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Review Article

AI in addiction: Harnessing technology for diagnosis, prevention, and recovery: A narrative review

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Abstract

Background: Addiction, both substance use and behavioral disorders, remains a significant global public health issue, affecting individuals, families, and societies. Traditional methods of addiction management struggle to meet the increasing demand for effective solutions. Artificial intelligence (AI) has emerged as a promising tool to address this challenge, offering innovative solutions across diagnosis, prevention, and recovery.

Objective: To explore and synthesize the current applications of AI in addiction care, evaluating its potential in diagnosis, risk assessment, prevention, and recovery, while addressing associated challenges and ethical considerations.

Methods: This narrative review draws from a range of studies, focusing on AI-driven technologies such as machine learning models, neuroimaging biomarkers, and wearable devices. The review discusses AI's role in identifying addiction risk, diagnosing disorders, predicting treatment outcomes, and providing continuous recovery support.

Results: AI has demonstrated significant effectiveness in addiction care, with machine learning algorithms achieving high diagnostic accuracy in substance use and behavioral disorders. Predictive analytics have shown promise in identifying at-risk populations and facilitating early intervention, while wearable devices and mobile applications support recovery by tracking physiological and behavioral indicators. Despite these advancements, challenges such as data privacy concerns, algorithmic bias, scalability in low-resource settings, and ethical considerations remain significant barriers.

Conclusions: AI holds transformative potential in revolutionizing addiction care by enabling earlier detection, personalized interventions, and continuous monitoring of recovery. However, for AI to be successfully integrated into addiction care, addressing challenges such as data security, bias, and accessibility is essential. Future research should focus on expanding datasets, conducting longitudinal studies, and establishing ethical frameworks to guide AI adoption in this field.

Keywords: Addiction, Artificial Intelligence, Machine learning, Risk assessment, Early intervention, Recovery, Ethical considerations, Public health

Introduction

Addiction is a chronic condition marked by loss of control over substance use or behaviors, driven by a compulsion for immediate pleasure despite long-term harm. It includes substance use disorders and behavioral addictions, both linked to the brain's reward system. These disorders disrupt lives, causing relationship strains, mental health issues, and physical decline [1].

Addiction is a major global public health challenge, affecting millions and straining healthcare systems. Recent estimates indicate that 5.5% of the global population aged 15–64 years (approximately 271 million people) used illicit drugs in 2017, with 31 million suffering from drug use disorders [2].

Alcohol and tobacco remain the most prevalent addictive substances, with alcohol use disorder affecting 4.9% of adults (240 million) and tobacco use impacting 22.5% of adults (1 billion) worldwide [3]. Among illicit drug users, opioids are linked to 76% of drug-related deaths, highlighting the severity of the crisis [4]. The prevalence of problem gambling is estimated at 1.5% in regions where it has been, and cannabis use, the most common among unsanctioned psychoactive drugs, affects 3.5% of the global population [3]. Behavioral addictions, such as gambling (1.5%) and cannabis use (3.5%), further underscore the widespread nature of addiction. However, limitations in data quality and regional reporting affect the accuracy of these estimates [5].

The economic and social burden of addiction profoundly impacts healthcare systems, workforce productivity, and family dynamics. Rising addiction rates, especially among youth, exacerbate these challenges, resulting in substantial long-term costs for individuals and communities. For instance, the opioid crisis alone cost the U.S. approximately $1 trillion between 2001 and 2017, including medical expenses and loss of life, while employers lose an estimated $18 billion annually due to opioid addiction, reflecting absenteeism and reduced productivity [6]. Globally, public health systems are strained as more individuals require addiction treatment, and in the U.S., substance misuse incurs an annual economic burden exceeding $740 billion, encompassing healthcare, lost productivity, and crime-related costs .Within families, addiction causes emotional distress, financial strain, and instability, often leading to child neglect, abuse, and long-term psychological harm, while the breakdown of trust perpetuates cycles of addiction, hindering the development of younger family members [7]. Beyond direct costs, addiction's broader societal impacts, including increased crime and strained social services, demand comprehensive strategies that prioritize prevention, treatment, and support for individuals and families.

