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The role of digital health in modern pharmacy: A review of emerging trends and patient impacts

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Abstract

The integration of digital health into modern pharmacy practices has revolutionized patient care and medication management, ushering in a new era of convenience, accessibility, and personalized healthcare services. This review provides an insightful review of the evolving role of digital health in pharmacy, focusing on emerging trends and their impacts on patients. Digital health technologies, such as telepharmacy services, mobile health applications, and virtual consultations, have transformed the traditional pharmacy model by bridging geographical barriers and expanding access to healthcare services. Pharmacists can now engage with patients remotely, providing medication counselling, monitoring, and adherence support through digital platforms. These innovations enhance patient convenience, empower individuals to take control of their health, and ultimately improve health outcomes. Furthermore, digital health solutions leverage advanced technologies like artificial intelligence (AI) and data analytics to optimize medication therapy and personalize patient care. AI-driven algorithms analyze patient data to identify trends, predict health outcomes, and optimize medication regimens, leading to more effective treatment plans and reduced medication errors. Moreover, digital health fosters greater collaboration and communication among healthcare providers, enabling seamless coordination of care and improved patient outcomes. Through secure electronic health records and interoperable systems, pharmacists can access comprehensive patient information, facilitating informed decision-making and enhanced patient safety. However, the adoption of digital health in pharmacy also presents challenges, including data privacy concerns, regulatory complexities, and disparities in digital literacy among patients. Addressing these challenges is crucial to ensure the ethical and effective implementation of digital health technologies in pharmacy practice. In conclusion, the integration of digital health into modern pharmacy represents a paradigm shift in patient care delivery, offering unprecedented opportunities to enhance accessibility, efficiency, and quality of care. By embracing emerging digital health trends, pharmacists can revolutionize medication management, improve patient engagement, and ultimately contribute to better health outcomes for individuals and communities.

Keywords: Digital Health; Patients Impacts; Trends; Modern Pharmacy

1. Introduction

In recent years, the integration of digital health technologies into pharmacy practice has reshaped the landscape of patient care and medication management. Digital health refers to the use of digital technologies, such as telemedicine, mobile applications, artificial intelligence, and data analytics, to improve healthcare delivery, patient engagement, and health outcomes within the pharmacy setting. This rapidly evolving field is revolutionizing how pharmacists interact

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with patients, manage medication therapies, and support broader healthcare objectives. At its core, digital health encompasses the application of technology to enhance various aspects of pharmaceutical care, from medication dispensing to patient education and adherence monitoring (Mantel-Teeuwisse, et al., 2021; Solomon & Rudin, 2020; Thornewill, et al., 2022). In parallel, advances in artificial intelligence and data analytics have introduced more sophisticated tools for predictive modeling and patient segmentation, facilitating the development of tailored treatment plans (Leghemo et al., 2024a; Segun-Falade et al., 2024; Awoyemi et al., 2025a).

The pivotal role of digital health in modernizing pharmacy practice cannot be overstated. These technologies address the evolving needs of patients and healthcare systems by improving the accessibility, personalization, and efficiency of pharmaceutical services. Pharmacists can now harness technology to optimize medication therapy, identify potential adverse effects proactively, and offer patient-specific interventions. For instance, the use of AI-driven platforms for medication adherence monitoring has shown promise in reducing errors and ensuring continuity of care (Awoyemi et al., 2025b; Leghemo et al., 2024b). Additionally, digital tools enhance coordination between healthcare providers, fostering a more integrated and patient-centric approach to care. The incorporation of data governance frameworks further strengthens this integration by ensuring the accuracy, security, and compliance of sensitive patient data across multiple touchpoints (Leghemo et al., 2025b; Awoyemi et al., 2023). As a result, pharmacy practices can evolve to meet the increasing demands of modern healthcare systems while maintaining high standards of patient care (Abernethy, et al., 2022; Awad, et al., 2021; Krendyukov & Nasy, 2020).

Emerging trends in digital health, such as telepharmacy, virtual consultations, and AI-enabled decision support systems, are significantly transforming the delivery of pharmaceutical care. Telepharmacy, for instance, expands access to pharmacy services, particularly for patients in remote or underserved areas, while AI-driven tools support pharmacists in making evidence-based clinical decisions. These innovations not only improve operational efficiency but also contribute to enhanced patient experiences and outcomes. By enabling real-time monitoring and intervention, digital health technologies can identify potential medication-related issues early, thus preventing complications and improving adherence rates (Awoyemi et al., 2024; Leghemo et al., 2024c). Furthermore, integrating digital health solutions with existing pharmacy management systems facilitates a seamless exchange of information, supporting holistic patient care and driving better health outcomes (Leghemo et al., 2024d; Awoyemi et al., 2025c).

This review will delve into the latest trends and advancements in digital health within the pharmacy sector, exploring how these innovations are transforming the delivery of pharmaceutical care. Additionally, it will examine the tangible impacts of digital health on patients, including improvements in medication adherence, accessibility to pharmacy services, and overall health outcomes. By examining emerging trends and patient impacts, this review aims to provide valuable insights into the transformative potential of digital health in modern pharmacy practice. The exploration of these themes highlights not only the opportunities presented by digital health but also the challenges associated with its implementation, such as data privacy, system integration, and training for healthcare professionals (Segun-Falade et al., 2024; Leghemo et al., 2025a; Awoyemi et al., 2024).

2. History of the Role of Digital Health in Modern Pharmacy

The history of the role of digital health in modern pharmacy spans several decades and reflects the evolution of technology in the healthcare sector. From the early adoption of electronic health records to the integration of advanced digital tools, the journey highlights the transformative impact of digital health on pharmacy practice. Let's delve into the key milestones and developments that have shaped this history (Cancela, et. al., 2021, D Aungst, Franzese & Kim, 2021, Trenfield, et. al., 2022).

