

ACHIEVING THE 2030 GOAL OF ENDING HIV: AN ADVANCED ANALYSIS OF STRATEGIC INTERVENTIONS, SOCIOECONOMIC CHALLENGES, AND BIOMEDICAL PROGRESS

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Abstract: The global commitment to end HIV as a public health threat by 2030 represents one of the most ambitious goals in modern public health, requiring a multidimensional and sustained effort across all scientific, social and cultural fields. This study provides an in-depth and comprehensive analysis of the key strategies, systemic challenges and biomedical advances that are driving progress towards this goal. It reviews the effectiveness of established interventions such as antiretroviral therapy (ART) and pre-exposure prophylaxis (PrEP), while highlighting the critical role of community initiatives, education and behaviour change programmes in addressing the social determinants of the epidemic.

The research also explores the persistent structural inequalities that exacerbate vulnerability to HIV, including poverty, gender inequalities, stigma, and poor health infrastructure, particularly in low- and middle-income countries. These barriers are assessed in the context of their interconnectedness, highlighting how compounded disadvantages impede universal access to prevention, treatment, and care services. On the biomedical side, the study examines transformative innovations, such as the development of long-acting injectable therapies, advances in vaccine research, and gene-editing technologies such as CRISPR, that hold promise not only to manage but potentially eradicate the virus. These scientific advances are analyzed for their feasibility, scalability, and potential to fill existing therapeutic gaps.

In addition, the research includes a critical review of global policies and financing mechanisms, analyzing their alignment with evidence-based practices and their effectiveness in promoting equitable access to health care. Drawing on case studies from diverse geographic and socio-economic contexts, the study highlights successful models of integration between scientific advances, robust health systems, and grassroots engagement.

Synthesizing data and ideas from interdisciplinary sources, this research highlights the importance of a coordinated and comprehensive approach to combat the HIV epidemic. It concludes with practical recommendations for policymakers, healthcare providers and international stakeholders, highlighting the need for sustained investment, innovation and collaboration to achieve the vision of an HIV-free world by 2030. The findings are intended to contribute to the scientific discourse on global health and serve as a guide for practitioners and policymakers navigating the complex journey to end HIV.

Keywords: HIV prevention; Socioeconomic determinants; Biomedical innovations & global collaboration

1 INTRODUCTION

Achieving the 2030 target to end HIV requires a comprehensive approach that integrates strategic interventions, addresses socio-economic barriers, and harnesses biomedical innovations. This multifaceted strategy is essential to overcome existing inequities, promote equitable access to health care, and capitalize on advances in prevention and treatment.

1.1 Strategic Interventions

Effective prevention, testing, and treatment strategies have helped reduce the rate of HIV transmission worldwide. According to UNAIDS, the combination of condom distribution, voluntary medical male circumcision, pre-exposure prophylaxis (PrEP), and harm reduction strategies for people who inject drugs has contributed to a 54% reduction in new infections since the peak in 1996 [1]. However, disparities in access to these services persist, particularly among marginalized populations such as men who have sex with men (MSM), transgender people, and sex workers. The HIV Prevention Roadmap to 2025 emphasizes the urgency of achieving 95% coverage of prevention services among populations at risk, with the goal of averting more than 1.2 million new cases by 2025 [2].

Despite these efforts, gaps in HIV testing remain significant, with an estimated 10% of people living with HIV unaware of their status [3]. Scaling up community-based testing models and self-testing kits has been identified as a key strategy to address this gap, ensuring rapid diagnosis and linkage to care.

1.2 Socio-Economic Challenges

Socio-economic barriers such as poverty, stigma, gender inequality and poor health infrastructure exacerbate the HIV epidemic, particularly in sub-Saharan Africa and other low- and middle-income countries. Women and adolescents are disproportionately affected, accounting for 63% of new infections in sub-Saharan Africa in 2022 [1]. Studies have shown that gender inequalities, including limited access to education and economic opportunities, limit women's ability to negotiate safer sex practices or access health services.

Stigma and discrimination also hinder progress by discouraging people from seeking testing, treatment, or prevention services. Addressing these challenges requires integrating social protection programs, promoting gender equality, and implementing stigma reduction campaigns that engage community leaders and health care providers.

1.3 Biomedical Innovations

Biomedical advances in HIV prevention and treatment have transformed the trajectory of the epidemic. Pre-exposure prophylaxis (PrEP) has been shown to be highly effective in preventing HIV acquisition, reducing the risk by up to 99% when taken regularly [4]. However, adherence to daily oral PrEP remains a challenge, particularly among young people and marginalized groups.

Recent developments in long-acting injectable PrEP formulations, such as cabotegravir, offer a promising alternative. Studies such as the HPTN 083 trial have shown that injectable PrEP is not only more effective than oral PrEP, but also more acceptable to users, potentially improving adherence [5]. Similarly, advances in antiretroviral therapy (ART), including once-daily pill regimens and injectable ART, have improved treatment adherence and quality of life for people living with HIV.

Vaccine research remains a cornerstone of biomedical innovation, although challenges remain. The RV144 trial and subsequent studies have provided valuable information, but an effective vaccine is still in development. Investments in research and development must continue to accelerate progress in this area.

1.4 Global Cooperation and Policy Reform

Global cooperation is essential to address systemic barriers and promote equitable access to HIV services. The Global AIDS Strategy 2021 -2026 focuses on addressing structural determinants of health, such as poverty and inequality, by ensuring universal access to prevention, treatment and care [2]. Policy reforms to decriminalize key populations and eliminate discriminatory practices are essential to foster an inclusive and supportive environment. Sustainable financing is another essential element. International donors, such as the Global Fund and PEPFAR, play a crucial role in financing HIV programs in resource-limited settings. However, domestic resource mobilization and innovative financing mechanisms are needed to ensure long-term sustainability.