Current approaches to addiction management face significant challenges. Diagnostic tools often lack early detection capabilities and rely on subjective assessments. While advanced techniques like neuroimaging and genetics improve our understanding of addiction risk, they fall short in addressing practical implications. Mobile technologies offer promising solutions by providing insights into addiction mechanisms and relapsing dynamics beyond conventional methods [8]. Current diagnostic tools also fail to incorporate neuropsychological advancements, such as transdiagnostic approaches using dimensional measures [9]. or cognitive processes like attention biases, which are critical predictors of relapse [10].

While advancements in diagnostic and neuropsychological tools are critical, addressing the broader challenges of relapse, treatment adherence, and prevention strategies remain essential. Research on behavioral addictions highlights the prevalence of these issues, emphasizing the need for studies on adherence and demographic factors [11]. Prevention strategies for substance use disorders are further complicated by stigma, accessibility issues, and the need for innovative solutions. Technological innovations, such as online and mobile interventions, offer potential solutions, but their efficacy requires further evaluation [12].

Artificial intelligence (AI) is transforming healthcare through technologies like machine learning, natural language processing, and computer vision. These tools are improving diagnostics, enabling personalized medicine, and enhancing patient monitoring [13,14]. For example, AI has demonstrated significant potential in increasing diagnostic accuracy in areas like cancer detection and radiology, while integrating genomic data and electronic health records to create tailored treatment plans (2024). AI-powered wearable devices and health apps also facilitate real-time monitoring, enabling early intervention and preventive care [13,15].

In addiction care, AI holds immense promise for transforming diagnosis, prevention, and recovery. AI algorithms can improve diagnostic accuracy, predict treatment outcomes, and enable early detection of addiction symptoms [16]. AI-driven tools also support personalized treatment plans and real-time monitoring, which can enhance recovery rates and reduce relapses [17].

However, the integration of AI in addiction care raises ethical concerns. However, the integration of AI in addiction care raises ethical concerns.

The aim of this study is to explore the potential of AI in improving the diagnosis, prevention, and recovery processes for addiction. By examining how AI technologies, such as machine learning, natural language processing, and real-time monitoring, can enhance treatment outcomes, this research seeks to identify key applications and innovations in addiction care. Additionally, the study will address the ethical challenges and barriers to AI integration, focusing on issues such as data privacy, algorithmic bias, and equitable access. Ultimately, this research aims to contribute to the development of more effective, personalized, and accessible addiction treatment strategies.

Methods

A comprehensive literature search was conducted using PubMed, Scopus, and Google Scholar. Keywords included "artificial intelligence," "addiction," "diagnosis," "prevention," and "recovery." Studies published between 2010 and 2024 were included if they focused on AI applications in addiction care and were written in English. Articles without empirical data or those focused solely on non-AI technologies were excluded. Data from selected studies were categorized into themes such as diagnosis, prevention, and recovery, and key findings were synthesized to provide a comprehensive overview of AI's role in addiction care.

Results

AI in addiction: current trend & innovation

Artificial intelligence (AI) is rapidly transforming the field of addiction science, offering innovative solutions across the addiction spectrum—from diagnosis and prevention to personalized recovery. By leveraging data analytics and machine learning, AI is redefining how addiction is understood, managed, and treated.

AI for diagnosis of addiction: AI is revolutionizing addiction diagnosis by enabling early detection, refining diagnostic accuracy, and enhancing clinical decision-making. Through advanced machine learning (ML) models, AI analyzes diverse data sources—such as electronic health records (EHRs), behavioral patterns, and demographic information—to identify early signs of addiction and predict treatment outcomes with remarkable precision.

Early detection and risk assessment: Early detection and risk assessment are critical components in addressing addiction, as timely identification of susceptibility and intervention opportunities can significantly improve patient outcomes. Advances in artificial intelligence (AI) and machine learning (ML) have revolutionized this domain, providing powerful tools to analyze complex datasets and predict addiction-related risks with unprecedented accuracy.

AI and ML models excel in analyzing complex datasets to predict addiction-related risks with high accuracy. A hybrid ML models have achieved 99.75% accuracy in diagnosing Internet Addiction by identifying critical risk factors [18]. These models surpass traditional diagnostic methods in sensitivity and specificity, enabling the development of personalized interventions and targeted treatment strategies [16,19].

