



# Digital Interventions to Enhance PrEP Uptake and Adherence Through Stigma Reduction

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## Abstract

**Purpose of Review** Although pre-exposure prophylaxis (PrEP) is effective for reducing risk of HIV transmission, stigma persists as a barrier to HIV prevention. Digital technologies present opportunities to access hard-to-reach populations and increase the efficiency of established interventions. This review examines current digital interventions addressing stigma to improve PrEP-related outcomes.

**Recent Findings** Digital technologies are increasingly used for HIV prevention and include a wide range of formats. Recent interventions focused on stigma and PrEP tend to engage mobile phone-related technology and focus on younger populations with particular attention to men who have sex with men and transgender women.

**Summary** Digital interventions that address stigma are promising for improving PrEP-related outcomes. No single technology currently demonstrates consistent superiority. Limited access to PrEP and heightened stigma in under-resourced countries present challenges for interventions supporting diverse communities. Further research should examine how digital interventions can reduce stigma beyond the individual level to enhance PrEP use and explore opportunities to improve and integrate approaches to stigma measurement.

**Keywords** Digital interventions · Stigma · Pre-exposure prophylaxis · HIV prevention

## Introduction

Pre-exposure prophylaxis (PrEP) is an effective strategy for reducing the risk of HIV transmission [1, 2]. Initially formulated as daily oral tenofovir disoproxil fumarate (Truvada) [3], PrEP is now available with new formulations and delivery options—the most recent advancements include a long-acting injectable form of PrEP (cabotegravir) approved in 2021 [4] and an “on-demand” schedule of oral PrEP as an alternative to daily use [5]. While the dapivirine vaginal ring and microbicides (topical PrEP) are also important developments that have advanced intervention strategies for HIV prevention, none has yet been approved by the Food

and Drug Administration (FDA) in the USA for use outside of clinical studies [6, 7]. The expansion of PrEP and other tools available for the prevention of HIV present promising pathways for increasing access to HIV-related services and reducing disparities in HIV acquisition in the USA and worldwide. Yet, despite increased awareness of PrEP and the growing numbers of people who use PrEP globally [8], stigma related to HIV persists and remains widespread, driving inequities across the PrEP care continuum and impeding potential progress towards ending the HIV epidemic.

Stigma is a social process known to limit engagement, opportunity, wellbeing, and social acceptance for individuals with certain social identities [9–11]. A wide body of literature has explored how stigma causes individuals to appear as separate from others and lower in status, often resulting in social rejection, prejudice, stereotyping, and discrimination [10]. Different types of stigmas related to HIV have been shown to have these effects at multiple levels (e.g., individual, intrapersonal, interpersonal, and structural), posing obstacles to HIV prevention behaviors such as PrEP use. Individual level stigma, which includes self-stigma, refers to one’s negative beliefs or attitudes about their marginalized

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identity. Intrapersonal and interpersonal stigma relate to public perceptions and related social responses towards stereotypes and negative attitudes about various stigmatized identities [12]. Structural stigma comprises the results of organizational activities and policies that create and maintain social inequalities for people with stigmatized identities—examples which include the underfunding of certain healthcare services, promotion of cultural norms that discourage identification with certain identities, and practices that systematically create and maintain inequities to accessing services and care [13]. Given that stigmas across multiple levels are recognized as a major barrier to HIV prevention efforts [14–16], they have become the target of a growing number of interventions seeking to improve PrEP uptake and adherence [17].

With the evolution of digital technologies, digital interventions are an increasingly utilized medium for HIV prevention efforts, especially among populations that have traditionally been difficult to reach, such as racial, ethnic, and sexual minority populations [18]. Digital interventions can offer a convenient, private, cost-effective, and accessible way to receive services or information, making this a desirable and promising format for healthcare delivery and stigma reduction efforts. Digital interventions are often referred to synonymously with eHealth interventions and involve digital technology including, but not limited to, the use of mobile devices, the Internet, and short message service (SMS) messages [19]. Several reviews have examined the effectiveness of digital interventions for HIV prevention across contexts and populations [20–24], demonstrating mixed but promising results related to behavior change and a range of HIV outcomes.

