REVIEW ARTICLE

PERSONALIZED RISK REDUCTION OF HIV PLANS WITH ARTIFICIAL INTELLIGENCE: A NARRATIVE REVIEW

Ezeanya, C.U.[1], Ukaigwe, J.A.[1], Nwoyibe, O.I.[2] and * Obeagu, E.I.[3]

[1]Department of Computer Science, National Open University of Nigeria
[2]Department of Computer Science, David Umahi Federal University of Health Sciences, Uburu, Ebonyi State, Nigeria.
[3]Department of Medical Laboratory Science, Kampala International University, Uganda.

ABSTRACT

This narrative review explores the current landscape and future potential of utilizing Artificial Intelligence (AI) in the development and implementation of personalized risk reduction plans for individuals at risk of HIV infection. Traditional HIV prevention strategies often adopt a generic approach, overlooking the diverse and dynamic factors contributing to an individual's risk profile. In contrast, this review synthesizes existing literature to highlight recent advancements in AI applications, focusing on their role in tailoring HIV risk reduction interventions to the unique characteristics and circumstances of each individual. The review encompasses studies employing machine learning algorithms, predictive modeling, and data analytics to analyze and interpret large datasets related to HIV epidemiology, behavioral patterns, and socio-economic determinants. By providing an overview of these AI-driven methodologies, the review aims to showcase the potential for personalized risk assessment and intervention planning. Furthermore, it examines the integration of AI into mobile health applications, wearable devices, and telehealth platforms, facilitating real-time monitoring, feedback, and support for individuals seeking personalized risk reduction strategies.

Keywords: Artificial Intelligence, HIV, Personalized risk reduction, Machine learning, Predictive modeling, Data analytics, Epidemiology.

*Corresponding Author
Emmanuel Ifeanyi Obeagu, Department of Medical Laboratory Science, Kampala International University, Uganda, emmanuelobeagu@yahoo.com, ORCID: 0000-0002-4538-0161.

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INTRODUCTION

HIV, an acronym for the Human Immuno-deficiency Virus, is a virus that attacks the body's immune system and has unarguably lingered as one of the leading causes of death globally [1-3]. At the beginning of 2019, the government of the U.S. began the ending of the HIV Epidemic initiative, which aims to reduce the incidence of HIV in the U.S. by 90% by 2030 [4] Also, the global HIV epidemic has had the strongest brunt on Sub-Saharan Africa (SSA). An approximated 67% of the 38.4 million individuals living with HIV (PLWH) worldwide in 2021 were from SSA. SSA was responsible for 670,000 of the 1.5 million new transmissions and 280,000 of the 650,000 AIDS-linked deaths reported globally in 2021. 70% of the new epidemics recorded in 2021 were amidst core populations and their partners. In Sub-Saharan Africa, significant populations accounted for 51% of recent infections in 2021 [5]. However, to impede the transmission and infection of HIV, the undivided attention of the public health sector and policymakers is recommended [6]. Novel strategies are also required for early detection of HIV to ameliorate and eradicate the spread, and this brings us to the potential of AI in Healthcare [7]. AI is increasingly becoming part of our everyday lives and has been implemented in education, financial services, language translation, social media, and virtual assistants. As AI progresses, its daily influence advances, impacting diverse areas and presenting cutting-edge solutions to different challenges.

Effective prevention, care, and treatment programs are very essential to combat the spread of HIV and as well as improving the lives of those infected. Artificial intelligence (AI) has become a potent instrument that could revolutionize HIV prevention and treatment in several ways [8]. The application of AI in the health sector has made significant improvements, especially in the prediction of illness and early detection of diseases for quick treatment. AI is also being deployed in the health sector and it has tremendously helped in identifying disease outbreaks and integrating complicated and divergent data sources in discovering uncommon illnesses. AI in medical care can be a significant tool for analyzing large amounts of precise patient and uncooked health data to produce more individual diagnoses and therapeutic strategies. AI is swift in evaluating data from various sources, identifying feasible challenges, and proffering quick fixes in various settings, including medical and business [9]. With approximately 38 million cases of infection globally, HIV/AIDS continues to be a major public health concern [9]. The U.S. Centers for Disease Control and Prevention (CDC) states that HIV is still one of the main causes of death in both the United States and the rest of the world [10]. During the coronavirus pandemic, it has been demonstrated that reliable information and those in the community are the ones that are likely to spread the disease and they are the two of the most crucial tools in the fight against any disease. Researchers at the Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS), together with the University of Southern California and Pennsylvania State University, developed an artificial intelligence (AI) system that can recognize the users that can successfully inform their peers about HIV prevention on a social network. The researchers discovered that their algorithm significantly decreased key risk behaviors for HIV transmission within the population in a field trial involving over 700 homeless youth [11]. With the heterogeneity and ceaseless rise in healthcare data, AI is essential. AI, which is an abbreviation of artificial intelligence, is a field that combines both computer science and vigorous datasets to facilitate problem-solving. This study aims to explore AI techniques as well as machine learning in enhancing the early detection, prevention, and intervention of HIV infections.