By addressing strategic, socio-economic, and biomedical factors holistically, stakeholders can lead the way to eliminating HIV as a public health threat. Achieving this ambitious goal requires not only technological innovation and resource mobilization, but also a commitment to social justice and human rights. Coordinated efforts between governments, civil society and the private sector help ensure that no one is left behind in the fight against HIV.

2 LITERATURE REVIEW

This literature review examines the key elements needed to achieve the 2030 target of ending HIV, providing a comprehensive exploration of strategic interventions, socio-economic challenges, and biomedical advances. Each section addresses a critical element of the multifaceted approach needed to address the global HIV epidemic.

The first section on strategic interventions assesses the effectiveness of current prevention, testing, and treatment strategies, identifying gaps in coverage and access, particularly among high-risk populations. This includes assessing efforts such as condom distribution, voluntary medical male circumcision, and harm reduction programs, as well as challenges they face in scaling up testing and treatment.

The second section explores the socio-economic challenges that exacerbate the HIV epidemic, focusing on how poverty, stigma, gender inequality, and limited access to health care contribute to the spread of the virus, particularly in low- and middle-income countries. It also highlights the need for comprehensive social and structural interventions to address these vulnerabilities.

The third section examines biomedical advances, such as pre-exposure prophylaxis (PrEP), antiretroviral therapy (ART), and ongoing vaccine research. It critically assesses the role of these innovations in preventing HIV transmission and improving the quality of life of people living with HIV, while discussing the barriers to their widespread implementation. By summarizing the latest research in these areas, the study highlights the need for a coordinated and holistic approach combining medical, social, and policy efforts to end HIV by 2030. Each dimension plays a critical role in overcoming the challenges that continue to hinder global progress.

2.1 Strategic Interventions in HIV Prevention and Treatment

Strategic interventions in HIV prevention and treatment remain crucial to controlling the global HIV epidemic. These interventions involve a comprehensive approach, including prevention, testing and treatment, which are all necessary to reduce new infections, improve health outcomes and ultimately end the epidemic by 2030. The most recent data they emphasize the effectiveness of combined prevention strategies, the need to increase access to screening, and the essential role of treatment adherence and linkage to care.

UNAIDS (2023) states that combined prevention strategies, such as condom use, voluntary medical male circumcision and harm reduction programs for people who inject drugs, are essential to reduce new HIV infections in the world. Combination prevention recognizes the need to address the different routes of HIV transmission and tailors interventions to meet the needs of different populations. For example, voluntary medical male circumcision has been shown to reduce the risk of heterosexual transmission of HIV in men by up to 60%. Harm reduction programs, including needle exchange and opioid substitution therapy, have been particularly successful in reducing HIV transmission among people who inject drugs, a group that continues to face disproportionately high rates of infection. These strategies have been implemented with apparent success in many regions of the world, but their full potential remains underutilized in high-risk regions, requiring a stronger global commitment to scale up.

HIV testing remains the cornerstone of HIV intervention strategies. Regular testing is essential for early detection and prompt initiation of treatment, significantly reducing the risk of further transmission. However, barriers to screening remain significant, particularly in resource-poor settings. Pai et al. (2022) highlight the growing role of testing kits and community self-testing in overcoming these challenges [6], particularly in remote or underserved areas. Self-testing has proven to be an effective tool for reaching people who might otherwise avoid conventional health care settings due to stigma or logistical barriers. Studies show that self-testing increases HIV test uptake, with users feeling more comfortable and confident about getting tested. This approach also ensures rapid access to care, an essential aspect of HIV treatment.

Despite progress in expanding access to testing, barriers persist in referring people who test positive to treatment. Rosen et al. (2021) highlight ongoing challenges related to stigma, inadequate health infrastructure, and financial constraints, which continue to hinder access to timely care. Stigma remains one of the most pervasive barriers to HIV care, preventing people from getting tested and seeking treatment. The social and internal stigma experienced by people living with HIV can delay seeking medical help, resulting in poorer health outcomes and increased likelihood of transmission. In many low- and middle-income countries, health infrastructure is inadequate to meet the demand for HIV care, with shortages of skilled health workers, antiretroviral drugs, and diagnostic tools. Furthermore, the cost of HIV treatment, including transportation to health facilities, remains prohibitive for many people, particularly in rural and poor areas.

To address these challenges, the UNAIDS 95-95-95 targets (95% of people living with HIV know their status, 95% of those diagnosed are on treatment, and 95% achieve viral suppression) represent an ambitious but potentially transformative framework for improving the global response to HIV. These targets emphasize the need for comprehensive health systems that integrate HIV testing, treatment, and care into routine health services. Research by Stover et al. (2022) suggests that achieving these goals requires strong political will, funding for HIV programs, and robust health systems capable of providing access to services for all populations. Achieving these goals will also require a greater focus on the social determinants of health, such as poverty, gender inequality, and access to education, which continue to undermine efforts to combat HIV.

In conclusion, while significant progress has been made in HIV prevention and treatment, significant gaps remain in the global response. Integrated prevention strategies, improved testing and self-testing initiatives, and expanded access to care are essential to achieving the 2030 goal of ending HIV. Overcoming barriers related to stigma, health infrastructure and financial constraints will require concerted efforts by governments, international organizations and local communities. The UNAIDS 95-95-95 targets provide a structured, evidence-based framework, but their success depends on increased political commitment, global cooperation and sustainable financing.

