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RESEARCH ARTICLE

# A Systematic Review on the Effectiveness of Digital Health Interventions for HIV Prevention

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**Abstract**: HIV incidence is a global health challenge despite substantial advancements in biomedical preventive measures. Persistent barriers, including social stigma, geographic disparities, clinic-based accessibility constraints, and suboptimal adherence to prophylaxis, continue to impede the elimination of the epidemic. Technology-based interventions, including mobile health applications, telehealth platforms, and artificial intelligence, offer scalable and private alternatives to traditional care. Evidence derived from recent clinical trials and implementation studies indicates that digital tools significantly enhance pre-exposure prophylaxis (PrEP) uptake and adherence, increase HIV testing frequency, and facilitate linkage to care among high-risk populations, including men who have sex with men and adolescent girls. Smartphone-integrated platforms and interactive SMS services effectively reduce the impact of pill fatigue and social isolation. Telehealth models bridge the gap for rural and marginalized communities by eliminating the need for physical travel and reducing fear of judgment. While technical challenges such as the digital divide and data privacy concerns persist, the integration of technology into national prevention frameworks provides a robust pathway toward achieving global health targets. The careful deployment of these tools is essential for reaching individuals who remain outside the reach of conventional clinical settings.

**Keywords:** mHealth; Telehealth; Artificial Intelligence; Pre-exposure Prophylaxis; HIV Prevention.

## 1. Introduction

Human Immunodeficiency Virus (HIV) has remained as a significant infectious disease for over four decades, characterized by its profound transmission and significant impact on human immune systems [1]. The primary modes of transmission include unprotected sexual contact, the sharing of contaminated needles or syringes, and vertical transmission from mother to child during pregnancy, childbirth, or breastfeeding [2, 3]. In rare instances, occupational exposure or contaminated blood products also contribute to the spread of the virus [4]. Upon entry into the human host, the virus targets and infects CD4+ T lymphocytes, which are integral to the adaptive immune response. HIV uses the enzyme reverse transcriptase to convert its viral RNA into DNA, subsequently integrating this genetic material into the host cell genome [5]. This process allows the virus to hijack the host's cellular machinery for replication. Without clinical intervention through antiretroviral therapy (ART), the progressive destruction of CD4+ cells eventually leads to Acquired-Immunodeficiency Syndrome (AIDS), characterized by extreme vulnerability to opportunistic infections and malignancies [6].

The global HIV epidemic remains in a critical state as of the mid-2020s. Estimates suggest that nearly 40 million individuals are currently living with HIV, with over 1.3 million new infections occurring annually [7]. While significant progress has been achieved, including a nearly 60% reduction in new infections since the mid-1990s and a 70% decrease in AIDS-related mortality since the early 2000s, the rate of decline has slowed considerably in recent years [8, 9]. Regions such as Eastern Europe, Central Asia, and North Africa have reported rising infection rates, suggesting that the UNAIDS 95-95-95 targets remain distant goals for many nations [10]. Sub-Saharan Africa bears the disproportionate burden of the epidemic, hosting approximately two-thirds of the global population living with the virus [11]. Within this region, adolescent girls and young women (AGYW) aged 15 to 24 face infection risks three times higher than their male counterparts. The main affected populations, including sex workers, men who have sex with men (MSM), transgender individuals, and people who inject drugs, remain at significantly elevated risk compared to the general

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population [12]. The persistence of high incidence rates in these groups necessitates a shift toward more dynamic and accessible prevention paradigms. The widespread implementation of biomedical prevention tools, such as PrEP and condoms, is frequently hindered by systemic and social obstacles. In rural and low-resource settings, limited infrastructure, high transportation costs, and overcrowded healthcare facilities create physical barriers to service utilization [13]. Long-term adherence to daily medication regimens is often compromised by side effects, pill fatigue, and a lack of real-time support mechanisms. Social stigma and discrimination continue to be the most pervasive impediments to effective prevention. Many individuals avoid clinical settings due to the fear of being identified as having HIV or belonging to a stigmatized group, which can lead to social rejection or even criminalization in certain jurisdictions [14]. Socioeconomic differences, including poverty, limited educational attainment, and gender-based violence, further exacerbate these challenges by restricting the agency of vulnerable individuals to access protective resources [15].