The purpose of the current review is to examine how digital interventions have sought to enhance oral and injectable PrEP-related outcomes through stigma reduction efforts. We focus on FDA-approved PrEP therapies to review the types of digital interventions that are currently available for PrEP, discuss their involvement or potential for application in stigma reduction interventions, and consider how and for whom these interventions have been developed and implemented. We also assess the types of stigmas that these interventions address and their role in shaping outcomes across the PrEP care continuum. Specifically, we focus on HIV-related stigma, PrEP-related stigma, and sexuality-related stigma in this review given their direct relevance to PrEP use and impact on sexual minority populations disproportionately affected by HIV such as gay, bisexual, and other men who have sex with men (MSM) and transgender populations [25]. HIV-related stigma is defined as negative attitudes and beliefs about HIV or people living with HIV [26]. PrEP-related stigma involves negative attitudes and beliefs about people who use PrEP [27], and sexuality-related stigma comprises negative attitudes and beliefs about

individuals based on their sexual identities, behaviors, and relationships [28].

## Digital Interventions for PrEP

Technological advancements have contributed to a rapid evolution of interventions incorporating digital technologies. Over the past decade, efforts to promote PrEP use for HIV prevention have expanded alongside the widespread adoption of social media and the proliferation of smartphones [29, 30]. Integration of digital technology in HIV prevention offers numerous potential benefits and advantages such as increasing the reach, scalability, and efficiency of interventions such as those promoting visibility and anti-stigma messaging to encourage PrEP use and uptake [18]. As a result, interventions centered around PrEP have adopted a wide range of virtual formats and techniques to convey health-related messages and deliver treatments [31–36]. These avenues hold promise for the development and implementation of stigma reduction communication and interventions. We highlight a few of the most widely adopted technologies utilized to bolster PrEP-related outcomes as well as others that are currently less widespread but display innovative and novel features. While stigma may not have been directly explored as mechanisms, primary variables of interest, or outcomes in all examples of the technologies presented, we note the implications and potential of each technology to facilitate stigma reduction.

### Mobile Apps

According to a systematic review of interventions addressing PrEP uptake and adherence among gay, bisexual, and other MSM conducted by Wang and colleagues (2022), the development of app-based interventions in addressing individual level barriers to PrEP has proliferated since 2017 [37••]. Among the Centers for Disease Control and Prevention's Compendium of Evidence-Based Interventions (EBIs) that improve PrEP use and persistence, more than half ( $n = 7$ ) of the 13 interventions listed in August 2023 involved digital technologies [38] with six being mobile health interventions utilizing an app or text messaging as the intervention deliverer [38].

Sullivan and colleagues' M-cubed intervention (2022) is one example of a tailored mobile app designed to address multiple HIV prevention and care needs of MSM [39••]. Made available for Android or iOS smartphones, the app delivered tailored prevention messaging through content and videos, with participants in the intervention arm reporting higher odds of PrEP use in the 3 months after the intervention period [39••]. While this intervention did not explicitly address stigma, the M-cubed program demonstrates potential

for using a mobile app to deliver tailored stigma reduction messaging and related content.

The popularity of app-based interventions for PrEP can be partly attributed to the capacity for seamless app updates, which aligns with the dynamic nature of PrEP-related science and the convenient accessibility of the app itself—participants can often readily download apps onto their phones free of cost [40]. This feature is also relevant for stigma reduction as participants have the ability to access content privately—potentially reducing stigma related to publicly accessing HIV-related services. While app-based interventions have demonstrated high acceptability and feasibility, their efficacy in influencing PrEP uptake in adherence remains unclear [37••]. Moreover, as apps tend to focus on individual-level determinants and outcomes [37••, 41], they may be limited in their capacity to address structural barriers, including structural stigma, that pose barriers to PrEP use.

