Yousef S A. Systematic Review: The opportunities and challenges for digital health in pharmacy practice. Pharmacy Practice 2026 Apr-Jun;24(2):3542.

https://doi.org/10.18549/PharmPract.2026.2.3542

Review Article

Systematic Review:The opportunities and challenges for digital health in pharmacy practice

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Received (first version): 30-Oct-2025 Accepted: 05-Mar-2026 Published online: 14-May-2026

Abstract

Background: Digital health technologies, including tele pharmacy, artificial intelligence (AI), mHealth, and electronic health records (EHRs), have all started to alter pharmacy practice by improving medication safety, adherence, workflow, and patient care. However, the unique impacts and challenges of these technologies in pharmacy practice necessitate more exploration. **Objectives:** The current systematic review explores the effectiveness of digital health interventions in pharmacy practice using evidence from recent studies. **Method:** A systematic review was performed on 50 studies published from 2019 to 2024, each assessing different digital health tools in pharmacy. Studies sourced from databases such as CINAHL, Cochrane Library, EMBASE, Google Scholar, PubMed, Scopus, and Web of Science. Primary outcomes included medication safety improvements, better clinical decision making, and operational factors like workflow efficiency and patient engagement. **Results:** Overall, the interventions yielded significant improvements in pharmacy practice activities among the surveyed 50 studies. Tele pharmacy service and AI - based decision support tools advanced medication, patient safety and care services over older technologies. On the contrary, key challenges identified included: issues of data privacy, regulations and standards, required infrastructure and IT support systems for tele pharmacy and AI - based technology systems, within underserved locations or lower - resourced pharmacy settings. **Conclusion:** The current systematic review concluded that while digital health technologies improve accessibility and medication management, addressing issues like regulatory limits and data security is critical for realizing their full potential. While digital health has shown promise, there is still a need for more research to demonstrate its effectiveness in pharmacy practice, especially regarding long-term patient outcomes.

Keywords: Digital health, pharmacy practice, artificial intelligence (AI), patient engagement, medication management

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INTRODUCTION

Digital health technology includes a variety of digital tools such as eHealth, mHealth, big data, and Artificial Intelligence (AI), all of which improve health care and contribute to the aim of universal health coverage[1]. AI transforms pharmacy by improving medication safety, reducing errors, and increasing operational efficiency. Vis incorporating Machine Learning (ML) algorithms to analyze clinical data, AI can predict drug interactions and support clinical decision-making[2-7]. These AI-driven systems also automate essential pharmacy tasks and facilitate real-time medication adherence monitoring[8,9,10,11]. AI platforms are efficient in resolving medication discrepancies, which are achieved through AI-tools improvement in prescription accuracy[5,12,13]. Additionally, the COVID-19 pandemic accelerated the implementation of tele pharmacy services, which ensured continuity of care and improved patient access to pharmaceutical services[14,15,16]. Traditional manual techniques are naturally more sensitive to adverse drug responses and prescription noncompliance due to the absence of real-time monitoring capabilities[7,17].

Therefore, the integration of preventative technologies is crucial in minimizing risk and enhancing the safety of patients. In summary, Digital health technology has led to dramatic improvements in how we dispense and consume pharmaceuticals, making them more widely available, safer and more efficient to use. The integration of artificial intelligence and other digital health tools should play a crucial role in advancing pharmacy practice, improving the health outcomes of patients and fostering a more effective healthcare system.

What is known? Previous study indicates that digital health solutions such as tele pharmacy, AI, electronic prescriptions (e-prescriptions), wearables, and big data analytics have significantly enhanced pharmacy practice. Tele pharmacy increases access and adherence, while AI improves pharmaceutical safety and decision-making. E-prescriptions reduce errors, while wearable gadgets improve adherence, particularly among chronic patients. Big data provides proactive care by identifying risks early on.

What is not known? Despite advancements, significant voids persist in the total implementation of digital health into pharmaceutical practice. Regulatory support for telehealth is required to boost acceptance and AI - driven advancements necessitate high quality control measures alongside the provision of specialized training for pharmacists to properly employ the technology. In terms of electronic prescriptions, universal international guidelines are lacking, as is the privacy protection for the collected information transmitted from wearable devices. Also, the establishment of standard data practices is an essential prerequisite to safely and

https://doi.org/10.18549/PharmPract.2026.2.3542

reliably carry out large - scale data technologies to inform patient care.

What current study will, add? With the aid of tele pharmacy, AI, e - prescription, wearables and big data, the reviewed literature examines the degree to which digital health technologies have progressed pharmacy practice through improved patient access, safety and engagement, however, the literature also identifies several substantial voids, such as lack of tele pharmacy regulation, data standards and assurance of quality with the use of AI, that need to be filled to use the full capacity of digital technologies. The review offers insight into the digital health efficiency and limitations that the current pharmacy possesses. This will offer a future roadmap of directions for current research and policies dedicated to improve pharmacy practice.