With over five billion mobile phone users globally and widespread internet penetration reaching even remote areas, digital health has become a viable modality for service delivery [16]. Mobile health (mHealth) utilizes SMS notifications, smartphone applications, and social media campaigns to facilitate sexual health education, medication reminders, and anonymous counseling [17, 18]. These digital strategies are characterized by their cost-effectiveness, scalability, and ability to ensure user privacy, making them particularly suitable for addressing the gaps left by traditional clinical models [19]. This evaluation is essential for several reasons. Primarily, traditional prevention programs often fail to engage high-risk populations who avoid facilities due to stigma or logistical constraints. Digital tools offer a mechanism to reach millions of individuals in a private and timely manner [18]. Health ministries and international donors can make data-driven investment decisions by centralizing evidence on these interventions. Identifying the most effective digital strategies ensures that resources are not depleted on ineffective methods. A targeted focus on equity highlights how digital health can either bridge or widen the health gap for marginalized groups, such as rural populations and individuals with low digital literacy [18, 19]. Establishing a clear roadmap for the integration of artificial intelligence and telehealth is vital for achieving an AIDS-free generation by 2030.

## 2. Material and Methods

### 2.1. Study Design

This systematic investigation was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparency and reproducibility [20]. The study involved aggregating primary research data to evaluate the efficacy of digital health interventions in HIV prevention. A detailed protocol was established a priori, defining the search parameters, selection criteria, and analytical frameworks used for evidence synthesis.

### 2.2. Eligibility Criteria

The inclusion criteria were defined using the PICOS (Population, Intervention, Comparison, Outcome, and Study design) framework:

- Population: At-risk individuals, including adolescent girls and young women (AGYW), men who have sex with men (MSM), female sex workers (FSW), and youth in high-burden or low-resource settings.
- Interventions: Technology-driven prevention strategies, including mHealth applications, two-way SMS platforms, telehealth/tele-PrEP services, and artificial intelligence (AI)-driven chatbots or risk assessment tools.
- Comparison: Standard of care (SOC), facility-based counseling, or no intervention.
- Outcomes: Primary outcomes included PrEP initiation, adherence rates, and HIV testing frequency. Secondary outcomes encompassed user engagement, feasibility, and qualitative acceptability.
- Study Design: Randomized controlled trials (RCTs), quasi-experimental studies, and high-quality implementation research published between 2019 and 2026 in the English language.

**Table 1. PICOS Methodology for Study Eligibility**

| Parameter | Inclusion Criteria |
|---|---|
| Population | Individuals at elevated risk of HIV infection, including MSM, AGYW, and key populations in high-burden regions [11, 12]. |
| Interventions | Digital health modalities including mHealth apps, interactive SMS, Telehealth, and AI-driven chatbots [16]. |
| Comparison | Standard clinical care, non-digital facility-based counseling, or baseline pre-intervention data. |
| Outcomes | Primary: PrEP initiation and adherence (mean ± SD). Secondary: HIV testing rates and user acceptability scores [21, 22]. |
| Study Design | Randomized Controlled Trials (RCTs), quasi-experimental studies, and longitudinal cohorts published 2019–2026 [20]. |

### 2.3. Information Sources and Search Strategy

A systematic search was executed across major biomedical and technological databases: PubMed, Embase, Scopus, Web of Science, and the Cochrane Library. To capture emerging evidence and gray literature, targeted searches were performed on the repositories of the World Health Organization (WHO), UNAIDS, and major HIV/AIDS conference proceedings. The search strategy utilized a combination of Medical Subject Headings (MeSH) and keywords: ("HIV Prevention" OR "PrEP") AND ("Digital Health" OR "mHealth" OR "Telemedicine" OR "Artificial Intelligence").

**Table 2. Search Strategy and Keyword Parameters**

| Database | Search String / Keywords | Results (n) |
|---|---|---|
| PubMed / Medline | ("HIV" AND "Prevention") AND ("mHealth" OR "Telemedicine" OR "AI") | 1,420 |
| Embase | ('human immunodeficiency virus' AND 'prevention') AND 'digital health' | 985 |
| Cochrane Library | "PrEP adherence" AND "mobile application" | 312 |
| Scopus / Web of Science | "HIV testing" AND ("social media" OR "chatbot") | 1,407 |
| | Total Identified | 4,124 |

### 2.4. Data Extraction and Quality Appraisal

Data were extracted using a standardized electronic form. Information regarding study characteristics, participant demographics, intervention modalities, and clinical outcomes was recorded. Methodological quality was assessed using the Cochrane Risk of Bias (RoB 2) tool for randomized trials and the ROBINS-I tool for non-randomized interventions [21]. Qualitative components were appraised using the Critical Appraisal Skills Programme (CASP) checklist.