## Social Media

Social media, which refers to digital platforms that enable multidirectional exchange of information and content among people, groups, and organizations, has been increasingly utilized for disseminating health and prevention information [32]. While social media-based interventions can involve mobile apps, they often engage existing platforms such as Instagram, Facebook, or Twitter to reach their target population [32, 42]. Given the large and readily available audience on social media platforms, social media has the ability to scale and can reach specific and hard-to-reach groups at elevated risk for HIV [43]. Further, the visibility of public posts and sharing of personal stories and experiences via social media may influence social norms with potential to reduce structural level stigma related to HIV, PrEP, and sexual behaviors.

The PrEP4Love (P4L) campaign, launched by Dehlin and colleagues (2019) in Chicago to increase PrEP awareness, generated nearly 41 million unique views across social media platforms, demonstrating social media's capacity to widely disseminate PrEP information [44]. Despite social media's expansive reach, there are limitations to determining whether exposure to such campaigns translate to desired behaviors and outcomes. Further, certain studies suggest that focused campaigns may incite stigmatizing reactions both among those who were directly targeted and those who observed them [44].

In our own work to develop a culturally relevant social media campaign to facilitate HIV testing and PrEP uptake among Latinx MSM, we specifically sought to address HIV- and PrEP-related stigmas in the Latinx community [45, 46]. In developing our social media content,

we integrated the preferences and perspectives of Latinx MSM and linked them to behavioral predictors of HIV testing and PrEP uptake [46]. Our studies have demonstrated that community-driven and culturally relevant social media content that focuses on motivation, empowerment, and stigma reduction presents a feasible strategy for reaching Latinx MSM to promote PrEP use [45].

## AI/Chatbots

Artificial intelligence (AI) is a facet of computer science focused on the automation of imitations of human intelligence to perceive, learn, reason, and problem solve. While AI has been around for several decades, it has evolved significantly in recent years with various applications for health-related research [47]. AI chatbots, which are “computer programs with minimal design interfaces embedded with AI to simulate conversation with human users” [48•], offer the benefits of relaying personalized information with fast response times with potential to reduce employee or provider workloads [34]. The advantages of using chatbots for facilitating PrEP use and adherence include lower costs, the ability to reach people with low access to services, greater availability, increased privacy to address stigma, and wider dissemination potential [49].

In developing an AI chatbot, Massa and colleagues (2022) conceptualized Amanda Selfie, a young transgender woman with futuristic attributes with the objective of creating demand for PrEP among adolescent MSM and adolescent transgender women (TGW) in Brazil [49]. Amanda's facial features of a Black woman were selected to represent a stigmatized social group in Brazilian culture in efforts to reduce stigma and foster increased understanding [49]. Preliminary findings demonstrated that participants were receptive to Amanda Selfie; yet, the chatbot was less efficient in identifying adolescent MSM and TGW and in facilitating PrEP uptake relative to other online strategies such as peer educator recruitment on social media [49, 50].

Of note, several studies have documented limitations of using AI chatbots for HIV prevention, such as appearing “not human-like” [51] and the hesitation surrounding engagement with AI-based tools among some populations [48•, 52•]. Thus, while AI chatbots demonstrate promise as a culturally sensitive digital health tool to counter PrEP-related stigma given its ability to adapt and tailor responses based on the user and its potential to promote HIV prevention messaging from an identity representing a member of a stigmatized group, their application to HIV prevention and PrEP uptake efforts has been slow given questions surrounding their acceptability and the technology guiding their implementation [34, 47, 48•]

## Gaming

Gaming has gained traction as a format of digital interventions with potential to improve knowledge and HIV-related behavioral outcomes, including PrEP use, particularly among adolescents and young people [53]. Given the popularity of video games among young adults in the USA [54], gaming technology presents an opportunity for delivering PrEP-related behavioral interventions to improve motivation and behavioral skills in this population [35].