The foundation of digital health in pharmacy can be traced back to the 1960s and 1970s with the emergence of electronic health records (EHRs). Initially, EHRs were rudimentary electronic databases used to store patient information, including medical history, medications, and allergies. The adoption of EHRs in pharmacy practice facilitated more efficient documentation, improved communication among healthcare providers, and enhanced patient safety. In the 1980s and 1990s, pharmacy management systems (PMS) began to emerge, offering pharmacies a comprehensive platform to manage various aspects of their operations (Aarts, 2023, Melton, et. al., 2021, Narayanan & Bakshi, 2021). PMS allowed pharmacists to streamline inventory management, automate prescription processing, and generate electronic prescriptions. These systems contributed to improved workflow efficiency, reduced medication errors, and enhanced patient experience.

Telepharmacy services, which enable remote consultations and medication dispensing, gained prominence in the late 20th century. Initially developed to address the healthcare needs of underserved rural areas, telepharmacy expanded access to pharmacy services beyond traditional brick-and-mortar settings. Through telepharmacy, pharmacists could

remotely review prescriptions, counsel patients, and monitor medication adherence, thereby improving access to care and medication management. The advent of the internet in the late 20th century paved the way for the rise of online pharmacies and e-prescribing platforms. Online pharmacies allowed patients to order medications remotely and have them delivered to their doorstep, offering convenience and accessibility. E-prescribing platforms facilitated electronic transmission of prescriptions between healthcare providers and pharmacies, reducing errors associated with handwritten prescriptions and enhancing medication safety (dos Santos, et. al., 2023, Jindasook, 2021, Kavanagh, et. al., 2022).

In recent years, the integration of advanced digital tools such as artificial intelligence (AI) and data analytics has transformed pharmacy practice. AI-powered algorithms can analyze vast amounts of healthcare data to optimize medication therapy, identify potential drug interactions, and personalize treatment plans. Data analytics tools enable pharmacists to derive insights from large datasets, identify trends in medication usage, and improve population health outcomes. The COVID-19 pandemic accelerated the adoption of telemedicine and remote patient monitoring technologies in pharmacy practice. Pharmacies began offering telehealth services, allowing patients to consult with pharmacists remotely for medication management, chronic disease management, and preventive care. Remote patient monitoring devices, such as wearable sensors and mobile health apps, enable pharmacists to remotely monitor patients' vital signs, medication adherence, and health outcomes (Khan, et. al., 2023, Mehta, Pandit & Shukla, 2019, Adelekan et al., 2024; Trenfield, et. al., 2022).

In conclusion, the history of the role of digital health in modern pharmacy reflects a continuous evolution driven by technological advancements and the evolving needs of patients and healthcare providers. As digital health continues to evolve, pharmacies will play an increasingly critical role in leveraging these technologies to improve patient care, enhance medication management, and promote better health outcomes.

3. Overview of Digital Health in Pharmacy

Digital health encompasses the use of digital technologies, such as mobile apps, wearables, telemedicine, and electronic health records, to improve healthcare delivery and outcomes. In pharmacy, digital health has transformed the way pharmacists deliver care and interact with patients. This overview explores the definition and scope of digital health, the evolution of digital health in pharmacy, and its impact on pharmacy practice (Al-Shorbaji & Al-Shorbaji, 2021, Segun et al., 2021; Dinh-Le, et. al., 2019, Senbekov, et. al., 2020, Balogun et al., 2020; Siddika et al., 2020; Ahmed & Ibisumbo, 2014).

Digital health refers to the use of digital technologies and data to improve health and healthcare delivery. It includes a wide range of technologies and applications, such as mobile health apps, wearable devices, telemedicine platforms, electronic health records (EHRs), and health information exchanges (HIEs). Digital health aims to improve access to healthcare, enhance the quality of care, and empower patients to take control of their health. The evolution of digital health in pharmacy can be traced back to the early days of electronic prescribing systems in the 1970s. These systems allowed healthcare providers to electronically send prescriptions to pharmacies, reducing errors and improving efficiency. Over the years, digital health in pharmacy has evolved to include a wide range of technologies and applications, such as medication management apps, medication adherence tools, and telepharmacy services (Awad, et. al., 2021, Jayaraman, et. al., 2020, Senbekov, et. al., 2020, Siddika et al., 2016; Balogun et al., 2019; Siddika et al., 2019).

Digital health has had a significant impact on pharmacy practice, transforming the way pharmacists deliver care and interact with patients. Digital health tools, such as medication management apps, help patients track their medications, set reminders, and monitor their adherence. This has led to improved medication adherence and better health outcomes. Digital health technologies, such as telepharmacy and telemedicine, have improved communication between pharmacists, healthcare providers, and patients. Pharmacists can now provide remote consultations, monitor patients' health remotely, and collaborate with other healthcare providers more effectively (D Aungst, Franzese & Kim, 2021, Silva, et. al., 2022, Ajala, 2024, Spiro, 2019, Siddika et al., 2020; Ahmed & Ibisumbo, 2014). Digital health has increased access to pharmacy services, especially in rural and underserved areas. Telepharmacy services allow pharmacists to provide care to patients in remote locations, improving access to medications and healthcare advice. Digital health tools empower patients to take control of their health. Patients can access their health information online, communicate with their pharmacists and healthcare providers, and participate more actively in their care.

Overall, digital health has revolutionized pharmacy practice, improving medication management, enhancing communication, increasing access to care, and empowering patients to take control of their health. As technology continues to advance, the impact of digital health on pharmacy practice is expected to grow, further improving patient outcomes and the quality of care.

4. Impacts of Digital Health on Patient Care

Digital health technologies have significantly improved the accessibility of pharmacy services, particularly for individuals facing geographical or mobility barriers. Telepharmacy services and virtual consultations enable patients to access pharmacist expertise remotely, eliminating the need for physical visits to brick-and-mortar pharmacies. This enhanced accessibility ensures that patients in rural or underserved areas can receive timely medication counseling, prescription refills, and clinical support without the constraints of distance (Al-Shorbaji & Al-Shorbaji, 2021, Borges do Nascimento, et. al., 2023, Thompson, 2021). Moreover, mobile health applications provide on-the-go access to medication information, refill requests, and health resources, further enhancing convenience and accessibility for patients.