Early Detection and Diagnosis

HIV infection has continuously become a serious concern to the global world. Since the infection is incurable [12-16], early detection and diagnosis will go a long way to help in curbing and preventing the spread. WHO (2023) on global health sector strategy on HIV projected that HIV infections will reduce from 1.5 million in 2020 to 335,000 by 2030, and the death rate will also reduce from 680,000 in 2020 to under 240,000 in 2030. The application of AI in the health sector especially in early detection and diagnosis of HIV has proven to be effective in the management and early detection of HIV [17]. Nisa et al. [18] developed a predictive system that considers other factors in a high-risk group while predicting the future acquisition of HIV. Such attributes are drug injection, sexual behavior, and other behavioral and biological factors. The prediction models were built using electronic medical data from Nai Zindagi Trust (NZ), Pakistan. SVM, Neural Network, J48, and PART machine learning algorithms. Considering other factors apart from early signs which were used for the early-stage prediction helps the high-risk group to reduce the rate of the spread of the deadly deadly. Early prediction creates early awareness among the peer group and it reduces the chances of being infected as well as deliberate protection of oneself. The developed model by Nis et all gave 82% accuracy according to the report and has an improvement of 10-15% of the dominant classifier.

Balzer et al. [19] also carried out research where 16 communities were tested for HIV using machine learning score prediction. 3 factors were involved in the selection. Individuals belonging to the "risk group" age 15–24 years, individuals with spouses living with HIV, Alcohol consumers, widows (er)s, persons who work in transportation companies, those who work in bars, or those whose occupations are fishing. The score was calculated by summing the groups to which an individual belonged. This also was able to predict those that are likely to be infected. With this prevention programmes were introduced to reduce the spread. Mutai [20] used the XGBoost algorithm with socio-behavioral-driven in identifying HIV predictors and predicting individuals at high risk of infection for targeted screening. This early detection of individuals at high risk is the most predictive factor for HIV positivity. The factor was determined by the AI algorithm and presented with high reliability. It was discovered that the age of an individual has a significant impact on the rate of being infected by HIV [20]. This was discovered using the AI algorithm. This makes it imperative to sensitive the individual who is at high risk of being contagious to be more careful. Grid search hyperparameter optimization AI techniques were used to diagnose HIV disease for early detection [21] of individual status. Early detection of this disease in individuals has significantly helped in preventing the individual from developing AIDs and improves the health of the individuals.

Treatment Personalization:

AI in Treatment Personalization of HIV

Artificial intelligence (AI) has attracted a lot of attention in the medical field lately, especially concerning the treatment of HIV. The human immunodeficiency virus, or HIV, is a virus that compromises immunological function. Unprotected sexual contact, sharing contaminated needles, and mother-to-child transmission during pregnancy, delivery, and breastfeeding are how HIV is spread [22]. AI in personalized medical treatment is the act of utilizing artificial intelligence to analyze genetic and medical data from a patient to create a customized treatment strategy [23]. This can lead to better outcomes and an enhanced quality of life for patients by assisting healthcare practitioners in making informed choices about which treatments and medications will work best for each patient.

Further application of AI in the Treatment Personalization of HIV is the use of machine learning algorithms to predict how a patient will respond to specific antiretroviral drugs based on their genetic makeup and other factors [24-26]. This can help identify the most effective treatment options and minimize the risk of drug resistance. However, HIV treatment involves the use of antiretroviral therapy (ART) to suppress the viral load and prevent the progression of the disease [27]. The challenges of HIV treatment include medication adherence, drug resistance, access to healthcare, stigma, and discrimination [28-31]. Others include:

1. Individual Variability Issues: Each patient has a unique genetic makeup, lifestyle, and drug interactions that impact the effectiveness and safety of ART.
2. Polypharmacy issue: HIV patients often need to take multiple medications, which can increase the risk of drug interactions and adverse side effects.
3. Long-term Adherence Culture: Maintaining consistent adherence to ART is crucial for achieving successful treatment outcomes. However, patients may face challenges such as forgetfulness or limited access to healthcare facilities.

