gay and bisexual men. Ann Behav Med. 2016;52(2):116–29.

74. Green SM, Lockhart E, Marhefka SL. Advantages and disadvantages for receiving Internet-based HIV/AIDS interventions at home or at community-based organizations. AIDS Care. 2015;27(10):1304–8.

75. Hirshfeld S, Downing MJ Jr, Parsons JT, Grov C, Gordon RJ, Houang ST, et al. Delivering a video-based eHealth intervention for HIV-positive gay, bisexual, and other men who have sex with men: study protocol for a randomized controlled trial. JIMR Res Protoc. 2016;5:e125.

76. Horvath KJ, Amico KR, Erickson D, Ecklund AM, Martinka A, DeWitt J, et al. Thrive with me: protocol for a randomized controlled trial to test a peer support intervention to improve antiretroviral therapy adherence among men who have sex with men. JIMR Res Protoc. 2018;7:e10182.

77. Mi G, Wu Z, Wang X, Shi CX, Yu F, Li T, et al. Effects of a quasi-randomized web-based intervention on risk behaviors and treatment seeking among HIV-positive men who have sex with men in Chengdu, China. Curr HIV Res. 2015;13(6):490–6.

78. Milam J, Morris S, Jain S, Sun XY, Dube MP, Daar ES, et al. Randomized controlled trial of an internet application to reduce HIV transmission behavior among HIV-infected men who have sex with men. AIDS Behav. 2016;20(6):1173–81.

79. Millard T, McDonald K, Elliott J, Slavin S, Rowell S, Girdler S. Informing the development of an online self-management program for men living with HIV: a needs assessment. BMC Public Health. 2014;14(1):1209.

80. Millard T, McDonald K, Elliott J, Slavin S, Rowell S, Girdler S. Informing the development of an online self-management program for men living with HIV: a needs assessment. BMC Public Health. 2016;20(6):1173–81.

81. Millard T, McDonald K, Elliott J, Slavin S, Rowell S, Girdler S. Informing the development of an online self-management program for men living with HIV: a needs assessment. BMC Public Health. 2016;20(6):1173–81.

82. Peterson J, Cota M, Gray H, Bazerman L, Kuo I, Kurth A, et al. Technology development of an online self-management program for men living with HIV: a needs assessment. BMC Public Health. 2016;20(6):1173–81.

83. Plewes A, Martello S, Goodman B, Wasylyshen A, Young SD. Only Live Once): a pilot evaluation of individually tailored video modules aiming to increase HIV testing among foreign-born latino men. J Acquir Immune Defic Syndr. 2017;74 Suppl 2:S104–12.

84. Greenberg S, Catalano A, Coates T, Kelleher C, Krieger N, Lee JY. Using eHealth to reach black and hispanic men who have sex with men regarding treatment as prevention and preexposure prophylaxis: protocol for a small randomized controlled trial. JIMR Res Protoc. 2018;7:e11047.

85. De Boni RB, Lentini N, Santelli AC, Barbosa A Jr, Cruz M, Bingham T, et al. Self-testing, communication and information technology to promote HIV diagnosis among young men and other men who have sex with men (MSM) in Brazil. J Int AIDS Soc. 2018;21:e25116.

86. Dolwick Grieb SM, Flores-Miller A, Guillette N, Clifford R, Page K. ‘Vive’: designing an intervention to improve timely HIV diagnosis among Latino immigrant men. Prog Community Health Partnersh. 2016;10(3):365–72.

87. Dolwick Grieb SM, Flores-Miller A, Page K. ‘Vive’: designing an intervention to improve timely HIV diagnosis among Latino immigrant men. Prog Community Health Partnersh. 2016;10(3):365–72.

88. Greenberg S, Catalano A, Coates T, Kelleher C, Krieger N, Lee JY. Using eHealth to reach black and hispanic men who have sex with men regarding treatment as prevention and preexposure prophylaxis: protocol for a small randomized controlled trial. JIMR Res Protoc. 2018;7:e11047.

89. Cho H, Yen PY, Dowding D, Merrill J, Schnall R. A multi-level usability evaluation of mobile health applications: a case study. J Biomed Inform. 2018;86:79–89.

90. Schnall R, Cho H, Mangone A, Pichon A, Jia H. Mobile health technology for improving symptom management in low income persons living with HIV. AIDS Behav. 2018;22(10):3373–83.