Digital health solutions have revolutionized medication management and adherence, leading to improved health outcomes for patients. Mobile health applications offer features such as medication reminders, dosage tracking, and refill notifications, empowering patients to adhere to their prescribed treatment regimens. These tools provide real-time feedback and support, helping patients stay organized and compliant with their medication schedules. Additionally, AI-driven algorithms can analyze patient data to identify adherence patterns, predict medication refill needs, and provide personalized adherence interventions. By promoting medication adherence, digital health technologies reduce the risk of medication errors, hospitalizations, and adverse health outcomes, ultimately improving patient safety and well-being (Awad, et. al., 2021, Dang, Arora & Rane, 2020, Santo & Redfern, 2020).

The integration of artificial intelligence (AI) into digital health has ushered in a new era of personalized patient care. AI-driven algorithms can analyze vast amounts of patient data, including medical records, genetic information, and lifestyle factors, to generate tailored treatment recommendations and care plans. Pharmacists can leverage AI-powered decision support systems to optimize medication therapy, identify drug interactions, and anticipate adverse reactions based on individual patient profiles. Moreover, AI algorithms can predict disease progression, stratify patient risk levels, and facilitate early intervention strategies, leading to more effective disease management and improved patient outcomes (Aggarwal, et. al., 2020, Fuchs, et. al., 2023, Li, et. al., 2021). By harnessing the power of AI, pharmacists can deliver precision medicine and personalized care that addresses the unique needs and preferences of each patient.

Digital health technologies have empowered patients to take a more active role in their healthcare journey, fostering greater engagement and autonomy in managing their health. Patient-facing applications provide educational resources, self-management tools, and interactive features that encourage proactive health behaviors and self-care practices. Through remote monitoring devices and wearable technology, patients can track vital signs, monitor chronic conditions, and share real-time health data with healthcare providers. This increased connectivity and engagement enable patients to make informed decisions about their health, participate in shared decision-making with healthcare providers, and actively collaborate in their treatment plans (Benis, et. al., 2021, Burr & Morley, 2020, Rich, Miah & Lewis, 2019). By empowering patients to play a more active role in their care, digital health technologies promote patient autonomy, improve health literacy, and enhance overall health outcomes.

5. Challenges and Considerations

One of the foremost challenges in the adoption of digital health technologies in pharmacy is the issue of data privacy and security. The sensitive nature of patient health information makes it imperative to safeguard against unauthorized access, breaches, and data misuse. Pharmacy systems that store electronic health records (EHRs), medication histories, and personal health information are prime targets for cyberattacks and data breaches. Ensuring robust encryption protocols, firewalls, and access controls is essential to protect patient data from security threats. Moreover, compliance with stringent data protection regulations such as the Health Insurance Portability and Accountability Act (HIPAA) is paramount to maintain patient trust and confidentiality (Senbekov, et. al., 2020, Siyal, et. al., 2019, Srivastava & Raina, 2021).

The rapid evolution of digital health technologies poses challenges for regulatory frameworks and compliance requirements in pharmacy practice. Regulatory bodies struggle to keep pace with the innovation and proliferation of digital health solutions, leading to ambiguity and inconsistency in regulations governing their use. Pharmacy professionals must navigate complex regulatory landscapes and adhere to varying standards across jurisdictions when implementing digital health initiatives. Compliance with regulations such as the Food and Drug Administration (FDA) regulations for medical devices and the European Union's General Data Protection Regulation (GDPR) adds an additional layer of complexity to the adoption of digital health technologies in pharmacy practice (Iqbal & Biller-Andorno, 2022, Kluwe, et. al., 2021, Miller, et. al., 2021).

Another significant challenge in leveraging digital health technologies in pharmacy is the presence of digital literacy disparities among patients. Not all patients possess the necessary skills, knowledge, or access to effectively utilize digital health tools and resources. Elderly individuals, socioeconomically disadvantaged populations, and those with limited technological proficiency may struggle to navigate digital platforms, understand health information, or engage with telehealth services. Addressing these disparities requires targeted interventions such as patient education programs, user-friendly interfaces, and multilingual support to ensure equitable access and usability of digital health solutions across diverse patient populations (Al-Shorbaji & Al-Shorbaji, 2021, Grande, et. al., 2020, O'Brien, et. al., 2023).

The adoption of digital health technologies in pharmacy practice raises ethical considerations surrounding patient autonomy, consent, and data ownership. Pharmacist-patient interactions mediated through telepharmacy services or digital communication channels may compromise the quality of care, patient confidentiality, and therapeutic relationships. Additionally, concerns about algorithmic bias, data transparency, and informed consent arise with the integration of artificial intelligence (AI) and predictive analytics in pharmacy practice (Chiruvella & Guddati, 2021, Moerenhout, 2019, Solomon & Rudin, 2020). Ensuring transparency, accountability, and adherence to ethical principles such as beneficence, non-maleficence, and respect for patient autonomy is essential to mitigate potential ethical risks associated with the use of digital health technologies in pharmacy.

6. Case Studies and Examples

Telepharmacy services have emerged as a viable solution to address healthcare access disparities, particularly in rural and underserved areas. A notable case study is that of North Dakota, where remote and rural communities face challenges in accessing pharmacy services. The North Dakota Telepharmacy Project, initiated in 2002, implemented telepharmacy systems to connect remote pharmacies with centralized pharmacists through audio-visual technology. The project significantly improved medication access, patient counseling, and prescription filling efficiency in underserved areas, leading to enhanced patient outcomes and satisfaction (Livet, et. al., 2021, Nwachuya, et. al., 2023). Moreover, telepharmacy has been successfully implemented by retail pharmacy chains like Walgreens and CVS Health, enabling pharmacists to remotely verify prescriptions, provide medication counseling, and facilitate medication adherence for patients across multiple locations.