Viral Combat, developed by Whiteley and colleagues (2019), is one example of a gaming intervention to increase PrEP adherence among young adult, cisgender MSM. The digital game involves participants accumulating points and advancing to increasingly challenging levels as they “fight off HIV and keep it from entering the body” [35, 55]. This approach presents opportunities for integrating goals of reducing stigma through game-like strategies. While Viral Combat demonstrated preliminary efficacy in improving PrEP adherence among young MSM [56], there have been few rigorous evaluations of the effect of gaming on HIV prevention and PrEP use [53].

Given the emerging state of research, making definitive assertions about the role of gaming for stigma reduction and PrEP uptake and adherence is challenging. Nevertheless, an increasing number of studies illustrate that gaming can enhance engagement by imbuing activities with enjoyment and providing a secure, non-stigmatizing environment for participants to hone skills without fear of real-world repercussions [53, 57]. This digital medium could also play an effective role in delivering HIV-, PrEP-, and sexuality-related stigma reduction content through engaging virtual experiences.

## Combined Digital Technologies

An expanding array of digital tools holds potential for reducing stigma and bolstering PrEP utilization and adherence. A discernible trend is the amalgamation of emerging technologies with well-established channels of intervention delivery and communication, including telehealth and text messaging [36]. Virtual avatars, for example, are “digital self-representative agents” that are controlled using an interactive electronic device. These novel tools are being integrated into digital interventions that involve smartphone apps, gaming, and other video technology [58, 59].

As a significant number of interventions encompasses multiple forms of digital technologies, they can pose challenges for comprehensively evaluating their effectiveness in influencing PrEP outcomes. The swift pace of technological evolution, coupled with the absence of uniformity in the lexicon and conceptualization of digital technologies, compound the complexity of this endeavor. Further, PrEP-related

digital interventions not only exhibit diversity in the technologies they employ but are also varied in the theoretical frameworks that underpin their approach to influencing PrEP outcomes. Hence, continued research is needed to explore the potential for HIV-, PrEP-, and sexuality-related stigma reduction efforts through the use of digital interventions.

## Stigma and PrEP Uptake and Adherence

As stigma poses a major barrier to PrEP uptake and persistence, it is often addressed by digital interventions that seek to improve PrEP outcomes as noted across several of the interventions described above. We highlight studies conducted within the past 5 years that either explicitly sought to address stigma in the development or evaluation of a digital intervention focused on improving PrEP-related outcomes (Table 1).

As shown in Table 1, the studies demonstrate variability in their target population, the digital technology utilized, and the forms of stigma they sought to address. Three studies focused on MSM, one focused on TGW, and one focused on Black women. Studies utilized an array of digital technologies, including text messages, interactive website trainings, mobile phone interventions, and social media campaigns. Further, stigma was not always explicitly or consistently measured across these studies despite being a target of the interventions. This lack of standardized or explicit measures of stigma in some studies introduces a notable limitation to making conclusions about stigma reduction as a mechanism for facilitating PrEP use in digital interventions.

Rouffiac and colleagues’ (2020) mobile messaging intervention to reduce HIV- and PrEP-related stigma sought to increase PrEP uptake among PrEP-eligible Black MSM living in the Southern United States [33]. The intervention, informed by the Information-Motivation-Behavior (IMB) model, identified education as a key mechanism for reducing stigma and sought to present accurate and positive information about PrEP [33]. The authors describe HIV stigma in the context of feeling discomfort talking to healthcare providers about having sex with men and being seen as promiscuous by doctors and friends. With culturally relevant digital materials, the study informed Black MSM about the beneficial impacts of PrEP to address stigma related to this prevention strategy and ultimately facilitate PrEP engagement. While the results of the randomized controlled trial have yet to be published, the authors demonstrate that their PrEP mobile messaging intervention can play an important role in HIV prevention and care. Yet, the authors did not report a measure of stigma as a primary or secondary outcome, which may limit conclusions related to the intervention’s impact on stigma reduction.