4. Monitoring Treatment Response: Monitoring the effectiveness of ART requires regular viral load tests and CD4 cell counts, but this process is time-consuming and costly.

AI-Driven Treatment Personalization

The integration of artificial intelligence (AI) into healthcare has ushered in a new era of personalized medicine, promising more effective and tailored treatments for patients [32]. Traditional medical approaches often adopt a one-size-fits-all model, but AI-powered personalized medicine is changing the game by harnessing the power of data, machine learning (ML), and advanced analytics to create individualized healthcare plans. Personalized medicine or healthcare, also known as precision medicine, is an approach to healthcare that customizes medical decisions, practices, and products to the individual patient. The goal is to provide more effective treatments, minimize side effects, and optimize outcomes based on each patient's unique genetic makeup, medical history, and lifestyle. This ensures that treatments are tailored to an individual's unique needs, improving both effectiveness and patient compliance. AI therefore holds great potential to revolutionize HIV treatment by personalizing treatment plans based on individual patient characteristics, medical history, and treatment response. By utilizing advanced algorithms and data analysis techniques, AI can:

i. Predict Treatment responses through the analysis of patient data, including viral load measurements, CD4 cell counts, and drug interactions, to predict the effectiveness of different ART regimens.
ii. Optimize ART Regimens using AI algorithms to identify the optimal combination of ART medications, taking into account factors such as drug interactions, resistance profiles, and patient-specific characteristics.
iii. Support Adherence by deploying AI-powered applications to provide reminders, motivational messages, and interactive tools to improve patient adherence to ART, reducing the risk of drug resistance.
iv. Monitor Treatment Response using AI algorithms to analyze patient data in real-time, identifying changes in treatment response and enabling timely adjustments to optimize patient care.

Drug Discovery

Prevention and Behavioral Insights

Researchers have been applying AI models in smart devices using data from social media to promote real-time HIV risk reduction and also using virtual reality tools to promote HIV serodisclosure [33], and chatbots for HIV education [34]. These media interventions using AI algorithms have tremendously reduced the risk involved in HIV by educating the high-risk group on the necessary measures to be taken to reduce the spread. Because AI algorithms are informed by human knowledge, they become an effective tool for identifying and preventing the spread of HIV. Rice et al. [35] and Wilder et al. [36] built an AI-enhanced PCA intervention to engage youth experiencing homelessness in Los Angeles, CA, and large USA cities to prevent HIV. The artificial intelligence was used to select peer change agents to deliver HIV messages to homeless youths. Rice and his group used a quasi-experimental method to extract data from homeless youths who are seeking refuge Los Angeles, CA, drop-in center. Since the AI-enhanced PCA was used to promote HIV testing and condom use, they created awareness among the homeless youth which in turn enhanced HIV prevention. AI in HIV Drug Discovery, Treatment Adherence, and Epidemiological Modelling:

AI in HIV Drug Discovery

AI has been increasingly used in HIV drug discovery to accelerate the process of identifying potential drug candidates and predicting their efficacy. By using machine learning algorithms and big data analysis, researchers can analyze vast amounts of genetic and molecular data to identify potential drug targets and predict the effectiveness of different compounds. Scientists can use AI algorithms to analyze vast amounts of data, including genetic information, biological mechanisms, and patient data, and identify potential drug targets by detecting patterns and correlations. Another special application area of AI in HIV drug discovery is the use of predictive modeling to identify potential drug candidates from large compound libraries [37]. By training machine learning models on existing data about the structure and activity of different compounds, researchers can predict which compounds are most likely to be effective against HIV. By leveraging AI techniques such as machine learning and natural language processing, scientists can analyze large datasets more efficiently, enabling researchers to identify potential treatments that were previously overlooked.

AI in Treatment Adherence

AI in treatment adherence refers to the use of artificial intelligence technology to improve patient adherence to their prescribed treatment plans. This can include AI-powered reminders, personalized treatment recommendations, and predictive analytics to identify patients at risk of non-adherence [38-39]. Artificial Intelligence (AI) has become a central focus for pharmaceutical industry leaders wanting to impact patient adherence and personalized support. Within the next ten years, pharma may be spending up to $50bn a year on AI to speed up drug development, according to Morgan Stanley. However, adherence to medications can be challenging, especially for individuals with complex healthcare needs. AI can be leveraged to monitor and track treatment adherence by analyzing data from various sources, such as wearable devices, mobile applications, and electronic health records [40]. By analyzing this data, AI algorithms can flag potential adherence issues and provide timely interventions and support to patients. This can help to ensure that patients are taking the correct medications at the right times, leading to improved health outcomes and reduced healthcare costs.