Mobile health applications have revolutionized medication management and adherence by empowering patients to take control of their health. Medisafe, a leading medication management app, employs personalized medication reminders, refill alerts, and adherence tracking features to support patients in adhering to their medication regimens. A study conducted by Brigham and Women's Hospital demonstrated that patients using the Medisafe app exhibited significantly higher medication adherence rates compared to those using traditional methods. Similarly, MyTherapy, another mobile health app, integrates medication reminders with health tracking tools, symptom monitoring, and health education resources, fostering improved medication adherence and health outcomes among users. These case studies underscore the effectiveness of mobile health applications in promoting medication adherence and self-management among patients, ultimately enhancing health outcomes and reducing healthcare costs (Abasi, et. al., 2021, Ghose, et. al., 2021, Sleurs, et. al., 2019).

Artificial intelligence (AI) holds immense potential to revolutionize pharmacy practice by augmenting decision-making processes, optimizing workflows, and improving patient outcomes. IBM Watson for Oncology is a notable example of AI-driven intervention in pharmacy practice, utilizing natural language processing and machine learning algorithms to analyze patient data, medical literature, and treatment guidelines to provide personalized treatment recommendations for cancer patients. The AI-powered platform assists oncologists in identifying optimal treatment plans based on patient-specific factors, clinical evidence, and expert consensus, leading to more informed clinical decisions and improved treatment outcomes. Similarly, NetraG, an AI-powered platform developed by Netra.AI, employs deep learning algorithms to analyze retinal images and detect diabetic retinopathy, a common complication of diabetes (Alowais, et. al., 2023, Chalasani, et. al., 2023, Khan, et. al., 2023). The platform enables early diagnosis and intervention, facilitating timely treatment and preventing vision loss in diabetic patients. These case studies demonstrate the transformative potential of AI-driven interventions in enhancing pharmacy practice and patient care.

Virtual reality (VR) has emerged as a powerful tool for patient education and engagement, providing immersive and interactive learning experiences to enhance health literacy and treatment adherence. AppliedVR, a VR platform, offers therapeutic programs for pain management, stress reduction, and symptom management in various healthcare settings, including pharmacy. The platform utilizes immersive VR environments, interactive exercises, and biofeedback mechanisms to educate patients about their conditions, medications, and treatment options, fostering greater understanding, empowerment, and engagement in their care. Additionally, VR simulations have been utilized to train pharmacy students and professionals in medication counseling, patient communication, and clinical decision-making,

enhancing their skills and confidence in delivering patient-centered care. These case studies illustrate the potential of VR applications in pharmacy practice to improve patient education, medication adherence, and healthcare outcomes (Adapa, et. al. 2020, Gulick, et.al., 2021, Van der Kruk, et. al., 2022).

7. Future Directions and Opportunities

Continued advancements in AI technologies hold immense potential to further revolutionize digital health in pharmacy. AI algorithms will become increasingly sophisticated, enabling more accurate predictive analytics, personalized treatment recommendations, and automated decision support systems. Additionally, AI-driven virtual assistants and chatbots will play a more prominent role in patient education, medication management, and adherence support, enhancing patient engagement and outcomes. The integration of IoT devices, such as smart medication dispensers, wearable sensors, and connected medical devices, will facilitate real-time monitoring of patient health parameters and medication adherence. IoT-enabled medication packaging will enable automatic tracking of medication usage, dosage adherence, and expiration dates, providing valuable insights for both patients and healthcare providers (Stasevych & Zvarych, 2023, Trenfield, et. al., 2022).

Blockchain technology has the potential to enhance data security, interoperability, and transparency in healthcare transactions. Blockchain-enabled platforms will enable secure sharing of patient health records, medication histories, and treatment outcomes among various healthcare stakeholders, promoting seamless care coordination and patient-centric healthcare delivery. The future of digital health in pharmacy lies in fostering collaborative relationships among pharmacists, physicians, nurses, and other healthcare professionals. Interprofessional care teams will leverage digital health technologies to facilitate seamless communication, care coordination, and shared decision-making, leading to improved patient outcomes and satisfaction (Mehta, Grant & Ackery, 2020, Yaqoob, et. al., 2021).

Community pharmacies will play an increasingly vital role in delivering digital health services and expanding access to care. Collaborative practice agreements between pharmacists and other healthcare providers will enable pharmacists to provide a broader range of clinical services, including chronic disease management, medication therapy management, and preventive care, leveraging digital health technologies to enhance patient engagement and health outcomes. Collaboration between academic institutions and industry partners will drive innovation in digital health research, technology development, and implementation. Academic researchers will collaborate with industry stakeholders to design and evaluate digital health interventions, conduct clinical trials, and translate research findings into practice. These partnerships will accelerate the adoption of digital health solutions in pharmacy and pave the way for future advancements (Airaksinen, et. al., 2021, Westerlund & Marklund, 2020).

Regulatory agencies should develop clear guidelines and standards for the safe and effective use of digital health technologies in pharmacy practice. Regulatory frameworks should address issues related to data privacy, security, interoperability, and reimbursement to ensure patient safety and quality of care. Payers should revise reimbursement policies to incentivize the adoption of digital health services in pharmacy practice. Reimbursement models should recognize the value of digital health interventions in improving patient outcomes, reducing healthcare costs, and enhancing quality of care, ensuring sustainable financing and reimbursement for digital health initiatives (Cortez, 2019, Mathews, et. al., 2019, Rassi-Cruz, Valente & Caniza, 2022).

Pharmacy schools and professional organizations should incorporate digital health education and training into pharmacy curricula and continuing education programs. Pharmacists should be equipped with the knowledge, skills, and competencies to effectively leverage digital health technologies in their practice, providing patient-centered care in an increasingly digital healthcare landscape (Mantel-Teeuwisse, et. al., 2021, Olsen, et. al., 2020). Government agencies and public health organizations should launch public awareness campaigns to promote the benefits of digital health and empower patients to engage in their healthcare using digital tools. Public health initiatives should address digital literacy disparities, promote health equity, and ensure equitable access to digital health services for all patients, regardless of socioeconomic status or geographic location.

In conclusion, the future of digital health in pharmacy holds tremendous promise for advancing patient care, improving health outcomes, and promoting population health. By embracing technological innovations, fostering collaboration, and implementing supportive policies, stakeholders can harness the full potential of digital health to transform pharmacy practice and promote the delivery of high-quality, patient-centered care in the digital age.