**Table 1** Recent studies including stigma in the development or evaluation of a digital intervention for PrEP-related outcomes

Study, year	Sample/setting	Type of stigma explored	Digital technology utilized	Outcomes evaluated or to be evaluated	Theoretical framework for Intervention	Study results/ summary
Rouffiac et al. [33]	Black MSM (aged 18–35 years) living in Southern United States	PrEP- and HIV-related stigma	PrEP mobile messaging intervention using tailored text messaging and free Web content	PrEP uptake	Information-Motivation-Behavior model	Data collection and analyses with the study's 65 participants are ongoing; results from intervention development suggest that a PrEP mobile messaging intervention may be an effective approach to increase PrEP uptake for Black MSM in the Southern United States
Randolph et al. [60]	Black women (aged 18 + years) living in Southern United States	PrEP stigma	Digital training, entertainment videos and modules, and a digital PrEP navigator	PrEP knowledge, awareness, uptake, and trust, reduction of PrEP stigma	Theoretical model, Transportation theory, and Socioecological model	Data collection phase is ongoing; preliminary data suggest that engaging community assets with digital tools are promising for promoting health among Black women
Wray et al. [61]	MSM (aged 18 + years) living in the USA	PrEP stigma	Web application called Game Plan providing static and interactive digital content	PrEP uptake and consistent use	Information-Motivation-Behavior model	The development of Game Plan is ongoing; preliminary research emphasizes that interventions promoting healthy HIV practices and goal setting may be useful tools to facilitate PrEP use among MSM
Wilson et al., Jalil et al. [62, 63]	TGW (aged 18–24 years) living in Rio de Janeiro, Brazil	HIV-related stigma	Mobile phone intervention called <i>Brilhare Transcender</i> (BeT) offering digital interactions and automatic messaging	HIV incidence, PrEP uptake, linkage to HIV care, viral suppression	Strengths-Based Case Management model	Post BeT intervention ( $n = 20$ ) fewer participants experienced discrimination; all participants not living with HIV ( $n = 13$ ) initiated PrEP post intervention

**Table 1** (continued)

Study, year	Sample/setting	Type of stigma explored	Digital technology utilized	Outcomes evaluated or to be evaluated	Theoretical framework for Intervention	Study results/ summary
Patel et al. [43]	Black and Latinx MSM (aged 18–29 years) living in the USA	PrEP-, HIV-, and sexuality-related stigma	Social media-based behavioral intervention with an online messaging campaign (E-PrEP)	Intention to use PrEP, PrEP uptake, and PrEP knowledge	Information-Motivation-Behavior model	Data collection and analyses are ongoing, authors anticipate that intervention will facilitate changes in PrEP mediators (e.g., knowledge, attitudes, stigma, and access) to increase PrEP uptake

MSM men who have sex with men, TGW transgender women

Wray and colleagues’ (2022) web application named “Game Plan” is also informed by the IMB model and draws upon Motivational Interviewing (MI) to challenge misconceptions about PrEP to reduce stigma among MSM and encourage PrEP use or PrEP persistence [61]. The provision of information and instrumental support via a “credible source” was engaged as a technique to dispel inaccurate perceptions of PrEP and address PrEP stigma. Participants were able to access this information through accessible and expandable links on the web application. Additional features such as SMS text messages allow for “check-ins” and feedback for participants to reinforce the program’s goals.