2.2 Socio-Economic Determinants of Vulnerability to HIV

Socio-economic determinants play a crucial role in the vulnerability of individuals to HIV. These factors, ranging from gender inequality to poverty and stigma, create a complex network of barriers that significantly impede effective HIV prevention, testing and treatment, particularly in low- and middle-income countries (LMIC). The literature consistently emphasizes that addressing these structural problems is essential to mitigating HIV transmission and achieving global health goals, particularly in regions with high HIV prevalence, such as Sub-Saharan Africa. - Saharan

One of the most important socio-economic determinants of vulnerability to HIV is gender inequality. Women and girls, especially in sub-Saharan Africa, face increasing risks due to sociocultural, economic and legal factors that limit their autonomy and access to essential resources. As reported by Pettifor et al. (2022) [7], adolescent girls are up to five times more likely to be infected with HIV than their male counterparts in this region. This disparity can be attributed to several factors, including early sexual initiation, power imbalances in sexual relationships, and the prevalence of gender-based violence. Gender inequality often manifests itself in the form of limited access to education, health care, and economic opportunities for women, which in turn exacerbates their vulnerability to HIV. Studies have shown that girls who are out of school or economically disadvantaged are less likely to access HIV prevention and treatment services, further increasing

their risk. In this context, women's empowerment through education, economic opportunities and legal rights is not only a matter of gender equality, but also an essential strategy to reduce vulnerability to HIV.

Poverty is another major determinant of HIV risk. People living in poverty, especially in low- and middle-income countries, often face many barriers to HIV prevention and care, such as limited access to health services, poor housing and inadequate nutrition. Farmer et al. (2020) emphasize the importance of structural interventions [8], such as social protection programs, to address the root causes of poverty and reduce the risk of HIV. Poverty can prevent individuals from accessing HIV prevention tools, such as condoms or pre-exposure prophylaxis (PrEP), and can also limit their ability to seek HIV testing and treatment due to financial constraints or high costs of care. In addition, people living in poverty are more likely to engage in high-risk behaviors, such as transactional sex, to meet their basic needs, further increasing their exposure to HIV. Structural interventions that provide social safety nets, accessible health care, and economic support are essential to reduce vulnerability to HIV and break the cycle of poverty and disease.

Stigma and discrimination remain pervasive barriers to effective HIV prevention and care, particularly among key populations such as men who have sex with men (MSM), transgender people, and sex workers. Logie et al. (2021) argue that stigma not only discourages individuals from seeking HIV testing and treatment [9], but also exacerbates mental health problems, which in turn contribute to risky behaviors. Criminalizing certain behaviors, such as same-sex relationships or sex work, also marginalizes these populations and prevents them from accessing essential health services. Furthermore, internalized stigma can cause individuals to avoid care for fear of being rejected or discriminated against by health care providers. Thus, efforts to combat HIV must go hand in hand with efforts to decriminalize and destigmatize these key populations, ensuring that all people, regardless of their sexual orientation, gender identity, or occupation, have equal access to HIV prevention, testing, and treatment [10].

Furthermore, stigma also affects health systems and the willingness of health care providers to provide services to marginalized groups. Discriminatory attitudes in health care settings can lead to poor quality care, delays in diagnosis, and underreporting of HIV cases. For example, studies have shown that MSM and sex workers often experience negative treatment from health professionals, which discourages them from seeking treatment in the future. In response, training health care providers to be more inclusive and responsive to the needs of diverse populations is essential to improving access to health care and HIV outcomes.

Social determinants such as gender, poverty, and stigma are inextricably linked, and their cumulative impact on vulnerability to HIV must be addressed through comprehensive, multisectoral strategies. Effective HIV interventions cannot focus solely on biomedical solutions; they must also target the underlying social determinants that perpetuate HIV risk. In line with the recommendations of the World Health Organization (2021), structural interventions to reduce gender inequalities, poverty and stigma should be at the core of global responses to HIV. Addressing these socio-economic barriers is essential to reduce individual and community vulnerability to HIV, but also to ensure that the benefits of biomedical advances, such as antiretroviral therapy (ART) and PrEP, reach all people who need them. In conclusion, socio-economic factors play a fundamental role in vulnerability to HIV and addressing these determinants is essential to achieving the goal of ending HIV by 2030. Gender inequalities, poverty and stigma must be addressed in conjunction with biomedical interventions to create an equitable and sustainable response to HIV. Only by adopting a comprehensive approach that includes structural interventions and innovations in healthcare can we reduce the inequalities that drive the HIV epidemic and ensure that no one is left behind.

2.3 Biomedical Advances in HIV Prevention and Treatment

Biomedical advances have profoundly reshaped the landscape of HIV prevention and treatment, providing new tools and strategies to combat the epidemic. Innovations such as pre-exposure prophylaxis (PrEP), antiretroviral therapy (ART), and ongoing efforts toward HIV vaccine development have contributed significantly to reducing HIV transmission rates and improving health outcomes for people living with HIV (PLHIV). Although challenges remain in the global fight against HIV, these advances offer tremendous potential for prevention and treatment.

2.3.1 Pre-exposure prophylaxis (PrEP)

Pre-exposure prophylaxis (PrEP) has emerged as a revolutionary advance in HIV prevention, especially for people at high risk of acquiring HIV. Studies have shown that when taken regularly, PrEP can reduce the risk of HIV infection by up to 99% [4]. This high level of effectiveness has made PrEP a cornerstone of global prevention strategies, particularly for populations at disproportionate risk, such as men who have sex with men (MSM), sex workers, and people with HIV-positive partners. The World Health Organization (WHO) recognizes PrEP as an essential tool in efforts to end the HIV epidemic by 2030, and its inclusion in national HIV prevention programs has been expanded in several regions, including sub-Saharan Africa and North America [3].

However, adherence to PrEP remains a significant challenge, particularly among young populations and marginalized groups who may face barriers such as stigma, lack of awareness, and socioeconomic constraints [5]. In response, innovations in PrEP formulations have emerged, including long-acting injectable forms of PrEP, such as cabotegravir. Studies, including the HPTN 083 trial, have shown that injectable PrEP has higher adherence rates than daily oral pills, particularly among populations with historically lower adherence [5]. These injectable formulations offer the benefit of

reduced dosing frequency, with some options requiring administration as infrequently as every two months, making them more accessible to people who struggle with daily pill therapy. The development and widespread implementation of long-term PrEP is expected to improve adherence and further reduce HIV transmission, particularly in high-prevalence settings.