8. Conclusion

Digital health has emerged as a transformative force in modern pharmacy, revolutionizing the way healthcare is delivered, managed, and accessed. Through innovative technologies and solutions, digital health has empowered pharmacists to enhance patient care, improve medication management, and promote better health outcomes. Throughout this review, we have explored various emerging trends in digital health for pharmacy, including telepharmacy services, mobile health applications, AI integration, and virtual reality applications. These trends have had significant impacts on patient care, such as improved accessibility to pharmacy services, enhanced medication management and adherence, personalized patient care, and increased patient engagement and empowerment.

As digital health continues to evolve and expand, there is a pressing need for pharmacists and healthcare stakeholders to embrace its potential fully. By leveraging digital health technologies, pharmacists can further optimize patient care, streamline workflows, and drive positive health outcomes. Therefore, it is essential for pharmacists to stay informed about emerging trends, invest in training and education, and actively integrate digital health into their practice.

In conclusion, the role of digital health in modern pharmacy cannot be overstated. It has the power to revolutionize pharmacy practice, empower patients, and transform healthcare delivery. By recognizing the importance of digital health, embracing emerging trends, and adopting innovative solutions, pharmacists can continue to lead the way in promoting patient-centered care and advancing the future of pharmacy practice.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Aarts, J. (2023). Histories of the electronic medical record in The Netherlands 1970-2015 (Master's thesis).

[2] Abasi, S., Yazdani, A., Kiani, S., & Mahmoudzadeh-Sagheb, Z. (2021). Effectiveness of mobile health-based self-management application for posttransplant cares: A systematic review. Health Science Reports, 4(4), e434.

[3] Abernethy, A., Adams, L., Barrett, M., Bechtel, C., Brennan, P., Butte, A., ... & Valdes, K. (2022). The promise of digital health: Then, now, and the future. NAM perspectives, 2022.

[4] Adapa, K., Jain, S., Kanwar, R., Zaman, T., Taneja, T., Walker, J., & Mazur, L. (2020). Protocol: Augmented reality in patient education and health literacy: a scoping review protocol. BMJ open, 10(9).

[5] Adelekan, O.A., Adisa, O., Ilugbusi, B.S., Obi, O.C., Awonuga, K.F., Asuzu, O.F. and Ndubuisi, N.L., 2024. Evolving Tax Compliance In The Digital Era: A Comparative Analysis Of Ai-Driven Models And Blockchain Technology In Us Tax Administration. *Computer Science & IT Research Journal*, *5*(2), pp.311-335.

[6] Aggarwal, N., Ahmed, M., Basu, S., Curtin, J. J., Evans, B. J., Matheny, M. E., ... & Thadaney-Israni, S. (2020). Advancing artificial intelligence in health settings outside the hospital and clinic. NAM perspectives, 2020.

[7] Airaksinen, M., Toivo, T., Jokinen, L., Savela, E., Parkkamäki, S., Sandler, C., ... & Dimitrow, M. (2021). Policy and vision for community pharmacies in Finland: A roadmap towards enhanced integration and reduced costs. Pharmacy Practice (Granada), 19(1).

[8] Ajala, O.A., 2024. Leveraging AI/ML for anomaly detection, threat prediction, and automated response.

[9] Akindejoye, J.A. and Ilugbusi, S.B., 2019. Compliance of Selected Firms Listed on Nigeria Stock Exchange with Requirements of International Accounting Standard 16. *Nigerian Studies in Economics and Management Sciences*, *2*(2), pp.1-10.

[10] Alowais, S. A., Alghamdi, S. S., Alsuhebany, N., Alqahtani, T., Alshaya, A. I., Almohareb, S. N., ... & Albekairy, A. M. (2023). Revolutionizing healthcare: the role of artificial intelligence in clinical practice. BMC medical education, 23(1), 689.

[11] Al-Shorbaji, N., & Al-Shorbaji, N. (2021). Improving healthcare access through digital health: The use of information and communication technologies. Healthcare Access, 10.

[12] Ahmed, H.A. & Ibisumbo, O. (2014). Factors Affecting Breastfeeding Practices in Odeda Local Government Area of Ogun State, Nigeria. International Journal of Engineering Science and Innovative Technology (IJESIT), 3(1), January 2014.

[13] Awad, A., Trenfield, S. J., Pollard, T. D., Ong, J. J., Elbadawi, M., McCoubrey, L. E., ... & Basit, A. W. (2021). Connected healthcare: Improving patient care using digital health technologies. Advanced Drug Delivery Reviews, 178, 113958.

[14] Awoyemi, O., Attah, R.U., Basiru, J.O., and Leghemo, I.M., 2024. Advanced brand management strategies for solving market penetration and competitiveness challenges in media enterprises. IRE Journals, 7(7), pp.560-561.

[15] Awoyemi, O., Attah, R.U., Basiru, J.O., and Leghemo, I.M., 2025. Data-driven marketing innovation: Solving revenue stagnation and efficiency problems in media and broadcasting sectors. IRE Journals, 8(7), pp.650-651.

[16] Awoyemi, O., Attah, R.U., Basiru, J.O., and Leghemo, I.M., 2023. A technology integration blueprint for overcoming digital literacy barriers in developing world educational systems. IRE Journals, 7(3), pp.722-723.

[17] Awoyemi, O., Attah, R.U., Basiru, J.O., and Leghemo, I.M., 2025. A community-policing innovation model to build sustainable trust and effectively reduce crime in urban areas. International Journal of Multidisciplinary Research and Growth Evaluation, 6(1), pp.848-853.

[18] Balogun, H., Rantala, A., Antikainen, H., Siddika, N., Amegah, A.K., Ryti, N., Kukkonen, J., Sofiev, M., Jaakkola, M. & Jaakkola, J. (2020). Effects of Air Pollution on the Risk of Low Birth Weight in a Cold Climate. Applied Sciences, 10, p.6399. DOI: 10.3390/app10186399.