Rationale

The emergence and rapid evolution of digital health technologies has unquestionably paved the way for a significant improvement in pharmacy practice about patient care, accessibility and safety. However, the integration of these innovations into clinical settings proves to be a multifaceted challenge, with varying degrees of success across different types of practice. While multiple articles have documented the individual gains yielded by these technologies, there's a conspicuous scarcity of literature that delves into the compounded advantages of using these instruments synergistically or the specific hurdles that must be confronted for their optimal utilization. Therefore, this narrative review is indispensable for a thorough appreciation of how digital health has transformed pharmacy practice. This comprehensive undertaking will accomplish this objective by pointing out discrepancies within the regulatory bodies and their legislation, shortcomings in data consolidation and concerns about quality and assurance measures. Additionally, the findings derived from this review will serve as a valuable reference and recommendation for future investigations and policies in this area.

Objectives

The primary objective of this research effort was to organize, retrieve and evaluate critically the effects of digital health on the practice of pharmacy and related processes by utilizing the methods of a systematic review.

METHODS

Protocol and registration

A protocol for the current systematic review developed, however, the protocol not registered in Prospero database.

Eligibility criteria

Iincluded studies were peer - reviewed publications written in English between 2019 and 2024 that reported on the application of digital health in pharmacy practice. We included studies within the last 5 years to ensure the most recent evidence of innovation in pharmacy practice was captured. We excluded studies with no full text, non-peer-reviewed articles and those lacking the required data for analysis.

Information sources

The review's sources included a thorough search of the following databases: Cochrane Library, PubMed, Web of Science, Scopus, CINAHL, and Embase. The search process followed the requirements of PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for systematic Reviews [PRISMA-ScR] Checklist), ensuring a systematic and transparent approach to study identification, screening, and inclusion [Supporting Information Document 1].

Database search

The electronic search strategy included the following MeSH terms: digital health"; "telehealth"; "telemedicine"; OR "mHealth"; OR "tele pharmacy"; "mobile health"; "eHealth"; "health technology"; "digital tools"; "health informatics" "artificial intelligence"; "Artificial Intelligence-AI"; "Machine Learning"; "pharmacy practice"; "pharmacists"; "clinical pharmacy"; "medication management"; "pharmaceutical services"; and "pharmaceutical care. The search used BOOLEEN OR/AND. Filters for human studies and trials conducted in the last five years applied. Selection of sources of evidence author screened the titles and abstracts of collected studies to determine relevancy. In the second stage, a full-text review for each study's eligibility determined by its inclusion and exclusion criteria, assuring a rigorous and fair selection. Data charting process a standardized data charting process was developed. The researcher tested this form to ensure its effectiveness in systematically capturing relevant data for the scoping review. The data extracted included: study design characteristics (author, year, country), intervention details (type of digital health tool, duration), outcomes (pharmacy practice outcomes, patient satisfaction), assessment of the impact on pharmacy practice. Critical appraisal of individual sources of evidence of the quality of the listed studies' methodology evaluated through critical appraisal using the Mixed Methods Appraisal Tool (MMAT). Synthesis of results data synthesis involved summarizing the findings based on the types of digital health interventions and their reported impact on pharmacy practice, with results grouped by outcome type (e.g., patient care, workflow efficiency).

RESULTS

For the current review, 1165 materials about the impact of digital health on practice were initially evaluated. Of them, 126 were selected as relevant and evaluated for eligibility. Ultimately, 50 studies were included in the review, while 76 excluded due to lack of relevance or insufficient data on the impact on pharmacy practice. See [Figure 1]. The characteristics of sources of evidence of the included sources charted based on crucial information such as the authors and publication year, the study design, the digital health interventions, and the outcome measures. The critical