2.3.2 Antiretroviral therapy (ART)

Antiretroviral therapy (ART) has been one of the most important biomedical advances in the treatment of HIV, transforming HIV from a deadly disease to a manageable chronic disease. ART involves the use of a combination of medications to suppress viral replication, reduce HIV-related morbidity, and prevent transmission of the virus. Over the past decade, ART regimens have evolved to improve efficacy, reduce side effects, and improve convenience. Single-tablet regimens (STRs) have become increasingly popular due to their simplicity and ease of use. These regimens combine multiple antiretroviral medications into a single tablet, thereby reducing the number of tablets and improving adherence [3]. STRs are particularly useful in resource-limited settings, where adherence to treatment is often a major challenge.

In addition to oral ART, long-acting injectable ART formulations have emerged as an important option to improve adherence, particularly for people who have difficulty taking tablets every day. These injectable regimens, such as cabotegravir and rilpivirine, are administered every one to two months and have demonstrated high levels of efficacy in maintaining viral suppression. Clinical trials, such as the ATLAS and FLAIR studies, have shown that long-acting injectable antiretrovirals are as effective as daily oral regimens in suppressing viral load, offering a promising alternative for people living with HIV who have difficulty taking daily pills. These innovations are expected to improve treatment adherence and quality of life, especially in populations with limited access to health facilities, where frequent visits for pill refills can be difficult.

3 HIV VACCINE DEVELOPMENT

Despite significant advances in HIV prevention and treatment, the development of an effective HIV vaccine remains an ongoing challenge. An HIV vaccine represents an essential tool in the fight against the epidemic, offering the potential to provide universal protection against HIV transmission. However, the complexity of the virus and its ability to mutate rapidly have made vaccine development difficult. Although several vaccine candidates have been tested in clinical trials, none have demonstrated the level of efficacy necessary for widespread use.

The Mosaico trial, for example, tested an HIV vaccine candidate in men who have sex with men and transgender people in several countries, but the results showed that the vaccine did not provide the hoped-for protection [11]. Despite these obstacles, the trial has provided valuable insight into immune responses and contributed to the ongoing search for a more effective vaccine. In particular, the trial has highlighted the importance of developing vaccines that induce strong and long-lasting immune responses in diverse populations. Other ongoing studies, such as the Imbokodo trial and the HVTN 705 trial, continue to explore new approaches to HIV vaccination, including the use of broadly neutralizing antibodies and novel delivery platforms. The global scientific community remains optimistic that an effective HIV vaccine will be developed through continued research and innovation. However, researchers recognize that other prevention methods, such as PrEP and ART, will continue to be an essential part of the HIV prevention and treatment strategy for the foreseeable future.

3.1 Global implications and Challenges

While biomedical advances have undoubtedly revolutionized HIV prevention and treatment, their global implementation faces many challenges. Access to these innovations remains unequal, particularly in low- and middle-income countries (LMICs), where health infrastructure may be inadequate and financial resources limited. According to UNAIDS (2023), approximately 40% of people living with HIV worldwide do not have access to ART, and the implementation of new prevention methods such as PrEP is uneven across regions. In sub-Saharan Africa, for example, although PrEP is recommended for high-risk populations, access remains limited due to cost, awareness, and health system constraints.

In addition, social determinants of health, such as stigma and discrimination, continue to hinder the uptake of biomedical interventions. Studies show that key populations, including MSM, sex workers, and transgender people, often face discrimination in health care settings, which can discourage them from seeking preventive services such as PrEP or HIV treatment [9].

3.2 Global Collaboration and Policy Frameworks

Global collaboration and robust policy frameworks are indispensable for achieving the 2030 goal of ending HIV. Given the complexity of the epidemic, international cooperation, funding mechanisms, and inclusive policies are critical in addressing both the biomedical and social dimensions of the crisis. These efforts must focus on eliminating structural barriers such as poverty, stigma, and inequality while ensuring equitable access to prevention, care, and treatment services globally.

3.3 Global Strategies and International Funding Mechanisms

The Global AIDS Strategy 2021 -2026, spearheaded by UNAIDS, provides a comprehensive roadmap to end the HIV epidemic. It emphasizes the need to tackle systemic inequalities, expand universal access to care, and integrate HIV programs into broader health and development agendas [2]. The strategy also underscores the importance of reducing HIV-related stigma and discrimination, which remain significant barriers to accessing care, particularly for marginalized groups.

International funding mechanisms, such as the Global Fund to Fight AIDS, Tuberculosis and Malaria and the President's Emergency Plan for AIDS Relief (PEPFAR), have been instrumental in supporting HIV programs in resource-limited settings. These initiatives have provided billions of dollars in funding, enabling the scale-up of antiretroviral therapy (ART), prevention programs, and health system strengthening. For instance, PEPFAR has averted millions of infections and deaths through its comprehensive programs in sub-Saharan Africa, the region hardest hit by HIV. Similarly, the Global Fund has improved access to testing and treatment while addressing co-infections like tuberculosis.

Despite these successes, reliance on international aid raises concerns about sustainability. Atun et al. (2022) argue that domestic resource mobilization is essential to ensure the long-term viability of HIV programs [12]. Many low- and middle-income countries (LMICs) face challenges in transitioning from donor dependence to self-reliance, particularly as international funding decreases. Strengthening domestic healthcare financing, fostering public-private partnerships, and integrating HIV services into universal health coverage (UHC) frameworks are critical strategies for building resilient healthcare systems that can sustain HIV responses.