[19] Balogun, H., Jaakkola, J. & Amegah, A.K. (2019). Association of Sunlight Exposure and Consumption of Vitamin D-Rich Foods During Pregnancy with Adverse Birth Outcomes in an African Population. Journal of Tropical Pediatrics, 65. DOI: 10.1093/tropej/fmz001.

[20] Benis, A., Tamburis, O., Chronaki, C., & Moen, A. (2021). One digital health: a unified framework for future health ecosystems. Journal of Medical Internet Research, 23(2), e22189.

[21] Borges do Nascimento, I. J., Abdulazeem, H., Vasanthan, L. T., Martinez, E. Z., Zucoloto, M. L., Østengaard, L., ... & Novillo-Ortiz, D. (2023). Barriers and facilitators to utilizing digital health technologies by healthcare professionals. NPJ digital medicine, 6(1), 161.

[22] Burr, C., & Morley, J. (2020). Empowerment or engagement? Digital health technologies for mental healthcare. The 2019 yearbook of the digital ethics lab, 67-88.

[23] Cancela, J., Charlafti, I., Colloud, S., & Wu, C. (2021). Digital health in the era of personalized healthcare: opportunities and challenges for bringing research and patient care to a new level. Digital health, 7-31.

[24] Chalasani, S. H., Syed, J., Ramesh, M., Patil, V., & Kumar, T. P. (2023). Artificial intelligence in the field of pharmacy practice: A literature review. Exploratory Research in Clinical and Social Pharmacy, 12, 100346.

[25] Chiruvella, V., & Guddati, A. K. (2021). Ethical issues in patient data ownership. Interactive Journal of Medical Research, 10(2), e22269.

[26] Chopra, H., Shin, D. K., Munjal, K., Dhama, K., & Emran, T. B. (2023). Revolutionizing clinical trials: the role of AI in accelerating medical breakthroughs. International Journal of Surgery, 109(12), 4211-4220.

[27] Cortez, N. (2019). Digital health and regulatory experimentation at the FDA. Yale JL & Tech., 21, 4.

[28] Coyne, L., Merritt, T. A., Parmentier, B. L., Sharpton, R. A., & Takemoto, J. K. (2019). The past, present, and future of virtual reality in pharmacy education. American journal of pharmaceutical education, 83(3), 7456.

[29] D Aungst, T., Franzese, C., & Kim, Y. (2021). Digital health implications for clinical pharmacists services: a primer on the current landscape and future concerns. Journal of the American College of Clinical Pharmacy, 4(4), 514-524.

[30] Dang, A., Arora, D., & Rane, P. (2020). Role of digital therapeutics and the changing future of healthcare. Journal of Family Medicine and Primary Care, 9(5), 2207.

[31] Dinh-Le, C., Chuang, R., Chokshi, S., & Mann, D. (2019). Wearable health technology and electronic health record integration: scoping review and future directions. JMIR mHealth and uHealth, 7(9), e12861.

[32] dos Santos, M. A., Herbert, J., Cinelli, I., Burmann, J. A. L., Soares, V. V., & Russomano, T. (2023). Development of a Digital Platform: A Perspective To Advance Space Telepharmacy. IEEE Open Journal of Engineering in Medicine and Biology.

[33] Fuchs, B., Studer, G., Bode-Lesniewska, B., Heesen, P., & Swiss Sarcoma Network. (2023). The Next Frontier in Sarcoma Care: Digital Health, AI, and the Quest for Precision Medicine. Journal of Personalized Medicine, 13(11), 1530.

[34] Ganesh, G. S., Kolusu, A. S., Prasad, K., Samudrala, P. K., & Nemmani, K. V. (2022). Advancing health care via artificial intelligence: From concept to clinic. European Journal of Pharmacology, 934, 175320.

[35] Ghose, A., Guo, X., Li, B., & Dang, Y. (2021). Empowering patients using smart mobile health platforms: Evidence from a randomized field experiment. arXiv preprint arXiv:2102.05506.

[36] Grande, D., Marti, X. L., Feuerstein-Simon, R., Merchant, R. M., Asch, D. A., Lewson, A., & Cannuscio, C. C. (2020). Health policy and privacy challenges associated with digital technology. JAMA network open, 3(7), e208285-e208285.

[37] Gulick, V., Graves, D., Ames, S., & Krishnamani, P. P. (2021). Effect of a virtual Reality–Enhanced exercise and education intervention on patient engagement and learning in cardiac rehabilitation: randomized controlled trial. Journal of Medical Internet Research, 23(4), e23882.

[38] Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., ... & Thépaut, J. N. (2020). The ERA5 global reanalysis. Quarterly Journal of the Royal Meteorological Society, 146(730), 1999-2049.

[39] Holmes, E. A., O'Connor, R. C., Perry, V. H., Tracey, I., Wessely, S., Arseneault, L., ... & Bullmore, E. (2020). Multidisciplinary research priorities for the COVID-19 pandemic: a call for action for mental health science. The Lancet Psychiatry, 7(6), 547-560.

[40] Iqbal, J. D., & Biller-Andorno, N. (2022). The regulatory gap in digital health and alternative pathways to bridge it. Health Policy and Technology, 11(3), 100663.

[41] Jayaraman, P. P., Forkan, A. R. M., Morshed, A., Haghighi, P. D., & Kang, Y. B. (2020). Healthcare 4.0: A review of frontiers in digital health. Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery, 10(2), e1350.

[42] Jindasook, C. (2021). Exploring drivers and barriers towards utilizing telepharmacy among pharmacists in Bangkok.

[43] Kavanagh, O. N., Courtenay, A., Khan, F., & Lowry, D. (2022). Providing pharmaceutical care remotely through medicines delivery services in community pharmacy. Exploratory Research in Clinical and Social Pharmacy, 8, 100187.

[44] Khan, O., Parvez, M., Kumari, P., Parvez, S., & Ahmad, S. (2023). The future of pharmacy: How AI is revolutionizing the industry. Intelligent Pharmacy, 1(1), 32-40.