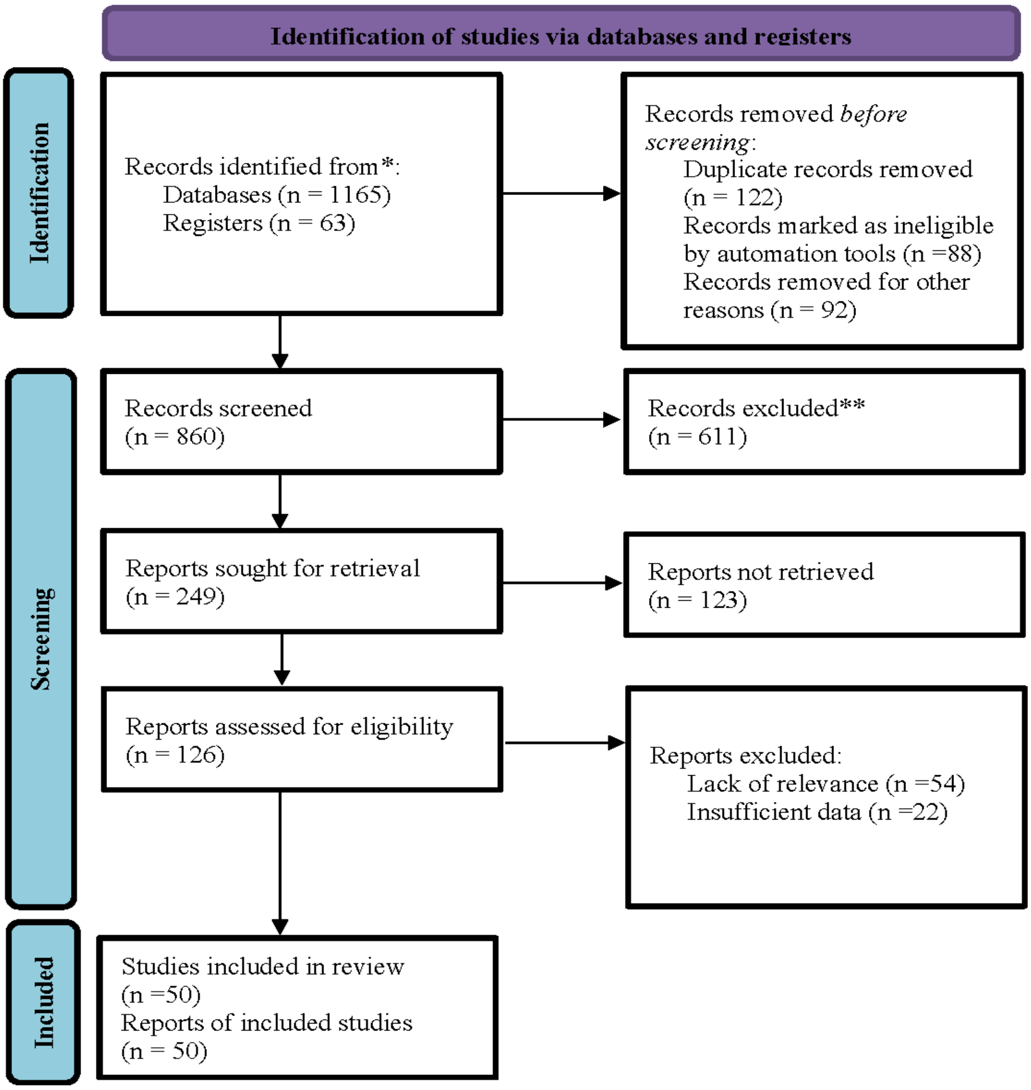

Figure 1: Prisma Flow Diagram

Table 1. PICOs for selected studies on tele pharmacy and remote patient monitoring

Study No	Author, Year	Study Design	Population	Intervention	Comparison	Outcomes
1	Santos et al, 2023	Pragmatic implementation study	Pharmacy students, practicing pharmacists, and healthcare professionals involved in pharmacy education and practice	Implementation of digital health technologies	Traditional in-person pharmacy education and practice methods	Improved accessibility to pharmaceutical care, enhanced learning outcomes in pharmacy education, increased medication adherence, and reduced hospital readmissions.

2	Ilkić et al, 2023	Qualitative study	Community pharmacists in the Republic of Serbia	Implementation of telepharmacy services	Standard care	Improved access to pharmaceutical care, potential for workload optimization, and increased patient satisfaction
3	Lopez de Coca, 2022	Cross-sectional study	Individuals interact with digital health technologies, particularly in pharmacy settings	Use of digital health technologies	Those with higher education and digital literacy versus those with lower education levels or older age groups	Improved healthcare access and understanding of treatments based on age, education level, and population location
4	Jirjees et al, 2022	Cross-sectional study	Licensed community pharmacists in the United Arab Emirates (UAE) providing telepharmacy services during the COVID-19 pandemic	Implementation and use of telepharmacy services	Telepharmacy services across different pharmacy types and pharmacist staffing levels	Adoption of telepharmacy services, barriers to implementation, and variation in service quality
5	Li et al, 2021	Experimental study	Patients requiring long-term medication management	Implementation of tele pharmacy services via the “Cloud Pharmacy Care” platform	Traditional in-person pharmacy services	Improved medication adherence, reduced medication-related issues, enhanced access to pharmaceutical care, and patient satisfaction
6	Ibrahim et al, 2020	Prospective, observational, comparative study	Community pharmacies	Implementation of telepharmacy services for patient consultation and medication dispensing	Traditional in-person pharmacy services without remote consultation	Increased access to pharmaceutical care, reduced medication dispensing errors (MDEs), and improved medication safety
7	Peláez Bejarano et al, 2021	Cross-sectional study	Patients unable to visit the hospital pharmacy during the COVID-19 pandemic	Implementation of a home delivery service for medications	Traditional in-person pharmacy services	Increased patient access to medications, high satisfaction levels, and safety during the pandemic
8	Bindler, 2020	Retrospective study	Rural healthcare institutions with telepharmacy services	Implementation of telepharmacy services	Institutions without telepharmacy services or traditional in-person pharmacy services	Reduction of medication discrepancies, high-alert medication deficiencies, and cost avoidance
9	Amkreutz et al, 2020	Prospective observational study	Patients admitted to remote intensive care units (ICUs) in Germany	Implementation of a telepharmaceutical expert consultation as part of tele-ICU services to identify drug-related problems (DRPs)	Standard care without telepharmaceutical consultation in ICU	Improved medication safety, detection of drug-drug interactions (DDIs), and dosage adjustments in organ failure

10	Asseri et al, 2020	Prospective evaluation	Patients served by King Fahad University Hospital during the COVID-19 pandemic	Implementation of telepharmacy services	Traditional in-person pharmacy services	Improved pharmaceutical care delivery, increased medication adherence, and enhanced patient safety
11	Stockton and Deas, 2019	Retrospective chart review	Patients with type 1 or type 2 diabetes	Pharmacist-led insulin titration telepharmacy service	Standard care without pharmacist involvement	Changes in hemoglobin A1c (HbA1c) levels, compliance with recommended HbA1c monitoring, and reduction in HbA1c
12	McGinnis et al, 2019	Cross-sectional analysis	Patients admitted to the emergency department (ED) at five large facilities	Implementation of a telepharmacy service using pharmacy technicians to collect medication histories	Traditional in-person medication history collection by nursing staff or other health care providers	Increased medication history completion rates and identification of potential medication errors, especially for high-risk medications

PICOs: P for Population, I for Intervention, C for Comparison, O for Outcomes, and S for Study Design, UAE for the United Arab Emirates and MDEs for Medication Dispensing Errors. DRPs (Drug-Related Problems), DDIs (Drug-Drug Interactions), HbA1c (Hemoglobin A1c), ICUs (Intensive Care Units), and ED (Emergency Department).