These advancements enhance understanding of the underlying mechanisms driving addiction, enabling the development of personalized interventions and targeted treatment strategies. Additionally, ML techniques can process diverse data types to identify specific addiction subtypes and predict treatment outcomes, further improving the precision of addiction medicine [16,20]. Despite the progress, challenges remain, including data quality, algorithm bias, interpretability, and integration into clinical workflows, highlighting the need for ongoing research to validate these models across varied populations and optimize their clinical applicability [19].

AI-driven diagnostic tools in addiction: AI is enhancing addiction diagnostics through innovative tools such as behavioral signal analysis, neuroimaging, and speech pattern evaluation. For instance, ML techniques have demonstrated significant efficacy in analyzing neuroimaging data to uncover neurobiological signatures linked to substance use disorders (SUDs) and predict treatment outcomes [21].

Moreover, voice signal analysis using wavelet transforms has been utilized as a non-invasive diagnostic tool, identifying distinctive speech features associated with addiction [22]. End-to-end deep neural networks have achieved 98.5% accuracy in diagnosing drug addiction through speech signals, enabling discreet and efficient evaluations [23]. These advancements are particularly valuable in resource-limited or remote settings, where traditional diagnostic methods may be inaccessible.

Collectively, these AI-enhanced methodologies not only refine diagnostic precision but also create opportunities for personalized intervention strategies. By harnessing the power of AI, clinicians can deliver targeted treatments tailored to individual patient needs, addressing the complex interplay of psychological and physiological factors in addiction treatment [16,19]. These innovations underscore the transformative potential of AI in reshaping the landscape of addiction diagnosis, prevention, and recovery.

Impact on clinical practice: AI-based diagnostics are transforming clinical practice by improving the accuracy and speed of addiction identification. These tools facilitate early detection, enabling timely interventions and personalized treatment plans. For example, AI can predict treatment outcomes, allowing clinicians to adjust therapeutic approaches and improve patient care [16,19,24]. Despite these advancements, challenges such as data accessibility and the need for extensive datasets persist. Further research is required to fully realize AI's potential in addiction medicine [19].

AI and machine learning are reshaping addiction diagnosis by enhancing early detection, risk assessment, and clinical decision-making. Advanced tools like behavioral analysis, neuroimaging, and speech pattern evaluation enable precise and personalized interventions, helping clinicians identify addiction subtypes and predict treatment outcomes. While challenges such as data quality and algorithmic bias remain, AI holds immense potential to revolutionize addiction care. Ongoing research and collaboration are essential to optimize its integration into clinical practice and ensure equitable access to these transformative technologies.

AI for addiction prevention: Artificial intelligence (AI) is increasingly being utilized in addiction prevention, offering innovative solutions to identify at-risk populations, provide targeted behavioral interventions, and reduce stigma associated with substance use disorders.

Predictive analytics for at-risk populations: AI models are proving highly effective in identifying individuals at higher risk for addiction, enabling the development of targeted prevention programs. Machine learning (ML) approaches, such as those discussed by Prasad *et al.* [25] and Abada *et al.* [26], analyze behavioral and environmental factors to assess addiction susceptibility with remarkable accuracy. For instance, Bayesian models have achieved up to 91.4% accuracy in predicting addiction risk by analyzing historical data, including previous addiction instances and life failures [26]. Deep learning mechanisms further extend this capability to internet addiction by leveraging user behavior data and bioinformatics, enabling large-scale population assessments [27]. These AI-driven methodologies not only enhance the precision of risk predictions but also support the creation of tailored intervention strategies, ultimately improving public health outcomes.

Behavioral interventions and support: AI-powered applications and virtual counselors are emerging as effective tools for delivering personalized prevention strategies for addiction, particularly through cognitive-behavioral techniques and behavioral nudges. These digital interventions, such as chatbots and virtual therapists, utilize natural language processing and machine learning to provide tailored support, psychoeducation, and coping strategies, thereby enhancing accessibility and reducing stigma associated with traditional mental health services [28,29]. For instance, AI-driven solutions can predict relapse rates and offer real-time recovery consultations based on individual user data, significantly aiding those recovering from alcohol addiction [29]. Moreover, a systematic review indicates that digital treatments, particularly those based on cognitive-behavioral therapy (CBT), effectively reduce substance use and improve treatment outcomes [30]. The integration of generative AI, such as ChatGPT, further enhances these capabilities by simulating human-like interactions, although concerns regarding accuracy and the therapeutic relationship remain [31]. Overall, these innovations represent a promising frontier in addiction prevention and recovery strategies.