[45] Kluwe, F., Michelet, R., Mueller-Schoell, A., Maier, C., Klopp-Schulze, L., van Dyk, M., ... & Kloft, C. (2021). Perspectives on model-informed precision dosing in the digital health era: challenges, opportunities, and recommendations. Clinical Pharmacology & Therapeutics, 109(1), 29-36.

[46] Krendyukov, A., & Nasy, D. (2020). Evolving communication with healthcare professionals in the pharmaceutical space: current trends and future perspectives. Pharmaceutical Medicine, 34(4), 247-256.

[47] Li, J. P. O., Liu, H., Ting, D. S., Jeon, S., Chan, R. P., Kim, J. E., ... & Ting, D. S. (2021). Digital technology, tele-medicine and artificial intelligence in ophthalmology: A global perspective. Progress in retinal and eye research, 82, 100900.

[48] Livet, M., Levitt, J., Cardenas, A., Thomas, J., Lee, A., Pathak, S., & Curran, G. (2021). Feasibility of a CMM telepharmacy service for patients with diabetes in rural and underserved communities: preliminary results. Journal of the American College of Clinical Pharmacy, 4(8), 947-958.

[49] Leghemo, I.M., Segun-Falade, O.D., Odionu, C.S., and Azubuike, C., 2025. A collaborative model for data governance: Enhancing integration across multi-line businesses. Gulf Journal of Advance Business Research, 3(1), pp.47-63.

[50] Leghemo, I.M., Azubuike, C., Segun-Falade, O.D., and Odionu, C.S., 2025. Data governance for emerging technologies: A conceptual framework for managing blockchain, IoT, and AI. Journal of Engineering Research and Reports, 27(1), pp.247-267.

[51] Leghemo, I.M., Odionu, C.S., Segun-Falade, O.D., and Azubuike, C., 2024. Conceptual framework for AI-driven personalization: Implications for consumer behavior and brand loyalty. World Journal of Advanced Research and Reviews, 21(02), pp.2045-2062.

[52] Leghemo, I.M., Odionu, C.S., Segun-Falade, O.D., and Azubuike, C., 2024. A model for integrating data governance and information management systems: Enhancing decision-making across industries. World Journal of Advanced Research and Reviews, 21(03), pp.2635-2654.

[53] Mantel-Teeuwisse, A. K., Meilianti, S., Khatri, B., Yi, W., Azzopardi, L. M., Acosta Gómez, J., ... & Uzman, N. (2021). Digital health in pharmacy education: Preparedness and responsiveness of pharmacy programmes. Education Sciences, 11(6), 296.

[54] Mathews, S. C., McShea, M. J., Hanley, C. L., Ravitz, A., Labrique, A. B., & Cohen, A. B. (2019). Digital health: a path to validation. NPJ digital medicine, 2(1), 38.

[55] Mbunge, E., Batani, J., Gaobotse, G., & Muchemwa, B. (2022). Virtual healthcare services and digital health technologies deployed during coronavirus disease 2019 (COVID-19) pandemic in South Africa: a systematic review. Global health journal, 6(2), 102-113.

[56] Mehta, N., Pandit, A., & Shukla, S. (2019). Transforming healthcare with big data analytics and artificial intelligence: A systematic mapping study. Journal of biomedical informatics, 100, 103311.

[57] Mehta, S., Grant, K., & Ackery, A. (2020). Future of blockchain in healthcare: potential to improve the accessibility, security and interoperability of electronic health records. BMJ Health & Care Informatics, 27(3).

[58] Melton, G. B., McDonald, C. J., Tang, P. C., & Hripcsak, G. (2021). Electronic health records. In Biomedical Informatics: Computer Applications in Health Care and Biomedicine (pp. 467-509). Cham: Springer International Publishing.

[59] Miller, R., Wafula, F., Onoka, C. A., Saligram, P., Musiega, A., Ogira, D., ... & Goodman, C. (2021). When technology precedes regulation: the challenges and opportunities of e-pharmacy in low-income and middle-income countries. BMJ global health, 6(5).

[60] Moerenhout, T. (2019). Treating the real or the digital patient?: impact of e-health applications on patient autonomy and the patient-doctor relationship: an ethical assessment (Doctoral dissertation, Ghent University).

[61] Narayanan, K. R. I. S. H. N. A. N., & Bakshi, A. (2021). History and future of digital health.

[62] Niazi, S. K. (2023). The coming of age of ai/ml in drug discovery, development, clinical testing, and manufacturing: The FDA perspectives. Drug Design, Development and Therapy, 2691-2725.

[63] Nwachuya, C. A., Umeh, A. U., Ogwurumba, J. C., Chinedu-Eze, I. N., Azubuike, C. C., & Isah, A. (2023). Effectiveness of Telepharmacy in Rural Communities in Africa: A Scoping Review. Journal of Pharmacy Technology, 39(5), 241-246.

[64] O'Brien, N., Li, E., Chaibva, C. N., Bravo, R. G., Kovacevic, L., Ayisi-Boateng, N. K., ... & Neves, A. L. (2023). Strengths, weaknesses, opportunities, and threats analysis of the use of digital health technologies in primary health care in the Sub-Saharan African Region: qualitative study. Journal of Medical Internet Research, 25(1), e45224.

[65] Olsen, A. A., Minshew, L. M., Morbitzer, K. A., Brock, T. P., & McLaughlin, J. E. (2020). Emerging innovations and professional skills needed within pharmacy curricula. Journal of medical education and curricular development, 7, 2382120520943597.

[66] Rassi-Cruz, M., Valente, F., & Caniza, M. V. (2022). Digital therapeutics and the need for regulation: how to develop products that are innovative, patient-centric and safe. Diabetology & Metabolic Syndrome, 14(1), 48.

[67] Rich, E., Miah, A., & Lewis, S. (2019). Is digital health care more equitable? The framing of health inequalities within England's digital health policy 2010–2017. Sociology of Health & Illness, 41, 31-49.

[68] Santo, K., & Redfern, J. (2020). Digital health innovations to improve cardiovascular disease care. Current Atherosclerosis Reports, 22, 1-10.