Table 2. PICOs for selected studies on artificial intelligence in pharmacy practice

Study No	Author, Year	Study Design	Population	Intervention	Comparison	Outcomes
13	Bazzari et al, 2024	Simulation trials	Pharmacists and healthcare providers in telepharmacy settings	Application of ChatGPT as a telepharmacist for patient inquiries, drug-related consultations, and medication management	Traditional pharmacist-led consultations or non-AI-supported telepharmacy systems	Accuracy, precision, and clarity in pharmaceutical care; improved access to pharmaceutical services remotely; potential improvements in pharmacy education
14	Sheikh et al, 2024	Comparative analysis	Patients with kidney disease using non-prescription, and pharmacists assessing drug safety	The use of ChatGPT-3.5 and ChatGPT-4 to assess the safety of non-prescription medications	Traditional resources like Micromedex, a drug safety database.	Pharmacy education will likely need to incorporate AI-based decision tools like ChatGPT into the curriculum
15	Albogami et al, 2024	Cross-sectional analysis	Pharmacists and patients engaging with drug-related inquiries	The use of large language models (LLMs) such as ChatGPT-4 for drug-related inquiries	Human pharmacists across different inquiry types	The need for future pharmacists to be proficient in using AI-driven tools like LLMs to complement their decision-making processes

www.pharmacypractice.org (eISSN: 1886-3655 ISSN: 1885-642X)

16	Ong et al, 2022	Experimental study	Pharmaceutical researchers and the healthcare industry, including those involved in personalized medicines and medical devices	Application of machine learning to improve and predict the outcomes of 3D-printed pharmaceutical products	Traditional empirical methods	Improved accuracy in predicting printability, mechanical characteristics, and processing temperatures, enhancing formulation efficiency
17	Yalçın et al, 2022	Prospective cohort study	Critically ill neonates in the neonatal intensive care unit	Use of a machine-learning-based risk score and web tool	Traditional ADR detection methods	Improved detection and prevention of high-risk ADRs in neonates
18	Bu et al, 2022	Descriptive observational study	Patients using AI-based pharmacy services in an internet hospital in China	Implementation of an AI-driven internet hospital pharmacy service	Traditional manual pharmacy services and prescription review in internet hospitals	Increased efficiency in prescription review, patient satisfaction, reduced prescription errors, and enhanced access to pharmacy services
19	Naeem et al, 2022	quasi-experimental study	Patients, especially the elderly and those with cognitive disabilities	AI-based system using Reinforcement Learning (RL), Deep Learning (DL), Optical Character Recognition (OCR), and barcode technology	The system integrates three AI methods (DL, OCR, barcode) to monitor medication adherence	Reduction in medication errors and improved adherence to prescribed medication routines
20	Takase et al, 2022	Uncontrolled before-and-after study	Medication dispensing processes in a hospital setting, involving pharmacists and pharmacy support staff	Implementation of a robotic dispensing system integrating three components	Traditional manual dispensing performed solely by pharmacists before introducing the robotic system	Significant reduction in dispensing errors and dispensing time, allowing pharmacists to focus more on clinical care
21	Rafiei et al, 2021	Viewpoint analysis	Patients with chronic conditions, healthcare providers, and the biopharmaceutical industry	Integration of digital health technologies in autoinjectable devices for disease management and remote care	Traditional autoinjectable devices without digital health technologies	Enhanced patient adherence, self-management of diseases, real-time data collection, and improved healthcare outcomes
22	McCoubrey et al, 2021	Experimental study	Gut bacteria strains and the pharmaceutical industry utilizing machine learning	Use of machine learning (ML) models to predict adverse effects of drugs on intestinal bacteria	Traditional experimental methods to test drug effects on gut bacteria	Improved prediction accuracy for drug-induced gut dysbiosis, enabling early identification of adverse effects during drug development
23	Mohsen et al, 2021	Computational research study	Drugs assessed for adverse drug reactions (ADRs) during the drug discovery phase, using databases such as Open TG–GATEs and FAERS	Application of deep learning models	Traditional methods of ADR prediction, which typically rely on clinical trials and post-marketing surveillance	Enhanced ability to predict ADRs early in the drug discovery process, improving safety assessments and reducing risks during clinical trials