Reducing stigma through technology: AI-driven platforms are increasingly recognized for their potential to provide anonymous counseling and peer support, effectively reducing barriers for addiction patients seeking help. Tools like Woebot, which employs principles of psychotherapy, have demonstrated efficacy in reducing substance use among users compared to those on therapy waitlists [31]. Additionally, mobile applications such as the Marigold App are being developed to offer 24/7 peer support, utilizing AI to ensure safe and constructive interactions by flagging critical content [32].

These platforms leverage NLP and ML to deliver personalized support, coping strategies, and continuous engagement, creating a judgment-free environment for individuals seeking help. Online communities further enhance the recovery journey by fostering peer interactions and reducing feelings of isolation [28,33]. Collectively, these innovations highlight the transformative role of AI in addiction treatment, fostering a supportive ecosystem for individuals in recovery.

AI is revolutionizing addiction prevention through accurate predictive models, personalized behavioral interventions, and stigma-reducing technologies. By enhancing early identification of at-risk individuals, improving treatment accessibility, and fostering supportive recovery environments, AI offers a promising path toward more effective and inclusive prevention strategies. However, challenges such as data privacy, algorithmic bias, and ethical concerns must be addressed to fully realize its potential. Continued research and collaboration are essential to maximize AI's impact on public health and ensure equitable access to these transformative tools.

AI for addiction recovery: Artificial intelligence (AI) is revolutionizing addiction recovery by enabling personalized treatment plans, continuous monitoring, and long-term support. Through advanced data analytics and machine learning, AI empowers healthcare providers to deliver tailored interventions, predict relapse risks, and provide emotional support, ultimately improving recovery outcomes.

Personalized Treatment Plans: AI plays a crucial role in personalizing treatment strategies for addiction patients by leveraging real-time behavioral feedback and health data. By analyzing vast datasets, including genetic, environmental, and lifestyle factors, AI creates comprehensive patient profiles that inform tailored treatment plans. This individualized approach enhances therapeutic efficacy while minimizing adverse effects [34].

AI also enables continuous monitoring and adjustment of treatment regimens based on patient responses, promoting proactive management of addiction [34,35]. Furthermore, AI's predictive analytics capabilities enable the identification of patterns that inform timely interventions, thereby reducing reliance on traditional trial-and-error methods [36,37]. However, the integration of AI in addiction treatment also raises challenges, including data privacy concerns and the need for robust regulatory frameworks to ensure ethical application [36,38]. Overall, AI's transformative potential in addiction treatment underscores a shift towards more effective, patient-centered care.

AI in monitoring and long-term support: AI-based tools, including wearables and mobile applications, are transforming how addiction recovery is monitored and supported. Wearable devices continuously track physiological signals such as heart rate and sleep patterns, while mobile apps facilitate ecological momentary assessments (EMA) to gather real-time self-reported data on mood, cravings, and triggers [39].

Digital phenotyping enhances this process by utilizing smartphone sensors to analyze behavioral patterns, enabling timely interventions when users approach high-risk environments [40]. Additionally, AI-driven virtual therapists provide personalized support and relapse predictions based on user data, fostering a proactive approach to recovery [29]. These technologies not only identify potential relapse indicators but also empower healthcare providers to initiate early interventions, ultimately improving treatment outcomes [41].

Virtual therapists and AI-powered support systems: AI applications, such as chatbots and virtual reality (VR) systems, are increasingly being used to support addiction recovery and prevent relapse by providing emotional support and therapeutic interventions. Chatbots, powered by natural language processing (NLP) and machine learning, deliver personalized interactions that offer psychoeducation, coping strategies, and continuous support. These tools effectively address barriers such as stigma and accessibility in traditional mental health care [28,42].