[69] Segun, I.B., Olusegun, I.F., Akindutire, Y.T. and Thomas, O.A., 2021. Capital Structure and Financial Performance: Evidence from Listed Firms in the Oil and Gas Sector in Nigeria.

[70] Segun-Falade, O.D., Leghemo, I.M., Odionu, C.S., and Azubuike, C., 2024. A conceptual framework for data governance in big data and cloud environments: Integrating security, compliance, and data quality. International Journal of Science and Research Archive, 12(02), pp.2984-3002.

[71] Senbekov, M., Saliev, T., Bukeyeva, Z., Almabayeva, A., Zhanaliyeva, M., Aitenova, N., ... & Fakhradiyev, I. (2020). The recent progress and applications of digital technologies in healthcare: a review. International journal of telemedicine and applications, 2020.

[72] Siddika, N., Rantala, A., Antikainen, H., Balogun, H., Amegah, A.K., Ryti, N., Kukkonen, J., Sofiev, M., Jaakkola, M. & Jaakkola, J. (2020). Short-term prenatal exposure to ambient air pollution and risk of preterm birth - A population-based cohort study in Finland. Environmental Research, 184, p.109290. DOI: 10.1016/j.envres.2020.109290.

[73] Siddika, N., Rantala, A., Antikainen, H., Balogun, H., Amegah, A.K., Ryti, N., Kukkonen, J., Sofiev, M., Jaakkola, M. & Jaakkola, J. (2019). Synergistic effects of prenatal exposure to fine particulate matter (PM2.5) and ozone (O3) on the risk of preterm birth: A population-based cohort study. Environmental Research, 176, p.108549. DOI: 10.1016/j.envres.2019.108549.

[74] Siddika, N., Balogun, H., Amegah, A.K. & Jaakkola, J. (2016). Prenatal ambient air pollution exposure and the risk of stillbirth: Systematic review and meta-analysis of the empirical evidence. Occupational and Environmental Medicine, 73. DOI: 10.1136/oemed-2015-103086.

[75] Silva, R. D. O. S., de Araújo, D. C. S. A., dos Santos Menezes, P. W., Neves, E. R. Z., & de Lyra Jr, D. P. (2022). Digital pharmacists: The new wave in pharmacy practice and education. International Journal of Clinical Pharmacy, 44(3), 775-780.

[76] Siyal, A. A., Junejo, A. Z., Zawish, M., Ahmed, K., Khalil, A., & Soursou, G. (2019). Applications of blockchain technology in medicine and healthcare: Challenges and future perspectives. Cryptography, 3(1), 3.

[77] Sleurs, K., Seys, S. F., Bousquet, J., Fokkens, W. J., Gorris, S., Pugin, B., & Hellings, P. W. (2019). Mobile health tools for the management of chronic respiratory diseases. Allergy, 74(7), 1292-1306.

[78] Solomon, D. H., & Rudin, R. S. (2020). Digital health technologies: opportunities and challenges in rheumatology. Nature Reviews Rheumatology, 16(9), 525-535.

[79] Spiro, S. (2019). Digital transformation of pharmacists' clinical services. Journal of the American Pharmacists Association, 59(2), S8-S12.

[80] Srivastava, M., & Raina, M. (2021). Consumers' usage and adoption of e-pharmacy in India. International Journal of Pharmaceutical and Healthcare Marketing, 15(2), 235-250.

[81] Stasevych, M., & Zvarych, V. (2023). Innovative robotic technologies and artificial intelligence in pharmacy and medicine: paving the way for the future of health care—a review. Big Data and Cognitive Computing, 7(3), 147.

[82] Takemoto, J. K., Bratelli, R. A., Parmentier, B. L., Merritt, T. A., & Coyne, L. (2020). Extended Reality in Patient Care and Pharmacy Practice: A Viewpoint. Journal of Contemporary Pharmacy Practice, 66(4), 33-38.

[83] Thompson, M. (2021). The geographies of digital health–Digital therapeutic landscapes and mobilities. Health & Place, 70, 102610.

[84] Thornewill, J., Antimisiaris, D., Ezekekwu, E., & Esterhay, R. (2022). Transformational strategies for optimizing use of medications and related therapies through us pharmacists and pharmacies: Findings from a national study. Journal of the American Pharmacists Association, 62(2), 450-460.

[85] Trenfield, S. J., Awad, A., McCoubrey, L. E., Elbadawi, M., Goyanes, A., Gaisford, S., & Basit, A. W. (2022). Advancing pharmacy and healthcare with virtual digital technologies. Advanced Drug Delivery Reviews, 182, 114098.

[86] Umar, A. K., Limpikirati, P., Luckanagul, J. A., Zothantluanga, J. H., Shumkova, M. M., & Prosvirkin, G. (2024). Telepharmacy: a modern solution for expanding access to pharmacy services. In Artificial Intelligence, Big Data, Blockchain and 5G for the Digital Transformation of the Healthcare Industry (pp. 111-150). Academic Press.

[87] Van der Kruk, S. R., Zielinski, R., MacDougall, H., Hughes-Barton, D., & Gunn, K. M. (2022). Virtual reality as a patient education tool in healthcare: a scoping review. Patient Education and Counseling, 105(7), 1928-1942.

[88] Ventola, C. L. (2019). Virtual reality in pharmacy: Opportunities for clinical, research, and educational applications. Pharmacy and Therapeutics, 44(5), 267.

[89] Westerlund, T., & Marklund, B. (2020). Community pharmacy and primary health care in Sweden-at a crossroads. Pharmacy Practice (Granada), 18(2).

[90] Williamson, E. J., Walker, A. J., Bhaskaran, K., Bacon, S., Bates, C., Morton, C. E., ... & Goldacre, B. (2020). Factors associated with COVID-19-related death using OpenSAFELY. Nature, 584(7821), 430-436.

[91] Yaqoob, I., Salah, K., Jayaraman, R., & Al-Hammadi, Y. (2021). Blockchain for healthcare data management: opportunities, challenges, and future recommendations. Neural Computing and Applications, 1-16.