24	Nagata et al, 2021	Retrospective study	Prescription data from Kyushu University Hospital, including 21 different drugs	Unsupervised machine learning approach using one-class support vector machine (OCSVM)	Other unsupervised outlier detection algorithms	High detection performance for both clinical and synthetic overdose/underdose prescriptions, reducing prescription errors with high precision and recall
25	Corny et al, 2020	Retrospective observational study	Hospitalized patients in a large private hospital in Paris	A hybrid clinical decision support system (CDSS) combining machine learning and a rule-based expert system	Traditional clinical decision support systems (CDS) and multicriteria query methods	Increased accuracy and reliability in detecting high-risk prescriptions and reducing the rate of prescription errors
26	Dandala et al,2019	Experimental study	Hospitalized patients, focusing on clinical notes with adverse drug events (ADEs) mentioned in their electronic health records (EHRs)	A neural network model that detects adverse drug events (ADEs) in clinical notes	Traditional methods of sequential entity and relation extraction without joint modeling	Improved accuracy in ADE detection using joint modeling and external resources.
27	Yang et al, 2019	Experimental study	Patients with clinical notes in electronic health records (EHRs) containing mentions of adverse drug events (ADEs)	A machine learning-based natural language processing (NLP) system	Traditional methods of detecting ADEs manually from clinical notes or using other NLP models	Improved detection accuracy and efficiency in identifying ADEs, medications, and their relations from unstructured clinical data
28	Segal et al, 2019	quasi-experimental study	Inpatients in an internal medicine department at a tertiary medical center	Implementation of a probabilistic, machine-learning-based clinical decision support system (CDSS)	Legacy rule-based clinical decision support systems	Reduction in medication prescription errors, lower false alert burden, higher clinical relevance of alerts, and significant physician responses

LLMs (Large Language Models), ADR (Adverse Drug Reactions), AI (Artificial Intelligence). RL (Reinforcement Learning), DL (Deep Learning), OCR (Optical Character Recognition), ADR (Adverse Drug Reactions), ML (Machine Learning). ADEs (Adverse Drug Events), EHRs (Electronic Health Records), NLP (Natural Language Processing), CDSS (Clinical Decision Support System), OCSVM (One-Class Support Vector Machine), CDS (Clinical Decision Support).

appraisal within sources of evidence of the included studies, adapted for practice settings, the clarity of the digital health interventions, and the reliability of outcome assessments related to patient care. Thirty-four articles out of fifty studies scored highly in participant selection and intervention clarity, while 16 had less clear outcome measures.

Results of individual sources of evidence

Tele pharmacy and remote patient monitoring

In Serbia, implementing tele pharmacy services in community pharmacies enhanced Remote consultations and improved access to pharmacological care, especially in remote regions and medication management. Challenges such as regulatory issues, technical infrastructure needs, and pharmacist training were noted[14]. Similarly, a study in Spain explored the digital divide in healthcare, focusing on older adults' use of tele

https://doi.org/10.18549/PharmPract.2026.2.3542

pharmacy, barriers like resistance to digital tools and the need for ongoing support persisted[18]. In the United Arab Emirates (UAE), tele pharmacy services during the COVID-19 pandemic-maintained continuity of care, reduced medication errors, and improved patient satisfaction through remote consultations and medication delivery[15]. In the Middle East, tele pharmacy services ensured continuous access to medications and supported chronic disease management, with noted benefits in adherence, cost savings, and reduced virus exposure, although technical infrastructure and patient education remained areas of concern[19]. In Spain, the home delivery service for medications during the pandemic improved medication adherence and patient satisfaction by reducing in-person visits[20] like the rural in United States. Healthcare institutions and tele pharmacy helped identify medication discrepancies and manage high-alert medications, significantly reducing medication errors and generating cost savings, though challenges related to internet infrastructure and initial setup costs were noted[21]. In Germany, tele pharmacy integrated into a tele-ICU model, improving medication safety and optimizing drug therapy for intensive care unit (ICU) patients by enabling real-time drug interaction checks; challenges included staff training and maintaining seamless digital communication[13]. Similarly, in the United States, pharmacist-run tele pharmacy service for outpatient insulin titration improved glycemic control for diabetic patients through regular remote consultations despite challenges with technology adoption and patient engagement[22]. In emergency departments, remote pharmacists improved the accuracy of medication histories, reducing discrepancies and enhancing patient safety. Coordination between departments and pharmacy technician training identified as challenges[23] [Table 1].

A study utilized digital tele pharmacy platform designed for long-duration spaceflights. The tool enabled real-time consultations, medication adherence monitoring, and dosage adjustments, enhancing medication safety and adherence for astronauts. The challenges reported, maintaining stable communication in the space environment and adapting the system for space-specific conditions[24]. In China, tele pharmacy through social media platforms like WeChat provides continuous remote consultations, medication monitoring, and prescription refills, proving particularly effective during COVID-19 lockdowns, with challenges such as ensuring data privacy and confidentiality and addressing the digital divide challenges such as ensuring data privacy and confidentiality, and addressing the digital divide[25]. Similarly, In Saudi Arabia, tele pharmacy in an academic medical city improved medication adherence, reduced in-person visits, and increased safety for vulnerable populations during the pandemic. Despite its success, the study identified challenges, such as technical issues[16] [Table 1].