For example, Empath.ai integrates emotion detection capabilities to tailor responses, enhancing user engagement and therapeutic outcomes [43]. Similarly, VR-based exposure therapy has proven effective in treating anxiety and post-traumatic stress disorder (PTSD), offering promising applications for addiction recovery [28].

While these AI-driven solutions offer significant benefits—such as 24/7 availability and judgment-free support—ethical considerations and the need for human oversight remain critical to ensure safe and effective use [44].

AI is transforming addiction recovery through personalized treatment plans, real-time monitoring, and AI-powered support systems. By leveraging predictive analytics, wearable technologies, and virtual therapists, AI enables proactive and patient-centered care. However, challenges such as data privacy, algorithmic bias, and ethical concerns must be addressed to fully realize its potential. Continued research and collaboration are essential to optimize AI's role in addiction recovery and ensure equitable access to these innovative tools.

Discussion

Addiction remains one of the most complex and pervasive public health challenges of our time, with far-reaching consequences for individuals, families, and societies. As traditional approaches to addiction management struggle to keep pace with the growing burden of substance use and behavioral disorders, artificial intelligence (AI) has emerged as a transformative tool, offering innovative solutions across the addiction spectrum—from diagnosis and prevention to recovery. This discussion synthesizes the current state of AI in addiction care, highlights its potential, addresses critical challenges, and outlines future directions for research and implementation.

The global burden of addiction

Addiction is a multifaceted issue that transcends geographical and socioeconomic boundaries. Globally, alcohol and tobacco are the most common forms of addiction, affecting 4.9% and 22.5% of adults, respectively [3]. Substance use disorders, coupled with behavioral addictions such as gambling and internet use, disrupt lives, strain healthcare systems, and substance use disordersy to mortality and economic losses. For instance, the opioid crisis in the United States alone cost approximately $1 trillion between 2001 and 2017, underscoring the immense societal impact of addiction [7].

The ripple effects of addiction extend beyond healthcare, affecting workplace productivity, family dynamics, and community well-being. Families bear the emotional and financial burden, while employers face losses due to absenteeism and reduced performance. These challenges highlight the urgent need for innovative, scalable solutions to address addiction effectively.

AI's transformative potential in addiction management: AI has demonstrated remarkable potential in revolutionizing addiction care, offering tools for early detection, personalized interventions, and continuous support.

Diagnosis and risk assessment: AI-driven models, such as hybrid machine learning (ML) algorithms, have achieved unprecedented accuracy in diagnosing addiction. For example, ML models have reached 99.75% accuracy in identifying internet addiction by analyzing behavioral and environmental risk factors [18]. Similarly, AI-powered tools like neuroimaging biomarkers and speech pattern analysis enable non-invasive, precise diagnostics. End-to-end neural networks have achieved 98.5% accuracy in detecting substance use disorders, paving the way for early intervention [21].

Prevention and early intervention: AI excels at identifying at-risk populations through predictive analytics. By analyzing diverse data sets, including electronic health records (EHRs), behavioral patterns, and demographic information, AI can predict addiction susceptibility and facilitate targeted prevention programs [25]. Digital tools, such as virtual therapists and chatbots, provide personalized support and psychoeducation, reducing barriers to care and addressing stigma [31].

Recovery and long-term support: AI-powered wearables and mobile applications enable real-time monitoring of physiological and behavioral indicators, helping prevent relapse. For instance, wearable devices track heart rate and sleep patterns, while apps facilitate ecological momentary assessments (EMA) to gather real-time data on cravings and triggers [45]. These technologies empower healthcare providers to intervene proactively, improving long-term outcomes.

Challenges and ethical considerations

Despite its promise, the integration of AI in addiction care is not without challenges. Addressing these issues is critical to ensuring equitable and ethical implementation.

Data privacy and security: Addiction-related data often includes sensitive personal information, raising concerns about privacy and confidentiality. Strong encryption protocols and secure storage methods are essential to protect patient data and build trust [46].

Algorithmic bias: AI systems trained on incomplete or non-representative datasets risk producing biased outcomes, potentially marginalizing underrepresented groups. Ensuring diversity in training data and developing bias-correcting algorithms are crucial steps toward equitable AI solutions [16].