91. Chiu CJ, Menacho L, Fisher C, Young SD. Ethics issues in social media-based HIV prevention in low- and middle-income countries. Camb Q Health Ethics. 2015;24(3):303–10.

92. Porrás H, Bächle D, Beauchemin M, Schnall R. Understanding the predisposing, enabling, and reinforcing factors influencing the use of a mobile-based HIV management app: a real-world usability evaluation. Int J Med Inform. 2018;117:88–95.

93. Cho H, Yen PY, Dowding D, Merrill J, Schnall R. A multi-level usability evaluation of mobile health applications: a case study. J Biomed Inform. 2018;86:79–89.

94. Schnall R, Cho H, Mangone A, Pichon A, Jia H. Mobile health technology for improving symptom management in low income persons living with HIV. AIDS Behav. 2018;22(10):3373–83.

95. Bauermeister J, Sullivan PS, Gravens L, Wolfe J, Countryman K, Smith-McCroskey J. Designing a mobile health intervention to increase HIV testing among foreign-born latino men. J Acquir Immune Defic Syndr. 2017;74 Suppl 2:S104–12.

96. Cho H, Porrás H, Bächle D, Beauchemin M, Schnall R. Understanding the predisposing, enabling, and reinforcing factors influencing the use of a mobile-based HIV management app: a real-world usability evaluation. Int J Med Inform. 2018;117:88–95.

97. Cho H, Yen PY, Dowding D, Merrill J, Schnall R. A multi-level usability evaluation of mobile health applications: a case study. J Biomed Inform. 2018;86:79–89.