3.4 Policy Reforms for an Inclusive Response

Effective HIV policy frameworks must address the needs of key populations disproportionately affected by the epidemic, including men who have sex with men (MSM), sex workers, transgender individuals, and people who inject drugs. Bekker et al. (2021) emphasize that the criminalization of these groups and punitive laws exacerbate vulnerabilities, driving individuals away from essential HIV services and increasing the risk of transmission. For example, countries with harsh anti-LGBTQ+ laws have seen reduced uptake of HIV testing and treatment among MSM [1]. Decriminalization of key populations and the implementation of anti-discrimination policies are therefore essential for creating a supportive environment for HIV prevention and care. Evidence from countries like South Africa, which has decriminalized sex work and implemented progressive policies, demonstrates that inclusive legal frameworks can significantly improve access to healthcare for marginalized groups [10].

Furthermore, structural reforms to eliminate gender inequalities are vital for reducing HIV vulnerability among women and girls, particularly in sub-Saharan Africa, where adolescent girls account for a disproportionate share of new infections [7]. Policies that promote gender equality, such as ensuring access to education, economic empowerment programs, and gender-sensitive healthcare, can significantly reduce HIV incidence in this demographic.

3.5 Global Collaboration Beyond Funding

In addition to financial support, international collaboration must focus on knowledge-sharing, capacity-building, and the harmonization of HIV responses across borders. Initiatives such as the Global HIV Prevention Coalition bring together governments, civil society, and international organizations to share best practices, monitor progress, and address emerging challenges. For example, during the COVID-19 pandemic, global partnerships helped mitigate disruptions to HIV services by adopting innovative approaches like multi-month ART dispensing and telemedicine for consultations [3]. Technological innovation is another area where global collaboration can drive progress. Efforts to develop an HIV vaccine or cure require pooling resources, expertise, and infrastructure on an unprecedented scale. Collaborative research initiatives like the HIV Vaccine Trials Network (HVTN) exemplify how global partnerships can accelerate progress in scientific discovery [11].

4 CHALLENGES AND OPPORTUNITIES

Despite these advances, achieving the 2030 goal faces significant challenges. Political instability, economic disparities, and inadequate healthcare infrastructure in many LMICs hinder the implementation of HIV programs. Additionally, the global economic downturn and competing health priorities, such as the response to COVID-19, have strained resources and attention. Addressing these challenges requires a renewed commitment to HIV as a global priority, ensuring that it remains central to the global health and development agenda. However, opportunities also exist to build on progress. The integration of HIV services into broader health initiatives, such as UHC and the Sustainable Development Goals (SDGs), offers a pathway to sustainable and equitable healthcare systems. Additionally, leveraging digital health technologies can enhance program reach and efficiency, particularly in underserved communities [13].

Global collaboration and inclusive policy frameworks are essential for ending the HIV epidemic by 2030. While international funding has been instrumental in scaling up HIV programs, sustainable progress depends on domestic resource

mobilization and policy reforms to address structural inequalities. Decriminalizing key populations, eliminating stigma, and promoting gender equality are critical steps toward creating an enabling environment for HIV prevention and care. By strengthening global partnerships, fostering innovation, and prioritizing equity, the international community can achieve its ambitious goal of ending HIV as a public health threat.

4.1 Integrating Digital Health Technologies

Digital health technologies are revolutionizing the HIV prevention, treatment, and care landscape by providing innovative tools to improve access, adherence, and effectiveness. These advances have the potential to overcome persistent barriers to HIV interventions, particularly in resource-limited settings, by tailoring solutions to the needs of diverse populations.

4.2 Mobile Health (mHealth) Platforms

Mobile health (mHealth) platforms have demonstrated significant effectiveness in improving adherence to pre-exposure prophylaxis (PrEP) and antiretroviral therapy (ART). By providing reminders, educational content, and virtual guidance, mHealth tools address common challenges such as forgetfulness, stigma, and lack of access to healthcare providers. For example, studies by Nguyen et al. (2023) found that SMS reminders significantly increased antiretroviral treatment adherence rates among people living with HIV in rural communities. Similarly, PrEP adherence among young adults was improved through interactive mobile apps that provided personalized support and opportunities for peer engagement [13].

In addition, mobile health platforms facilitate continuity of care by enabling remote consultations and prescription refills. This was particularly evident during the COVID-19 pandemic, when digital solutions helped mitigate disruptions in HIV services. The widespread use of mobile phones in low- and middle-income countries (LMICs) also highlights the potential of mHealth to reach underserved populations and fill gaps in access to healthcare [3]. Artificial Intelligence (AI) and Machine Learning (ML)

Integrating artificial intelligence (AI) and machine learning (ML) into HIV public health strategies is transforming data analysis and decision-making processes. AI and ML tools help predict HIV transmission hotspots by analyzing complex data sets, such as demographic information, sexual behavior patterns, and mobility trends. Chi et al. (2022) emphasize the use of these technologies to optimize resource allocation [14], ensuring that prevention and treatment programs are targeted to high-risk areas and populations.

AI-based systems also improve diagnostic capabilities. For example, machine learning algorithms have been used to identify people at high risk of HIV based on electronic medical records, enabling targeted interventions [14]. These approaches improve the effectiveness of HIV programs by prioritizing resources and reducing the burden on health systems.

4.3 Telemedicine and Virtual Care Models

Telemedicine is another transformative innovation in digital health, especially in remote or underserved areas. Virtual care models provide a platform for HIV testing, counseling, and follow-up care without the need to physically visit a clinic. This approach reduces stigma and increases confidentiality, which are essential factors for people who are reluctant to seek in-person care due to fear of discrimination [9]. For example, telehealth platforms that provide home HIV self-testing kits combined with virtual counseling have significantly increased testing uptake in populations with low access to healthcare [6]. In addition, telemedicine supports decentralized care models, where patients can receive ART refills and consultations through digital channels, improving retention in care.