Artificial intelligence in pharmacy practice

In Turkey, a machine-learning-based tool developed for detecting neonatal adverse drug reactions (ADRs) achieved a 91.1% accuracy rate, assisting clinicians in optimizing drug use for critically ill neonates[26]. Similarly, in Shanghai, an AI-driven pharmacy service incorporated prescription previews and QR-enabled medication pick-up, achieving 83.65% accuracy and improving workflow efficiency during the COVID-19 pandemic[27]. Moreover, in the U.S, AI-based models impact chronic disease management significantly and foster patient compliance when used on auto injectable, connected in adapters[28]. Similarly, a deep learning framework in Japan utilized gene expression to identify adverse drug reactions (ADRs). It trimmed the drug development process by estimating 89.4% of the predictors indicating high-risk compounds[6]. Another research conducted in Japan employed ML algorithms to spot prescription overdose circumstances and indicate syllabication mechanisms for better medication[7]. In Paris, a hybrid Clinical Decision Support System (CDSS) implemented to combine ML and rule-based systems in prescribing, which successfully restricted high-alert prescriptions and used AI to ease tasks in clinical decision-making[12] [Table 2]. ChatGPT studied in several studies, for instance a study evaluated the feasibility of ChatGPT by using versions 3.5 and 4.0 in simulated patient scenarios. ChatGPT 4.0 performed with greater consistency and accuracy, showing potential for remote tele pharmacy services, though challenges like input limitations and feedback issues were noted[29]. Similarly, the Mayo Clinic study compared ChatGPT versions for evaluating the safety of non-prescription medications, finding an 81.4% agreement with the Micromedex database, underscoring AI's rapid evaluation capabilities[30]. While at King Saud University, ChatGPT-4 outperformed pharmacists in risk mitigation and provided accurate drug-related information 64.3% of the time and 95% safe responses[31]. 3D printing enhanced with ML models that improved formulation precision, demonstrating AI's potential in personalized drug manufacturing[32]. Further emphasizing AI's role in patient safety, a system integrating reinforcement learning and deep learning aimed to reduce medication errors for elderly patients by providing real-time feedback[33]. Automated dispensing robots in Japan significantly reduced manual errors, allowing pharmacists to focus on clinical tasks[34]. Additional models developed at a School of Pharmacy helped predict drug impacts on intestinal bacteria, contributing to more personalized medicine approaches[35]. A neural network model improved ADE detection accuracy, utilizing external data from the Food and Drug Administration (FDA)[4]. The MADEx system advanced pharmacovigilance with a natural language processing (NLP) tool for detecting ADEs in clinical notes, improving medication safety[3]. Prospectively, ML CDSS conducted at Chaim Sheba Medical Center had an 85% success in flagging prescriptions, making physicians alter treatment in 43% of the flagged cases, again highlighting AI's ability to minimize ADEs and prescription errors[5] [Table 2].

Mobile health (mHealth) applications in pharmacy practice

"Crypto Pharmacy," a blockchain-based app, used the NEM blockchain to secure the pharmaceutical supply chain and prevent counterfeit drugs through QR code-based tracking, enhancing transparency and efficiency[36] [Table 3]. In the United States, a pharmacist-led mHealth app improved post-transplant patients' medication adherence and safety through direct pharmacist-patient communication despite some challenges in patient education and privacy[37]. Similarly, India's "Smart Pill Sticker" system, which uses touch-point

Table 3. PICOs for selected studies on mobile health (mHealth) applications in pharmacy practice

Study No	Author, Year	Study Design	Population	Intervention	Comparison	Outcomes
29	Gonzales et al, 2021	Randomized controlled trial	Kidney transplant recipients	Pharmacist-led, mobile health-based intervention	standard monitoring and clinic visits	Reduction in medication errors, adverse events, and hospitalization
30	Subramanian et al, 2021	Observational	Stakeholders in the pharmaceutical supply chain, including manufacturers, pharmacists, healthcare providers, and patients	Integration of a mobile application with a hybrid blockchain system for secure and transparent tracking of pharmaceutical products	Existing traditional supply chain systems lacking transparency and prone to counterfeit issues	Improved security, transparency, and traceability of pharmaceutical products across the supply chain, reducing counterfeit medicines
31	Kataria et al, 2021	Quasi-Experimental	Elderly patients requiring polypharmacy for managing multiple health conditions	Implementation of a smart pill management system using conductive ink stickers and a mobile app	Existing pill management technologies	Improved medication adherence, reduction in medication mismanagement, ease of use for older adults
32	Cobelli et al, 2020	Quasi-Experimental	Italian pharmacists, primarily SMEs	Adoption of mobile health (mHealth) apps for service digitalization	Traditional customer service methods without mHealth apps	Improvement in customer satisfaction and loyalty, barriers to adoption

mHealth: Mobile Health, RCT: Randomized Controlled Trial, SMEs: Small and Medium Enterprises, Quasi-Experimental: A study design without randomization but with intervention and outcome measurement, Polypharmacy: Concurrent use of multiple medication.