98. Schnall R, Cho H, Mangone A, Pichon A, Jia H. Mobile health technology for improving symptom management in low income persons living with HIV. AIDS Behav. 2018;22(10):3373–83.
108. Jenkins Hall W, Sun CJ, Tanner AE, Mann L, Stowers J, Rhodes SD. HIV-prevention opportunities with gps-based social and sexual networking applications for men who have sex with men. AIDS Educ Prev. 2017;29(1):38–48.
109. Lampkin D, Crawley A, Lopez TP, Mejia CM, Yuen W, Levy V. Reaching suburban men who have sex with men for STD and HIV services through online social networking outreach: a public health approach. J Acquir Immune Defic Syndr. 2016;72(1):73–8.
110. Lelutiu-Weinberger C, Pachankis JE, Gamarel KE, Sarace A, Golub SA, Parsons JT. Feasibility, acceptability, and preliminary efficacy of a live-chat social media intervention to reduce HIV risk among young men who have sex with men. AIDS Behav. 2015;19(7):1214–27.
111. Patel VV, Ginsburg Z, Golub SA, Horvath KJ, Rios N, Mayer KH, et al. Empowering with PrEP (E-PrEP), a peer-led social media-based intervention to facilitate hiv preexposure prophylaxis adoption among young black and latinx gay and bisexual men: protocol for a cluster randomized controlled trial. JMIR Res Protoc. 2018;7:e1375.
112. Rhodes SD, Mccoy TP, Tanner AE, Stowers J, Bachmann LH, Nguyen AL, et al. Using social media to increase HIV testing among gay and bisexual men, other men who have sex with men, and transgender persons: outcomes from a randomized community trial. Clin Infect Dis. 2016;62(11):1450–3.
113. Sun CJ, Stowers J, Miller C, Bachmann LH, Rhodes SD. Acceptability and feasibility of using established geosocial and sexual networking mobile applications to promote HIV and STD testing among men who have sex with men. AIDS Behav. 2015;19(3):543–52.
114. Sun WH, Wong CKH, Wong WCW. A peer-led, social media-delivered, safer sex intervention for Chinese college students: randomized controlled trial. J Med Int Res. 2017;19:e284.
115. Tucker JD, Wei CY, Li HC, Liu CC, Tang SY, Tang WM, et al. Crowdsourcing to promote HIV testing among MSM in China: study protocol for a stepped wedge randomized controlled trial. Trials. 2017;18:447.
116. Tang W, Wei C, Cao B, Wu D, Li KT, Lu H, et al. Crowdsourcing to expand HIV testing among men who have sex with men in China: a closed cohort stepped wedge cluster randomized controlled trial. PLoS Med. 2018;15: e1002645.
117. Washington TA, Applewhite S, Glenn W. Using Facebook as a platform to direct young black men who have sex with men to a video-based hiv testing intervention: a feasibility study. Urban Soc Work. 2017;1(1):36–52.
118. Tanner AE, Mann L, Song E, Alonzo J, Schafer K, Arellano E, et al. Wecare: a social media-based intervention designed to increase HIV care linkage, retention, and health outcomes for racially and ethnically diverse young MSM. AIDS Educ Prev. 2016;28(3):216–30.
119. Baltierra NB, Muesig KE, Pike EC, LeGrand S, Bull SS, Hightow-Weidman LB. More than just tracking time: complex measures of user engagement with an internet-based health promotion intervention. J Biomed Inform. 2016;59:299–307.
120. Bauermeister JA, Muesig KE, LeGrand S, Flores DD, Choi SK, Dong W, et al. HIV and sexuality stigma reduction through engagement in online forums: results from the healthMpowerment intervention. AIDS Behav. 2019;23(9):742–52.
121. Hightow-Weidman L, LeGrand S, Simmons R, Egger JR, Choi SK, Muesig K, et al. HealthMpowerment: effects of a mobile phone-optimized, Internet-based intervention on condomless anal intercourse among young black men who have sex with men and transgender women. 9th IAS Conference on HIV Science (IAS 2017). July 23-26, 2017, Paris, France. 2017.
122. Hightow-Weidman LB, Muesig KE, Pike EC, LeGrand S, Baltierra N, Rucker AJ, et al. HealthMpowerment.org: building community through a mobile-optimized, online health promotion intervention. Health Educ Behav. 2015;42(4):493–9.
123. Hightow-Weidman L, Muesig K, Knudtson K, Srivatsa M, Lawrence E, LeGrand S, et al. A gamified smartphone app to support engagement in care and medication adherence for HIV-positive young men who have sex with men (AllyQuest): development and pilot study. JIMIR Public Health Survey. 2018;4:e34.
124. LeGrand S, Muesig KE, McNulty T, Soni K, Knudtson K, Lemann A, et al. Epic allies: development of a gaming app to improve antiretroviral therapy adherence among young HIV-positive men who have sex with men. JMIR Serious Games. 2016;4:e6.
125. LeGrand S, Muesig KE, Platt A, Soni K, Egger JR, Niwoko N, et al. Epic allies, a gamified mobile phone app to improve engagement in care, antiretroviral uptake, and adherence among young men who have sex with men and young transgender women who have sex with men: protocol for a randomized controlled trial. JIMIR Res Protoc. 2018;7:e94.
126. Whiteley L, Brown L, Lally M, Heck N, van den Berg J. A mobile gaming intervention to increase adherence to antiretroviral treatment for youth living with HIV: development guided by the information, motivation, and behavioral skills model. JIMIR MHealth UHealth. 2018;6:e96.
127. Shegog R, Craig Rushing S, Gorman G, Jessen C, Torres J, Lane TL, et al. NATIVE-it’s your game: adapting a technology-based sexual health curriculum for american indian and alaska native youth. J Primary Prevent. 2017;38(1-2):27–48.
128. Schonnesson LN, Bowen AM, Williams ML. Project SMART: preliminary results from a test of the efficacy of a Swedish internet-based HIV risk-reduction intervention for men who have sex with men. Arch Sex Behav. 2016;45(6):1501–11.
129. Montanaro E, Fiellin LE, Fakhouri T, Kyriakides TC, Duncan LR. Using videogame apps to assess gains in adolescents’ substance use knowledge: new opportunities for evaluating intervention exposure and content mastery. J Med Internet Res. 2015;17:e245.
130. Fiellin LE, Kyriakides TC, Hiefte KD, Pendergrass TM, Duncan LR, Dziura JD, et al. The design and implementation of a randomized controlled trial of a risk reduction and human immunodeficiency virus prevention videogame intervention in minority adolescents: PlayForwards: El City Stories. Clin Trials. 2016;13(4):400–8.
131. Lukhele BW, Musumari P, El-Saaidi C, Techasrivichien T, Sugimoto SP, Ono Kihara M, et al. Efficacy of mobile serious games in increasing HIV risk perception in swaziland: a randomized control trial (sgprev trial) research protocol. JIMIR Res Protoc. 2016;5:e224.
132. Enah C, Piper K, Moneyham L. Qualitative evaluation of the relevance and acceptability of a web-based HIV prevention game for rural adolescents. J Pediatr Nurs. 2015;30(2):321–8.

**SUPPORTING INFORMATION**

Additional information may be found under the Supporting Information tab for this article.

**Figure S1.** Results of the database search for recently published eHealth interventions.

**Table S1.** eHealth interventions found in the published literature, 2014 to 2018