AI in Epidemiological Modeling

AI in Epidemiological Modeling refers to the use of artificial intelligence techniques, such as machine learning and data mining, to analyze and predict the spread of diseases within a population. This can include identifying patterns in disease transmission, predicting outbreaks, and optimizing public health interventions. Epidemiological modeling is a critical tool in understanding the spread of infectious diseases like HIV. One example of AI in Epidemiological Modeling is the use of machine learning algorithms to analyze large datasets of patient information and public health data to identify risk factors for disease spread and to predict the impact of different interventions [41].

AI in HIV Contact Tracing, Data Privacy, and Ethical Consideration

While AI-driven treatment personalization offers significant benefits, it also raises ethical concerns. It is crucial to ensure that AI systems are trained on diverse data sets, avoiding potential biases and ensuring fairness and equity in patient care. Additionally, maintaining patient privacy and ensuring that patient data is protected is of utmost importance [42]. In HIV contact tracing, artificial intelligence (AI) has become a potentially helpful technology that can help identify people who may have been exposed to the virus more accurately and efficiently [43]. An essential public health tactic is HIV contact tracing, which identifies and notifies people who may have come into contact with the virus so they may get tested and receive the necessary medical attention [44]. This approach, which moves from development to implementation, can potentially improve PrEP delivery using machine learning, a branch of artificial intelligence. Equity should be considered while developing and accessing AI and ML solutions for HIV prevention. An implementation science approach, which includes qualitative user assessments, may be beneficial. Artificial intelligence (AI) systems can facilitate targeted therapies and preventive tactics by analyzing vast amounts of data to detect trends and anticipate possible transmission pathways [45]. This process may result in early identification of HIV patients and prompter interventions, which would ultimately stop the virus's spread. AI can also be used in HIV contact tracing to gather and analyze private data, such as contact details and HIV status [46]. These are other ways AI can help with HIV contact tracing:

1. Efficient Contact Tracing: Artificial Intelligence can examine huge volumes of data from several sources, including social media, lab findings, and electronic health records, to detect high-risk populations and possible patterns of HIV transmission. It can automate contact identification by evaluating patient data and locating possible contacts more rapidly and precisely [46].

2. Privacy-Preserving Contact Tracing: Artificial

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Intelligence can utilize privacy-preserving methods such as safe multi-party computation or federated learning to facilitate contact tracing while protecting people's confidential data. Preventing direct access to personal data throughout the contact tracing process helps protect privacy [47].

3. Informed Consent and Transparency: By giving people precise information about how their data will be used in contact tracing, AI can help informed consent processes. It can provide contact tracing process transparency, enabling people to know how their data is managed and shared [48].

4. Data Anonymization: By eliminating or obscuring personally identifiable information, AI can help anonymize data and protect the privacy of those involved in contact tracing. Sensitive information in datasets can be automatically identified and redacted with the assistance of machine learning algorithms [49].
5. Bias Detection and Mitigation: To avoid unjustly targeting particular demographics or reinforcing preexisting biases, AI can recognize and eliminate biases in contact tracing data. Contact tracing initiatives can be made more egalitarian and just by using bias detection tools and ensuring that the algorithms used for HIV contact tracing are trained on diverse and representative [50]
6. Ethical Decision Support: Healthcare professionals and contact tracers can make ethical decisions concerning contact tracing and alerts with the support of AI, which offers moral insights and recommendations. When handling sensitive health data, it can help with difficult ethical decisions such as determining the appropriate level of notification and disclosure to individuals who may have been in contact with someone with HIV [51].
7. Data Security and Access Controls: Cybersecurity powered by AI may monitor and safeguard contact tracing data, preventing data breaches and unwanted access. AI-driven access controls guarantee that private health information is only accessible to those permitted to view it, and encryption measures can protect the data during transmission and storage
[52].

8. Algorithm Transparency and Explainability: AI may be utilized to create tools that improve the transparency and understandability of contact tracing methods. By doing this, you may build trust and make sure that people know how decisions for contact tracing are made [53].

9. Ethical Audits: To evaluate the contact tracing process's accountability, fairness, and transparency, as well as its adherence to legal and ethical requirements, AI can do ethical audits [54].

10. Red teaming and adversarial testing: By mimicking attacks and evaluating the strength of privacy protections, AI can help uncover weaknesses and ethical issues in AI systems [55].