Table 4. PICOs for selected studies on electronic Health Records (EHRs) integration in pharmacy

Study No	Author, Year	Study Design	Population	Intervention	Comparison	Outcomes
33	Alshehri et al, 2023	Cross-sectional study	Pharmacists using Drug Utilization Review (DUR) systems in a tertiary healthcare hospital	Electronic Health Record (EHR) systems with integrated DUR alerts for improving medication safety	Traditional non-electronic or less integrated medication review processes	Pharmacist satisfaction, reduced alert fatigue, and improved medication safety
34	Jungreithmayr et al, 2021	Retrospective before-and-after study	Medication prescriptions at a tertiary care hospital	Introduction of a CPOE system integrated with a clinical decision support system (CDSS)	Paper-based prescription system used before the CPOE implementation	Improved fulfilment of documentation criteria for safe, complete, and actionable prescriptions
35	Balestra et al, 2021	Observational study	Providers submitting medication orders in a major urban academic hospital system	Implementation of a machine learning model to predict pharmacy order interventions based on provider actions and contextual features	Traditional approaches comparing orders to patient medical records	Identification of orders requiring pharmacy intervention

https://doi.org/10.18549/PharmPract.2026.2.3542

36	Van der Nat et al, 2021	Prospective cohort study	Patients scheduled for elective admissions	Use of an online Personal Health Record (PHR) by patients to update their medication lists before admission	Medication reconciliation (MR) conducted by a pharmacy technician	Level of agreement in medication discrepancies identified between MR and PHR, and the accuracy of the medication lists updated through the PHR
37	Aldughayfiq et al, 2021	Comparative analysis and survey-based study	Physicians and pharmacists using e-prescription systems across different countries	Implementation of digital health systems, particularly focusing on e-prescription systems	Traditional prescription systems and digital health systems across different countries	Improvement in patient safety, reduction in medication errors, enhancement of patient care, digital security, and privacy protocols
38	Peltoniemi et al, 2021	Comparative observational study	Finnish community pharmacies	Introduction of electronic prescriptions (ePrescription) and the direct dispensing model	Traditional dispensing model using paper prescriptions	Improved workflow efficiency, reduction in dispensing times, sociotechnical implications, and digital transformation in pharmacy settings
39	Farghali et al, 2021	Observational study using a secondary analysis of survey	Canadian community pharmacists in five provinces	Introduction and adoption of electronic prescribing (e-prescribing) systems	Traditional handwritten or faxed prescriptions	Impact on medication errors, productivity, and workflow in community pharmacies
40	Foreman et al, 2020	Cross-sectional retrospective review	Healthcare workers (HCWs) involved in documenting adverse drug reactions (ADRs) in electronic health records (EHRs)	Use of an electronic health record system with ADR documentation features	Evaluating the existing system's design and its influence on ADR categorization.	Accuracy of ADR categorization (allergy vs. intolerance), frequency of free-text entries, and the impact of EHR design on documentation practices
41	Chapman et al, 2019	Experimental study	Clinical notes from electronic health records (EHRs) with mentions of drugs, symptoms, and other related entities	Development and implementation of an NLP-based system for ADE detection using machine learning models	erformance of existing systems or manual ADE reporting	Improved accuracy and efficiency in detecting ADEs from clinical narratives

DUR: Drug Utilization Review, CPOE: Computerized Physician Order Entry, PHR: Personal Health Record, MR: Medication Reconciliation. ePrescription: Electronic Prescription, HCWs: Healthcare Workers, ePrescribing: Electronic Prescribing, NLP: Natural Language Processing.

technology and reminders to increase adherence, benefited elderly and chronically ill patients but faced initial cost and adaptability issues[38]. In Italy, digital health solutions like mHealth Enhanced communication and reduced wait times to increase patient satisfaction, though infrastructure and data security remained concerns[39] [Table 3].

Electronic Health Records (EHRs) integration in pharmacy

Saudi pharmacists perceived drug safety alerts generated by the DUR module of electronic health records positively, however, the perceived prevalence of alerts contributed to alert fatigue and prompted them to consider adjusting the number of alerts to maximize efficiency[40]. Researchers at US - based academic institutions developed an ML model to predict the requirement for a pharmacy intervention after analyzing EHR data on provider action. The model was evaluated against simulated prescribing scenarios. It successfully predicted the requirement for intervention after identifying numerous potentially dangerous prescriptions, enhancing the workflow efficiency by facilitating the proactive identification and handling of concerning medication orders, however, it also identified the difficulties of EHR integration and the importance of data quality[41]. A Dutch study assessed several reconciliation approaches in primary care, concluding that the optimal combination is using pharmacy technicians for verification along with PHRs to reduce medication discrepancies and involve patients more strongly[42]. E An examination of e - prescription systems in eight countries showed improved error reduction, however, it noted variation in security standards across these countries and suggested international guidelines to create standardized protocols[43]. In Finland, e-prescriptions observed to improve medication management and communication between providers and pharmacies, though initial setup costs and the need for system updates presented challenges[44]. Community pharmacists reported that, electronic prescribing significantly reduced prescription errors but faced technical issues, indicating the need for continuous technical support[17]. In Australian hospitals, EHRs enabled improved ADR identification, though standardization protocols recommended to address data inconsistencies[45]. A study in the United States used ML to detect ADEs within EHRs, achieving high accuracy in identifying patterns indicative of ADEs while stressing the importance of data quality and managing false positives[46] [Table 4]. A study at Heidelberg University Hospital assessed the impact of a CPOE system on prescription documentation, which notably improved documentation quality post-implementation, although areas such as allergy documentation required further improvement[47] [Table 4].