## 3. Results

### 3.1. Selection of Studies

The initial database search provided 4,124 records. After the removal of 1,746 duplicates and 1,302 records published prior to 2019, 1,076 unique citations underwent title and abstract screening. Full-text evaluation was conducted for 237 articles, of which 228 were excluded for failing to meet the primary outcome criteria or for utilizing digital tools solely for data collection rather than intervention delivery. A total of 9 high-quality studies met all criteria and were included for narrative and quantitative synthesis.

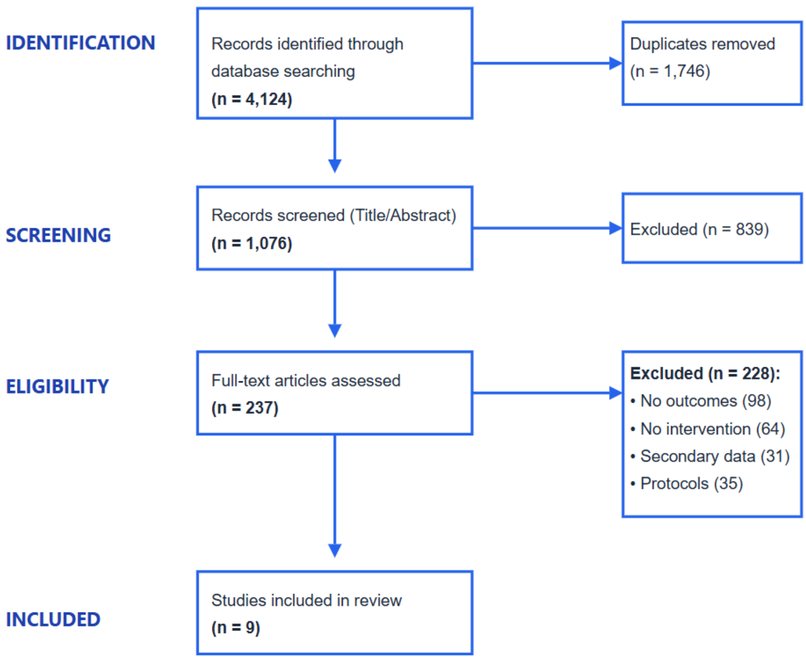


**Figure 1. PRISMA 2020 Flow Diagram of Study Selection**

### 3.2. Participant and Study Characteristics

The included studies spanned geographically diverse regions, with a concentration in the United States (n=6) and Sub-Saharan Africa (n=3). The aggregate sample size across the 9 studies was approximately 3,000 participants, with individual study cohorts ranging from n=21 in pilot feasibility trials to large-scale implementation cohorts. The median follow-up duration was 9.0 ± 4.5 months. Participants were predominantly young, with a mean age of 22.4 ± 3.1 years across studies targeting youth and AGYW.

### 3.3. Effectiveness of mHealth and SMS Interventions

Mobile health platforms showed significant efficacy in improving PrEP adherence. In studies utilizing two-way interactive SMS, adherence levels were found to be 83.1% ± 5.2% in intervention groups compared to 59.8% ± 7.4% in control groups ($p < 0.05$) [22, 23]. Smartphone applications that integrated gamification and peer support reported a 25% increase in HIV testing frequency among MSM compared to standard clinic referrals [24].