However, the application of AI to HIV contact tracing has brought up significant issues with data privacy and the possibility of stigmatizing or discriminating against those living with HIV [56]. The creation and application of AI systems for HIV contact tracing have brought up significant ethical, legal, and societal issues, including informed consent for data access, data privacy, and security, algorithmic biases and fairness, and transparency. To guarantee that the use of AI in HIV contact tracing respects people's right to privacy, guards against discrimination, and ensures the responsible and ethical use of gathered data, ethical considerations must be taken into account. An essential ethical review for AI-based HIV contact tracing is data privacy [57].
Although AI algorithms can effectively detect and follow HIV cases, privacy protection must come first [58]. Establishing suitable frameworks for regulations and policies is essential to directing the responsible use and governance of AI and data in HIV contact tracing [59]. Ensuring the safeguarding of personal privacy is crucial when monitoring HIV patients [60]. This context can be accomplished by putting policies in place to reduce the sharing of personal data and provide protection from any privacy violations [61]. Furthermore, to guarantee that people are aware of the possible hazards and advantages connected with these technologies, education, and awareness of the ethical

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implications of AI in HIV contact tracing should be given top priority [62]. Transparency should also be a primary goal in AI-enabled HIV contact tracing, addressing ethical and data privacy issues. People should know how AI algorithms operate and the rationale for identifying particular people as possible contacts.

Ethical and data privacy-aware AI integration into HIV contact tracking is essential for responsible and successful public health initiatives. Finding the correct balance between privacy, ethics, and public health demands is crucial, and maintaining constant watchfulness is necessary to ensure these values are respected. Cooperation between data scientists, policymakers, ethicists, and healthcare providers is essential to accomplish these goals. Though AI can be a useful tool in HIV contact tracing, it should be used in conjunction with other public health initiatives and under the guidance of medical professionals. When implementing AI-driven contact tracing solutions, effort should also be taken to address ethical issues, data protection, and the possibility of bias in AI systems.

Recommendations

Encourage collaboration between public health experts, data scientists, healthcare practitioners, and ethicists to ensure a holistic approach to the development and implementation of AI-driven personalized risk reduction plans. Develop and adhere to clear ethical guidelines addressing issues such as privacy, consent, transparency, and equity to ensure responsible and fair use of AI in HIV prevention. Implement AI models that continuously learn and adapt to evolving patterns and emerging trends in HIV transmission, allowing for dynamic and up-to-date risk reduction plans. Prioritize community engagement and involvement in the development of AI-driven interventions, ensuring that solutions align with the cultural, social, and contextual realities of the target populations. Prioritize robust data security measures to safeguard sensitive health information, addressing concerns related to the potential misuse of personal data and ensuring compliance with relevant privacy regulations.

Facilitate the seamless integration of AI-driven risk reduction plans with existing healthcare systems, enhancing accessibility and effectiveness in real-world healthcare settings. Advocate for the integration of AI-driven personalized risk reduction strategies into public health policies, fostering a supportive regulatory environment for the adoption and scaling of these interventions. Allocate resources and funding for ongoing research and development in AI applications for HIV prevention, with a focus on improving accuracy, accessibility, and scalability. Foster international collaboration and information sharing to leverage collective knowledge and resources, especially in regions with high HIV prevalence and limited resources. Prioritize user-centered design principles in the development of AI-driven applications, ensuring that the end-users, including individuals at risk of HIV, find the tools intuitive, accessible, and culturally sensitive. Invest in education and training programs for healthcare professionals, data scientists, and community health workers to enhance their understanding and proficiency in utilizing AI for personalized HIV risk reduction. Establish long-term monitoring and evaluation mechanisms to assess the effectiveness, impact, and potential unintended consequences of AI-driven personalized risk reduction interventions.

Conclusion

The integration of Artificial Intelligence (AI) in the development of personalized risk reduction plans for HIV represents a promising frontier in public health. The evolution of AI technologies, including machine learning and predictive modeling, has the potential to revolutionize HIV prevention strategies by tailoring interventions to individual needs and circumstances. This narrative review has highlighted the current state of AI applications in personalized risk reduction for HIV, emphasizing the importance of interdisciplinary collaboration, ethical considerations, and community engagement. The synthesis of existing literature has showcased the diversity of AI-driven methodologies, ranging from predictive analytics to mobile health applications, all aimed at providing targeted and context-specific interventions.

As we envision a future with AI-enhanced personalized risk reduction plans, it is essential to remain vigilant about the potential societal impacts and continually assess the effectiveness and ethical implications of these interventions. By embracing these recommendations

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and learning from ongoing research, we can collectively work towards a more targeted, accessible, and impactful approach to reducing the burden of HIV on a global scale. The integration of AI into HIV prevention holds great promise, but it is our responsibility to ensure that its implementation aligns with ethical principles, respects individual rights, and contributes to the overall well-being of communities affected by HIV.

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