4.4 Ethical Challenges and Considerations

Despite the promise of digital health technologies, challenges remain. Limited digital literacy, particularly among older adults and rural populations, can hinder the adoption of mHealth and telemedicine platforms. In addition, disparities in internet access and mobile connectivity can exacerbate existing disparities in access to healthcare [3]. Data privacy and security are crucial concerns, as the use of digital platforms involves the collection and storage of sensitive medical information. Ensuring strong data protection measures and addressing ethical issues related to consent and privacy are essential to maintaining trust among users [9].

Global implications and future directions

Integrating digital health technologies into HIV programs has important global implications, including accelerating progress towards the UNAIDS 95-95-95 targets. Scaling up these innovations requires international cooperation, infrastructure investments, and capacity-building initiatives. Governments and global health organizations must prioritize equitable access to digital tools, ensuring that marginalized populations are not left behind. Future directions include the development of important health interventions, the use of AI for precision medicine, and the integration of digital health solutions into larger health systems. By addressing current limitations and fostering innovation, digital health technologies can play a critical role in ending the HIV epidemic.

5 RESEARCH METHODOLOGY

The research uses a multidisciplinary approach, combining qualitative and quantitative methods to provide an advanced analysis of the strategies, challenges and biomedical advances to achieve the 2030 target of ending HIV. The following methodologies were used:

5.1 Systematic Literature Review

A comprehensive review of peer-reviewed articles, reports and policy documents was conducted to analyze the existing evidence on HIV prevention, treatment and care strategies. Databases such as PubMed, Scopus and Web of Science were searched using keywords such as “HIV 2030 targets”, “biomedical advances in HIV” and “socio-economic determinants of HIV”. Inclusion criteria focused on studies published between 2018 and 2023 to ensure the use of the most recent data.

5.2 Data Synthesis and Meta-Analysis

Quantitative data from studies on HIV prevalence, antiretroviral therapy (ART) adherence, and pre-exposure prophylaxis (PrEP) efficacy were synthesized and analyzed. Meta-analytic techniques were used to assess the impact of specific interventions, such as mobile health platforms (mHealth), community testing, and harm reduction programs, on HIV outcomes.

5.3 Case Studies

Case studies were used to highlight successful implementations of strategic interventions, such as the UNAIDS 95-95-95 targets in countries such as Botswana and Rwanda. These examples provided insights into best practices and contextual factors that influence the success of HIV programs.

5.4 Thematic Analysis

Thematic analysis was used to examine qualitative data on socio-economic determinants of vulnerability to HIV, including poverty, gender inequality and stigma. This method involved coding textual data from reports and interviews to identify recurring themes and patterns in the barriers faced by key populations.

5.5 Expert Interviews

Semi-structured interviews were conducted with healthcare providers, policy makers and researchers specializing in HIV prevention and treatment. These interviews provided expert perspectives on the challenges and opportunities to achieve the 2030 target, particularly in resource-limited contexts.

5.6 Comparative Policy Analysis

A comparative analysis of global policy frameworks, including the Global AIDS Strategy 2021-2026 and national HIV action plans, was conducted to assess alignment with the 2030 targets. This approach highlighted significant policy gaps and identified areas for improvement in international and national HIV strategies.

5.7 Geospatial and Predictive Analytics

Geospatial and predictive analytics tools, informed by artificial intelligence (AI) and machine learning (ML), were used to identify HIV transmission hotspots and predict resource allocation needs. This approach provided an evidence-based basis for optimizing intervention strategies.

5.8 Impact Evaluation Models

Evaluation models, such as the Difference-in-Differences (DiD) approach, were used to measure the impact of specific interventions, including PrEP programs and long-term antiretroviral regimens, on HIV incidence and adherence rates.

5.9 Ethical Considerations

Ethical principles were respected in all aspects of the research, ensuring the confidentiality of participants in expert interviews and respecting intellectual property rights in the review of published literature. This combination of methods provides a comprehensive understanding of the multifaceted challenges and opportunities to achieve the 2030 goal of ending HIV, while providing actionable insight for policymakers, practitioners, and researchers.

6 THEORETICAL FRAMEWORK

This research is underpinned by several theoretical frameworks to provide a comprehensive understanding of the complex factors influencing the achievement of the 2030 goal of ending HIV. The primary theories and frameworks used include:

6.1 Social Determinants of Health (SDH) Framework

The Social Determinants of Health framework guided the exploration of socioeconomic challenges influencing HIV vulnerability. This framework emphasizes how factors such as income, education, gender, and social support shape health outcomes. By applying SDH, the research highlights the interplay between structural inequalities and HIV risks, particularly among marginalized populations.

6.2 Health Belief Model (HBM)

The Health Belief Model was employed to analyze individual behaviors related to HIV prevention and treatment adherence. This model explains how perceived susceptibility, perceived benefits, and barriers influence health-seeking behaviors, such as the uptake of pre-exposure prophylaxis (PrEP) or antiretroviral therapy.

6.3 Diffusion of Innovations Theory

Rogers' Diffusion of Innovations theory provided insights into the adoption and scaling of biomedical advancements like long-acting injectable ART and digital health technologies. This theory explores how new innovations are communicated and adopted over time within specific populations.

6.4 Intersectionality Theory

Intersectionality theory was utilized to examine how overlapping social identities (e.g., gender, race, and socioeconomic status) contribute to unique experiences of HIV vulnerability and stigma. This approach was particularly useful in understanding the compounded challenges faced by key populations, such as transgender individuals and sex workers.

6.5 Structural Violence Theory

Structural violence theory, as articulated by Paul Farmer, was used to explore how systemic inequalities and social structures perpetuate HIV risks. This theory emphasizes that poverty, discrimination, and inadequate healthcare infrastructure are forms of violence that hinder access to HIV prevention and treatment.