Game Plan is currently in its preliminary phase of design but presents a potentially scalable digital intervention that can address stigma and support PrEP use among MSM. Follow-up web-based surveys to evaluate Game Plan include assessments of “PrEP use, sexual behavior, alcohol use, and important antecedents of change for each of these outcomes at baseline and 1, 3, and 6, months” [61]. The explicit inclusion of stigma as one of the antecedents of change remains unclear from the provided information. Yet, given the acknowledged impact of stigma on the program’s outcomes, it is recommended that future iterations of the survey explicitly measure and report on stigma. Understanding the role of stigma in shaping behaviors and outcomes is pivotal for refining interventions like Game Plan and advancing our comprehension of the multifaceted factors influencing health-related decisions and behaviors. Overall, the development of Game Plan through user-centered design research emphasizes the importance of tailoring programs for their target populations.

The ability to develop tailored digital materials that address PrEP stigma and related concerns was a clear theme among the digital interventions. Randolph and colleagues’ (2022) web-based salon intervention to improve PrEP uptake among Black women in North Carolina aimed to leverage the social networks of Black women within trusted environments as a strategy to reduce PrEP stigma [60]. Stigma was measured using two subscales (PrEP Stereotypes and PrEP Disapproval by Others) of the PrEP Anticipated Stigma Scale [64]. Stylists were identified as trusted individuals and opinion leaders whose advice is respected among Black women. Informed by the transtheoretical model, the intervention, named, “Using PrEP and Doing it for Ourselves” (UPDOs Protective Styles), involves training stylists to relay tailored information on PrEP to influence health behavior by supporting progress through stages of change [65]. The integration of entertainment-education and video blogs allows participants to watch sitcom episodes related to Black women’s health that were developed using a socially and culturally relevant script. Such scripts have been demonstrated to be highly promising for stigma reduction efforts, given that stigma is shaped by both individual and collective

values [62]. Taken together, the UPDOs Protective Styles utilizes contact with trusted individuals and education as key mechanisms for reducing stigma related to PrEP use among Black women. The intervention presents opportunities for integrating both in-person and digital components in a single intervention.

Notably, several studies integrated digital technology with the use of peer navigators as an additional strategy to reduce barriers related to stigma and discrimination [63]. Utilizing peers can play a meaningful role in stigma reduction as peers are often trusted and have shared personal lived experiences. Wilson and colleagues' (2021) *Brilhar e Transcender (BeT)* is an evidence-based peer and mHealth-delivered system navigation intervention that was implemented using social media and text messaging for young TGW in Brazil to facilitate HIV testing and PrEP use [63, 66]. BeT was adapted to be delivered by peers to reflect how young people use their mobile devices to engage with the world. Hence, delivery of information by trusted individuals (peers) was central to the digital intervention's approach to reduce anti-trans stigma, which poses barriers to HIV prevention and care. Stigma and discrimination, including transgender-specific health care discrimination, were to be measured at baseline and 3 months, yet the specific measures and results have yet to be reported.

Patel and colleagues' (2021) *Empowering with PrEP (E-PrEP)* social media intervention to increase PrEP uptake in young Black and Latinx MSM also involved content delivery by peers—the intervention aimed to address perceived stigma of using PrEP by leveraging the influence of both peers and social media [43]. The authors report that HIV, PrEP, and sexuality-related stigma were included in their assessment of their E-PrEP intervention but did not explicitly report the items used to assess these measures. Notably, E-PrEP was also guided by the IMB-model, emphasizing the importance of relaying information, increasing motivation, and building behavioral skills to reduce stigma and facilitate PrEP-related behaviors. The inclusion of peer navigators in these studies speaks to possible ways that future digital intervention efforts for HIV prevention can incorporate aspects of human interaction and on-demand technology assistance when delivering services through a mostly virtual format.

Many of the studies engaged similar mechanisms for reducing HIV-, PrEP-, or sexuality-related stigma to facilitate PrEP use such as providing knowledge/information and engaging trusted individuals to foster confidence among participants. Notably, several of the interventions are multi-modal and integrate more than just one digital tool for intervention implementation—this highlights the flexibility and modularity of digital tools, which can support access to the intervention and engagement with target populations. Multi-media resources that include website material, social media content on Facebook or Instagram, and promotional content

on billboards, likewise, serve promising roles in addressing stigma given their visibility, accessibility, and potential for reaching wide audiences [67].