Scalability and accessibility: The lack of standardization in AI implementation limits its scalability, particularly in low-resource settings. Collaborative frameworks involving policymakers, healthcare professionals, and technologists are needed to address these disparities and ensure widespread adoption [47].

Ethical concerns: The increasing autonomy of AI systems raises ethical questions about their role in clinical decision-making. While AI can enhance diagnostics and treatment, it should not replace human judgment. Transparent communication between patients and providers about AI's role in care is essential to foster trust and acceptance [48].

Future directions for research and implementation

To fully realize AI's potential in addiction care, future research should focus on several key areas:

1. Expanding dataset diversity: Including underrepresented populations and a broader range of addiction scenarios can improve model accuracy and reduce bias [19].
2. Conducting longitudinal studies: Assessing the long-term effectiveness of AI interventions on relapse rates, patient adherence, and quality of life is essential [30].
3. Developing ethical frameworks: Robust guidelines for data privacy, consent, and equitable access will ensure responsible AI integration [16].
4. Integrating emerging technologies: Biosensors and digital phenotyping can enhance real-time monitoring and provide deeper insights into patient behavior [39].
5. Fostering interdisciplinary collaboration: Partnerships between technologists, clinicians, and social scientists can drive innovation while addressing cultural and societal nuances [33].
6. Broader implications for healthcare and society

AI can revolutionize workflows by improving diagnostic speed and accuracy, enabling early intervention, and personalizing treatment strategies. For example, AI-driven tools can predict treatment outcomes, allowing clinicians to tailor interventions to individual patient needs

a. **Clinical practice:** AI can revolutionize workflows by improving diagnostic speed and accuracy, enabling early intervention, and personalizing treatment strategies. For example, AI-driven tools can predict treatment outcomes, allowing clinicians to tailor interventions to individual patient needs [49].
b. **Public health policy:** Policymakers can leverage AI insights to allocate resources more effectively and design inclusive public health campaigns targeting at-risk populations [12]. By addressing barriers such as stigma and limited access, AI can promote equitable healthcare delivery.
c. **Societal impact:** More effective addiction management through AI can reduce the economic burden on healthcare systems and foster healthier communities. AI's ability to provide anonymous, judgment-free support represents a significant step toward reducing stigma and improving access to care.

Conclusion

Addiction, including substance use and behavioral disorders, is a global public health crisis with severe health, economic, and social impacts. Its rising prevalence, especially among youth, highlights the need for innovative solutions. The opioid crisis, costing trillions, underscores the urgency to rethink prevention, diagnosis, and treatment.

AI is transforming addiction care by enabling early detection, risk assessment, and tailored interventions. Tools like machine learning, wearables, and virtual therapists enhance diagnostic accuracy, personalized treatment, and monitor recovery, reducing relapse. AI also reduces stigma and improves access through anonymous digital platforms. AI) demonstrates considerable potential to transform addiction care through early detection, tailored interventions, and real-time monitoring of recovery trajectories. The first study reinforces this transformative role by showing how targeted educational interventions can significantly enhance nurses' knowledge and attitudes toward AI in mental health and addiction services, thereby strengthening AI's integration into clinical practice. The second study, while primarily focused on predictors of eating addiction, highlights the promise of machine learning in identifying key variables such as hedonic hunger, thereby exemplifying AI's utility in uncovering complex behavioral patterns. Nevertheless, for AI to be effectively embedded in addiction care, literature urges critical attention to challenges including data privacy, algorithmic bias, and equitable access [50,51]

However, AI integration faces challenges, including algorithmic bias, data privacy, and equitable access. Robust frameworks and diverse datasets are needed to ensure ethical implementation. Interdisciplinary collaboration is crucial to address these barriers and maximize AI's potential.

The future of addiction care lies in combining AI with holistic, patient-centered models that address social, environmental, and individual factors. By fostering collaboration across research, healthcare, and policy, AI can bridge gaps in prevention, diagnosis, and recovery.

Despite challenges, AI's transformative potential offers hope for more effective addiction management, restored lives, and stronger communities. Continued innovation, ethical vigilance, and collaboration can pave the way for a healthier, more equitable world.

Data Availability Statement

No data are associated with this article.

Author Contributions

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Competing Interests

The authors declare no competing interests.

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