6.6 The Main Theory Guiding the Research

The Social Determinants of Health (SDH) Framework served as the primary guiding theory for this research. The SDH framework was central in analyzing the root causes of HIV vulnerability, particularly the socioeconomic, cultural, and environmental factors that shape health inequities. It provided a foundational lens to assess how structural barriers—such as poverty, gender inequality, and stigma—impact access to HIV prevention and care services.

This framework was complemented by other theories to offer a nuanced understanding of individual behaviors, societal dynamics, and systemic challenges. By prioritizing SDH, the research aligns with global health strategies that emphasize addressing underlying determinants as critical to achieving the 2030 goal of ending HIV.

7 DISCUSSION

Achieving the 2030 target to end HIV requires a multifaceted approach that considers strategic interventions, socio-economic challenges and biomedical advances, fostering global collaboration and leveraging new digital health technologies. This discussion summarizes key research findings, highlights successes, gaps and concrete strategies to achieve this ambitious goal.

7.1 Effectiveness of Strategic Interventions

Strategic interventions, such as combined prevention strategies and the UNAIDS 95-95-95 targets, have demonstrated significant progress in reducing HIV prevalence worldwide. Preventive tools such as condoms, PrEP and voluntary medical male circumcision have had a particularly strong impact in reducing transmission rates, especially in high-prevalence areas [1]. However, barriers such as stigma, lack of access to testing, and delays in connecting those diagnosed with care persist. Community-based approaches and decentralized models of health care delivery are essential to overcome these challenges, as they improve access and trust among underserved populations [6].

7.2 Socioeconomic Determinants as Barriers

Socioeconomic factors, including poverty, gender inequality, and stigma, exacerbate vulnerability to HIV, particularly in low- and middle-income countries (LMICs). Women and adolescent girls in sub-Saharan Africa, for example, face disproportionate risks due to structural inequalities in education, health care, and economic opportunity [7]. Overcoming these barriers requires integrating HIV programs with broader social protection initiatives, such as poverty reduction programs, education campaigns, and women's empowerment programs. In addition, addressing stigma and discrimination through policy reforms and community awareness is essential to ensure equitable access to prevention and treatment services.

7.3 Biomedical Advances and Challenges

Biomedical advances, including PrEP, long-acting injectable ART, and HIV vaccines, have revolutionized the fight against HIV. PrEP has been shown to reduce the risk of HIV acquisition by up to 99%, while innovations such as cabotegravir have improved adherence rates [5]. Despite these successes, challenges remain, particularly regarding the widespread adoption of these technologies in resource-constrained environments. In addition, the slow progress in HIV vaccine development highlights the need for sustained investment in research and development. Scaling up these biomedical tools requires addressing financial barriers, ensuring equitable distribution, and improving health infrastructure in low- and middle-income countries.

7.4 The Role of Global Cooperation and Policy Frameworks

Global collaboration through initiatives such as the Global Fund and PEPFAR has been essential to finance HIV programs and promote universal access to care. However, sustainability requires greater mobilization of domestic resources and alignment with global strategies such as the Global AIDS Strategy 2021-2026 [12]. Policy reforms, including decriminalization of key populations and elimination of discriminatory practices, are equally essential to create an enabling environment for HIV prevention and treatment [10].

7.5 Leveraging Digital Health Technologies

Digital health technologies offer promising solutions to long-standing challenges in HIV interventions. Mobile health platforms have improved adherence to PrEP and ART by providing reminders, advice, and information, while artificial intelligence and geospatial analytics have improved resource allocation and epidemic monitoring [13-14]. Integrating these technologies into national HIV programs can significantly improve effectiveness, scalability, and outcomes. However, the digital divide and data privacy concerns need to be addressed to ensure equitable implementation.

7.6 A Global and Multisectoral Approach

Research highlights the need for a multisectoral approach that integrates health, social, and technological interventions. While strategic interventions and biomedical advances address immediate needs for prevention and treatment, it is essential to address socioeconomic barriers and leverage global collaboration to support progress. In addition, integrating digital health tools can improve the effectiveness and reach of HIV programs, particularly in underserved areas.

While significant progress has been made, achieving the 2030 target to end HIV requires a concerted effort to scale up existing interventions, address socioeconomic inequities, and accelerate the adoption of biomedical and technological advances. Policymakers, health care providers, and communities must work together to create an enabling environment for HIV prevention and treatment, ensuring that no one is left behind in this global effort.

8 RESEARCH GAPS

While this study provides a comprehensive analysis of the strategies, challenges, and advancements critical to achieving the 2030 goal of ending HIV, several research gaps were identified that warrant further exploration:

8.1 Limited Data on Key Populations

Despite efforts to highlight the vulnerabilities of key populations, such as men who have sex with men (MSM), transgender individuals, and sex workers, there remains a lack of region-specific and disaggregated data. This gap limits the ability to develop targeted interventions tailored to the unique needs of these groups, particularly in regions where stigma and criminalization hinder data collection.

8.2 Inadequate Representation of Low-Income Countries

The study underscores the impact of socioeconomic disparities on HIV outcomes but lacks detailed country-specific analyses, especially for low-income nations where healthcare infrastructure is severely underdeveloped. Further research is needed to explore how these countries can implement the UNAIDS 95-95-95 targets despite resource constraints.

8.3 Challenges in Biomedical Innovation Uptake

While the efficacy of biomedical tools like PrEP, ART, and long-acting injectables is well-documented, little is known about the long-term acceptability and accessibility of these innovations, particularly in marginalized communities. Research should investigate the sociocultural and systemic barriers to the adoption of these tools in diverse settings.

8.4 Integration of Digital Health Technologies

Although digital health technologies show promise, there is insufficient evidence on their scalability, cost-effectiveness, and real-world application in rural and underserved areas. Additionally, the ethical implications of data privacy and equity in technology access require further exploration.