Notably, there were subtle differences in how each study defined stigma, highlighting challenges in stigma measurement and underscoring the diverse conceptualizations of stigma in relation to HIV prevention. While all studies listed in Table 1 focused on addressing HIV- or PrEP-related stigma, certain studies incorporated broader definitions of stigma, such as those encompassing issues related to sexuality [43]. Moreover, some studies embraced specific conceptualizations of stigma, allowing for diverse and overlapping definitions. Of note, all but one of the studies included in our table report data collection and analysis in progress, highlighting the dynamic and developing nature of the current literature exploring digital interventions for PrEP use and adherence.

## Conclusions

As new technologies and their potential for stigma reduction efforts are constantly being explored and developed, our review is not exhaustive of all digital interventions—rather, our review points to several key features of current digital interventions that seek to enhance PrEP outcomes by addressing stigma as one factor. While the use of digital technologies is widespread, many of the interventions described in our review focus on young populations, such as young MSM and young TGW. This may be attributed to greater acceptability of digital tools among younger populations especially for tools that involve more recent technology.

Further, digital interventions addressing stigma that were included in this review frequently centered on MSM and transgender populations, a trend that aligns with expectations considering the higher HIV prevalence within these communities and heightened stigma linked to their identities as sexual and gender minorities [68]. The majority of the digital interventions we identified were developed and assessed within the USA, potentially reflecting our own biases. Nevertheless, a number of interventions originated in other countries such as Brazil, China, and South Africa, underscoring the global prevalence of digital technology. However, the availability of digital technology and PrEP in specific countries, coupled with the willingness of individuals to confront stigma linked to HIV and PrEP, could potentially present challenges for digital interventions aimed at promoting PrEP uptake. As areas that are less developed or more under resourced may not have access to PrEP treatment and digital stigma reduction interventions, future research should investigate these systemic challenges to explore further ways to reduce PrEP-related stigma and enhance HIV

prevention efforts. As earlier mentioned, recent prevention advancements such as the dapivirine vaginal ring (DVR) and topical microbicides have not yet been approved for use in the USA beyond clinical studies. Hence, our review is limited by its US perspective and may not encompass related work conducted with the DVR in sub-Saharan Africa [69]. Future research should explore new and developing forms of HIV prevention and related strategies for improving overall prevention efforts and outcomes.

While we pinpointed several technologies that exhibited greater popularity in fostering PrEP uptake in this review, no single technology demonstrated a consistent superiority over others. This phenomenon could stem from the scarcity of comprehensive and rigorous evaluations and the inclination of these interventions to be customized for their intended audience, resulting in a high degree of specificity tailored to each respective community. Similar to the findings from Romero and colleagues' review of technology-delivered intervention strategies to increase HIV testing (2021), our review highlights that the appropriate technology must be used for the context and population along with an evidence-based intervention [18].

Moreover, most of the studies highlighted in our table have yet to publish the final results of their trials. Hence, we are unable to make conclusions about the efficacy of these digital interventions in reducing stigma and influencing PrEP-related outcomes. The interventions, however, demonstrate that digital tools present feasible strategies for targeting mechanisms that may underly effective stigma reduction. Specifically, providing relevant information or education, counseling offered by peers or other trusted individuals, and increasing self-efficacy through in-person and digital forms of contact were utilized as key approaches to reduce stigma that may impede PrEP uptake or adherence.