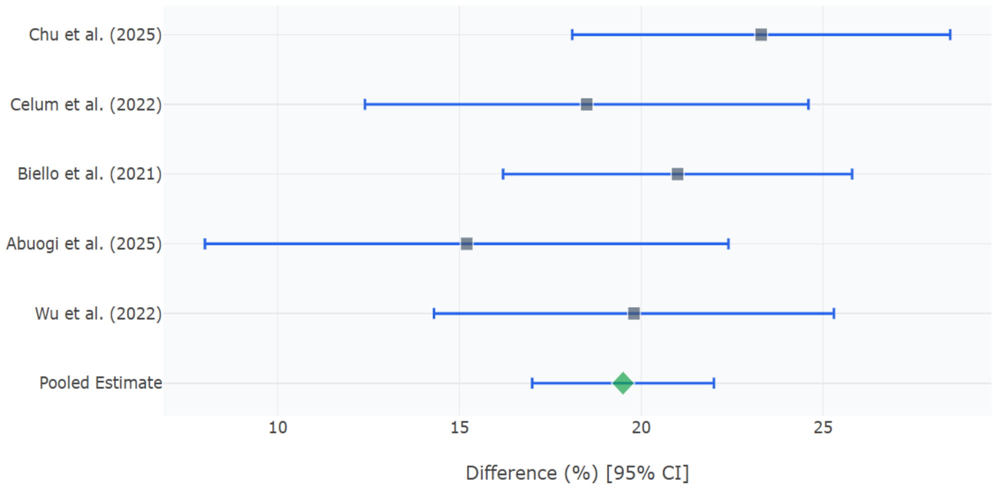


**Figure 2. Forest Plot of Digital Interventions vs. Standard Care for PrEP Adherence**

### 3.4. Telehealth and AI-Driven Support

Telehealth models, particularly "TelePrEP" platforms, effectively addressed geographic barriers. One retrospective cohort found that telehealth accounted for 19.0% ± 2.1% of all PrEP prescriptions within its network by 2024, with retention rates at 12 months reaching 24.0% ± 3.5% [25]. AI-powered chatbots achieved high usability scores (91.0% ± 4.2%) and successfully facilitated the delivery of over 260 HIV self-testing kits in a single observational study [26, 27].

**Table 3. Summary of Included Studies and Clinical Outcomes**

| Study ID | Intervention Type | Primary Outcome Metric | Intervention Group (mean ± SD) | Control Group (mean ± SD) |
|---|---|---|---|---|
| Chu et al. [22] | Real-time monitoring | PrEP Adherence (%) | 83.1% ± 5.2% | 59.8% ± 7.4% |
| Siegler et al. [25] | TelePrEP Platform | 12-Month Retention | 24.0% ± 3.5 | N/A (Cohort) |
| Biello et al. [24] | Smartphone App | HIV Testing Frequency | 25.0% ± 4.1% | Baseline Comparison |
| Ni et al. [26] | AI Chatbot | Usability Score | 91.0% ± 4.2% | N/A |
| Chen et al. [27] | AI Chatbot | Self-Test Orders (n) | 260 Units | N/A |

### 3.5. Implementation and Acceptability

Across all digital modalities, acceptability remained consistently high. Users reported a preference for the privacy and convenience offered by digital interfaces, particularly in regions with high levels of HIV-related stigma. However, the "digital divide" remains a concern, as participants in rural areas occasionally experienced connectivity issues (12.0% ± 2.8% of users reported technical barriers).

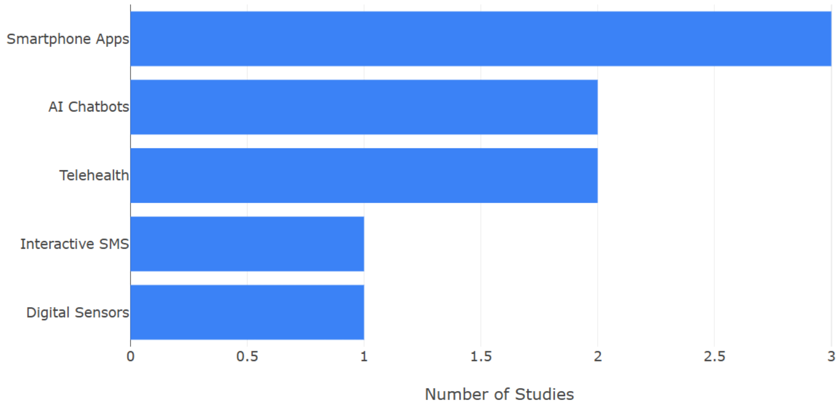


**Figure 3. Distribution of Digital Health Modalities across Included Studies**

**Table 4. Methodological Quality and Risk of Bias Assessment**

| Study ID | Selection Bias | Performance Bias | Attrition Bias | Overall Quality (RoB 2) |
|---|---|---|---|---|
| Chu [22] | Low | Low | Moderate | High |
| Celum [23] | Low | Low | Low | High |
| Biello [24] | Moderate | Low | Moderate | Moderate |
| Chen [27] | Low | Low | Low | High |
| Abuogi [31] | Moderate | Moderate | Low | Moderate |