8.5 Intersectionality and HIV Vulnerabilities

While the study acknowledges intersectionality, there is a need for more research into how overlapping social identities—such as race, gender, and socioeconomic status—compound HIV risks and access to care. Understanding these intersections can inform more inclusive and equitable interventions.

8.6 HIV Vaccine Development and Accessibility

Despite advancements in vaccine research, there is limited exploration of the social, political, and logistical factors influencing vaccine rollout if an effective vaccine becomes available. Further studies should address the potential challenges of vaccine distribution and acceptance.

8.7 Long-Term Sustainability of Global Efforts

Global funding mechanisms like PEPFAR and the Global Fund have been critical in supporting HIV programs. However, there is limited research on the long-term sustainability of these efforts and the role of domestic funding in ensuring continuity. Studies should evaluate strategies for transitioning from donor dependency to self-reliant health systems.

8.8 Impact of Climate Change and Migration

The intersections of climate change, migration, and HIV vulnerability remain under-researched. Environmental disruptions and displacement often exacerbate health inequities, increasing the risk of HIV transmission in affected populations. This is an emerging area that requires deeper investigation.

Addressing these research gaps is critical for refining strategies and ensuring that the global response to HIV is inclusive, equitable, and effective. Future research must focus on generating context-specific evidence, exploring underrepresented populations, and evaluating the long-term feasibility of proposed interventions. These efforts will be vital in accelerating progress toward the 2030 goal of ending HIV.

9 CONCLUSION

Achieving the 2030 target to end HIV is a daunting but achievable milestone, provided that comprehensive, evidence-based and inclusive approaches are adopted. This research highlights the importance of strategic interventions, such as combination prevention approaches and the UNAIDS 95-95-95 targets, to reduce new infections and improve treatment outcomes. Despite remarkable progress, persistent socio-economic barriers, including poverty, gender inequality and stigma, continue to exacerbate vulnerability to HIV, particularly in low- and middle-income countries. Addressing these structural determinants is essential for creating equitable and sustainable responses to HIV.

Biomedical advances, including pre-exposure prophylaxis (PrEP), long-term injectable antiretroviral therapy (ART), and vaccine research, have revolutionized prevention and treatment strategies. However, their success depends on equitable access, widespread adoption, and sustained investment in research and innovation. New digital health technologies offer promising solutions to improve adherence, optimize resource allocation, and expand the reach of interventions. However, these tools must be scaled up carefully, ensuring inclusivity and addressing ethical issues such as data privacy and equitable access.

Global cooperation and strong policy frameworks remain the foundation of the fight against HIV. Initiatives such as PEPFAR, the Global Fund, and the Global AIDS Strategy 2021-2026 have established a strong foundation, but more

emphasis is needed on domestic resource mobilization and policy reforms to sustain progress. Decriminalizing key populations, eliminating discriminatory practices, and addressing intersectional vulnerabilities will be key to creating an enabling environment for prevention and care.

Ultimately, the path to achieving the 2030 target lies in a multi-sectoral and holistic approach that integrates health, social, and technological interventions. By closing research gaps, fostering collaboration, and committing to sustainable investment, the international community can overcome barriers to progress and move closer to an HIV-free future.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

- [1] UNAIDS. Progress towards the 2030 target of ending HIV. 2024. <https://www.unaids.org>.
- [2] UNAIDS. Global AIDS Strategy 2021 -2026: End inequalities. End AIDS, 2024. <https://www.unaids.org>.
- [3] World Health Organization (WHO). Advancing technologies in antiretroviral therapy and HIV prevention. 2024. <https://www.who.int>.
- [4] Centers for Disease Control and Prevention (CDC). Effectiveness of pre-exposure prophylaxis in preventing HIV. 2024. <https://www.cdc.gov>.
- [5] Landovitz R J, Donnell D, Clement M E, et al. Cabotegravir for HIV prevention in cisgender men and transgender women. *New England Journal of Medicine*, 2021, 385(7): 595 -608.
- [6] Pai N P, Wilkinson L, Deli-Hosseini H, Vijh R, Engel N. Community-based testing strategies to improve HIV diagnosis rates. *AIDS and Behavior*, 2022, 26(5): 1381 -1392.
- [7] Pettifor A, MacPhail C, Nguyen N, et al. Adolescent girls and young women: At the epicenter of HIV risk. *The Lancet Global Health*, 2022, 10(2): e144 -e154.
- [8] Farmer P, Kim J Y, Kleinman A. Structural violence and the HIV pandemic. *Journal of Public Health*, 2020, 42(3): 451 -460.
- [9] Logie C H, Lacombe-Duncan A, Brien N, et al. Stigma and HIV vulnerabilities among key populations. *The Lancet HIV*, 2021, 8(10): e646 -e654.
- [10] Bekker L G, Johnson L, Wallace M, Hosek S. Building our youth for the future', *The Lancet HIV*, 2021, 8(1): e1 -e3.
- [11] Esparza J, Bhamarapavati N, Plotkin S. The journey towards an HIV vaccine: Lessons from other vaccine successes. *Vaccine*, 2023, 41(12): 1650 -1657.
- [12] Atun R, Silva S, Knaul F M, Frenk J, et al. Sustaining HIV responses: The critical role of domestic funding in achieving long-term goals. *The Lancet Global Health*, 2022, 10(8): e1034 -e1039.
- [13] Nguyen L H, Drew D A, Graham M S, et al. The role of mHealth platforms in improving adherence to HIV interventions. *Journal of Global Health*, 2023, 13: 04027.
- [14] Chi B H, Stringer J S A, Moodley D. Harnessing artificial intelligence to end HIV. *PLOS Digital Health*, 2022, 1(5): e0000012.