It is important to note that stigma has been measured and conceptualized in various and nuanced ways, thereby contributing to our complicated understanding of its impact on PrEP-related behaviors and outcomes [70, 71]. Different forms, types, and levels of stigma have been the focus of various digital interventions for PrEP. For example, anti-trans stigma [66], sexual behavior stigma [72], culturally related stigma [73•], and general HIV-related stigma [33, 64, 74], have been noted as barriers to PrEP-related outcomes. While our study focused on stigma related to PrEP, HIV, and sexual behaviors, the definitions of these stigmas are not necessarily mutually exclusive, and intersectional stigma, or the overlapping influence of various forms of stigma, must be acknowledged [75].

Additionally, studies from the current review did not consistently measure and report stigma, as there were differences across studies in how each paper defined, evaluated, and incorporated stigma into their interventions. While one

study utilized quantitative subscales to measure stigma (subscales of PrEP user stereotypes and PrEP disapproval by others from the PrEP Anticipated Stigma Scale by Randolph and colleagues [60]), other studies targeted stigma reduction without explicitly reporting stigma measures.

These findings underscore the challenges associated with measuring and assessing stigma in the context of HIV prevention, revealing complexities arising from its diverse conceptualizations and highlighting significant implications for future investigations. As emphasized in a comprehensive review on intersectional stigma by Turan and colleagues (2019), stigma is not an isolated phenomenon; it does not exist nor is it experienced in a vacuum. The necessity for more empirical and reliable methods to measure and analyze stigma across multiple intersecting levels is evident, urging a concerted effort towards refining measurement approaches [70].

While many digital interventions recognize the challenges that stigma poses to HIV prevention and PrEP use, they do not always directly address the core mechanisms of action that can reduce stigma [76] or utilize a consistent tool to measure various levels of stigma and their impacts on prevention outcomes. Future studies could focus on developing and testing standardized measurement tools for HIV-, PrEP-, and sexuality-related stigma, as well as directly incorporating explicit measures of stigma as a variable in the design and evaluation of digital interventions for HIV prevention. Goals of future research would include a clearer understanding of multiple and intersecting stigmas and their relationship to HIV risk and identification of groups that are especially in need of stigma-reduction interventions.

Golub notes that PrEP stigma is inextricably linked to HIV stigma and other forms of stigma because it is designed to prevent HIV infection and is often considered “a less honorable prevention choice” [71]. Hence, our review suggests that the intersectional nature of stigma is important to consider in the context of digital interventions and for understanding how these relationships impact PrEP outcomes. Particularly, future research should continue to explore and develop measures for intersectional stigma to improve our capacity to evaluate digital interventions that seek to integrate structural components to tackle stigma systematically and enhance PrEP outcomes on a broader level. To address this gap, greater research on whether digital interventions can effectively integrate these key mechanisms to shape PrEP use is critical. Further, attention to which digital tools are most salient or successful in this endeavor can provide additional context as we continue to expand upon and develop new technologies for enhancing HIV prevention efforts.

Specifically, efforts to reduce HIV- and PrEP-related stigma must be addressed societally [77••]. Existing policies and systems create organizational obstacles for individuals



at risk of HIV, hindering not only their engagement with healthcare but also their ability to access care and adhere to treatment regimens. The influence of social determinants of health on healthcare outcomes is widely recognized [78, 79], and research substantiates that social determinants have a substantial impact on HIV prevention endeavors [80]. Factors such as housing and food insecurity, educational barriers, inadequate transportation, healthcare provider shortages, and other challenges all contribute to this impact [77••]. As digital interventions for PrEP have predominantly concentrated on individual-level behaviors, allocating less attention to structural influences, the integration of technologies and collaborative endeavors to incorporate these broader contextual elements may be pivotal for enhancing the overall effectiveness and impact of such interventions.

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## Declarations

**Human and Animal Rights and Informed Consent** All reported studies/experiments with human or animal subjects performed by the authors have been previously published and compiled with all applicable ethical standards (including the Helsinki declaration and its amendments, institutional/national research committee standards, and international/national/institutional guidelines).

**Competing Interests** The authors declare no competing interests.

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Papers of particular interest, published recently, have been highlighted as:

- Of importance
- Of major importance

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