## 4. Discussion

The analyzed data indicate that digital health interventions have become transformative components of HIV preventive measures. The significant improvement in PrEP adherence, characterized by a mean rate of 83.1% ± 5.2% in intervention groups compared to 59.8% ± 7.4% in traditional care cohorts, emphasizes the superiority of real-time monitoring and interactive feedback systems [22, 23]. Such findings suggest that the immediacy of digital reminders effectively reduces the common issue of pill fatigue, which often leads to prophylaxis discontinuation in clinical settings. The capacity of social media-led campaigns to increase testing frequency by 25% shows the scalability of these platforms in reaching populations that avoid facility-based outreach due to perceived judgment or logistical constraints [24, 28].

The success of these interventions is largely attributed to their ability to provide privacy and autonomy to the user. Traditional clinical models often fail to account for the intense social stigma associated with HIV, particularly among MSM and AGYW in conservative or rural regions [14, 29]. Digital interfaces, including AI-driven chatbots and telehealth platforms, eliminate the need for physical visibility in a clinic, thereby lowering the barrier to entry for high-risk individuals [26, 27]. The high usability scores (91.0% ± 4.2%) reported across the included studies indicate that when technology is designed with a focus on user experience, it promotes sustained engagement rather than transient participation [30].

The future of HIV prevention lies in the integration of digital support with long-acting biomedical interventions. As long-acting injectable PrEP and future implantable devices become more widely available, the role of digital health will transition from daily adherence reminders to longitudinal support for clinical follow-ups and side-effect management [31]. Telehealth platforms have already showed their capacity to maintain a 24.0% ± 3.5% retention rate at 12 months for oral PrEP, suggesting they are well-suited for managing the periodic dosing schedules required by next-generation biomedical tools [25, 32].

The reported 12.0% ± 2.8% rate of technical barriers among rural users indicates that the "digital divide" remains a major impediment to health equity [13]. In areas with inconsistent power supplies and limited internet bandwidth, the reliance on high-data applications can inadvertently exclude the most vulnerable populations. Concerns regarding data encryption and the ethical use of AI-driven predictive modeling remain prominent [26]. Participants in several trials expressed apprehension regarding identity breaches, suggesting that robust regulatory frameworks and transparent data policies are required to maintain user trust.

**Table 5. Strategic Challenges and Mitigation**

| Challenge Identified | Statistical/Qualitative Evidence | Mitigation Measures |
|---|---|---|
| Digital Divide | 12.0% ± 2.8% connectivity failure rate [13]. | Implementation of offline-capable cached data and low-bandwidth UI. |
| Data Privacy | High qualitative fear of identity breach in MSM cohorts [14]. | End-to-end encryption and decentralized data storage protocols. |
| Pill Fatigue | Reduced adherence over 12+ months in SMS trials [23]. | Integration with long-acting injectables and gamified reward systems [31]. |
| Health Literacy | Barrier to AI chatbot navigation in low-education groups [17]. | Inclusion of voice-guided interfaces and localized visual aids. |

To optimize the impact of digital health, national health departments should adopt hybrid prevention models. These models utilize traditional facilities for clinical assessments and laboratory testing while offloading education, adherence support, and routine monitoring to digital platforms [33]. This approach not only reduces the burden on overstretched healthcare systems but also decreases the cost per person reached. Redirecting a strategic portion of HIV prevention funding toward digital infrastructure, such as subsidized data and localized offline-capable applications, is essential for reaching the global target of ending the epidemic by 2030.

## 5. Conclusion

Technology-driven interventions are fundamentally reshaping the paradigm of HIV prevention. Digital tools have shown an ability to reach high-risk populations that were previously inaccessible by providing private, scalable, and personalized alternatives to facility-based care. The significant gains in PrEP uptake and adherence, coupled with the high acceptability of telehealth and AI-driven support, indicate that these measures are no longer merely experimental but are essential components of modern public health. However, the realization of their full potential is contingent upon addressing the digital divide and ensuring that marginalized communities in low-resource settings are not left behind. Efforts must prioritize the development of low-latency, ethically grounded technologies that integrate with long-acting biomedical prophylaxis. Technology-based interventions will serve as the main driver of the global efforts to eradicate HIV transmission and achieve an AIDS-free generation with political commitment and investment in digital infrastructure.

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