Wearable devices for medication management

A study in the Netherlands assessed a prototype smart pill bottle designed to improve adherence, finding high user acceptability and functionality, though challenges like battery life and connectivity issues were noted[11]. In a related study, In the United States, a study explored a real-time medication monitoring pill bottle linked to a human immunodeficiency virus (HIV) self-management app, in which patients reported improved adherence through reminders. However, privacy and technical concerns were mentioned[10], [Table 5A]. Researchers in Thailand developed an automated pill dispenser system for pharmacies, demonstrating significant time saving and improved customer experience despite needing accuracy refinements[48]. Similarly, a study in South Korea developed an Internet of Things (IoT) enabled medication behavior monitoring system to support remote healthcare, especially for elderly patients during the pandemic, significantly improving adherence through real-time monitoring[49] [Table 5A].

Big data analytics in pharmacy practice

A study in the United States revealed that adults with morbidity were more likely to use health information technology (HIT) to access test results and communicate with providers, although older adults (≥65 years) showed lower HIT engagement. This suggests a need for educational interventions to improve HIT literacy in pharmacy care for chronic conditions[50]. Similarly, research in China developed a ML-based risk-warning platform to predict potentially inappropriate prescriptions for elderly cardiovascular patients, effectively identifying high-risk individuals and assisting in targeted interventions[9]. In the United States, one more research focused on determining factors, which led to inappropriate NSAIDs usage among older adults with osteoarthritis. It stressed personalized prescribing to avoid adverse reactions[8]. In Sweden, another analysis focused on difficulties using EHR and pharmacy data for adherence estimation, stating that standard definitions and data quality must be improved for credible studies[51] [Table 5B]. A study from Ethiopia evaluated an electronic pillbox-enabled self-administered therapy for tuberculosis, finding it improved adherence, reduced patient costs, and was well-received compared to traditional directly observed therapy, demonstrating its potential for enhancing Tuberculosis (TB) treatment adherence[52] [Table 5B].

Synthesis of results: the synthesis of results from these studies demonstrates the enormous impact of digital health tools on pharmacy practice. Digital health technologies improve medication safety, reduce adverse drug events, and improve patient care by allowing for more precise and timely clinical decision-making [Figure 2].

DISCUSSIONS

The results of the current review reflect the influence of digital health tools on pharmacy practice, particularly in terms of enhancing access, efficiency, and medication safety, mainly through innovations like tele pharmacy, AI, mHealth applications, EHR integration, wearable devices, and big data analytics.

The Thematic Literature Review

Tele pharmacy and remote patient monitoring

The reviewed studies confirm the substantial benefits of tele

https://doi.org/10.18549/PharmPract.2026.2.3542

Table 5A. PICOs for selected studies on wearable devices for medication management

Study No	Author, Year	Study Design	Population	Intervention	Comparison	Outcomes
42	Maneetham et al, 2023	Experimental design	Pharmacies and individuals seeking over the counter (OTC) medication and supplements	Implementation of an automatic pill dispenser designed for pharmacies	Traditional manual pharmacy pill dispensing versus automated systems	Improved dispensing accuracy, efficiency, time savings for both customers and pharmacists, and enhanced user experience
43	Roh et al, 2021	Experimental study	Patients, particularly elderly individuals with mobility issues or chronic conditions	The use of a deep learning-based medication behavior monitoring system (MBMS) that incorporates IoT devices	Traditional medication monitoring methods	Enhanced medication adherence, remote monitoring capabilities, improved patient health outcomes through timely medication intake
44	Zijp et al, 2020	Proof-of-concept trial	Volunteers using a novel smart pill bottle prototype	Use of the Smart Pill Bottle Prototype (SPBP) for supporting medication adherence	Standard methods implied	Medication adherence, user acceptability, and technical robustness
45	Cho et al, 2019	Descriptive qualitative study	People living with HIV (PLWH) who use a real-time medication monitoring pill bottle linked to a mobile-based HIV self-management app	Use of a real-time medication monitoring pill bottle (Clever Cap™ LITE) connected to a mobile app	Traditional methods of medication adherence	Improvement in medication adherence and user engagement through app reminders, tracking of medication adherence

OTC: Over the Counter, MBMS: Medication Behavior Monitoring System, IoT: Internet of Things, SPBP: Smart Pill Bottle Prototype, PLWH: People Living with HIV.

Table 5B. PICOs for selected studies on big data analytics in pharmacy practice

Study No	Author, Year	Study Design	Population	Intervention	Comparison	Outcomes
46	Manning et al, 2023	Cross-sectional study	Adults in the USA with multimorbidity	Use of health information technology (HIT)	Those with one or no chronic condition, in terms of their usage and engagement with (HIT)	There are significant disparities in (HIT) use based on multimorbidity status and age
47	Wu et al, 2022	Retrospective observational study	Elderly patients (≥65 years) with cardiovascular disease	Development of a machine learning-based risk warning platform	Traditional approaches using manual assessment methods	Improved identification of PIP, PIM, and PPO with the best models achieving AUCs
48	Patel et al, 2021	Retrospective cohort study	Older adults (aged ≥65 years) with osteoarthritis (OA) in the United States	Use of machine learning to identify predictors of potentially inappropriate non-steroidal anti-inflammatory drugs (NSAIDs) use	Standard prescription practices without machine learning-based prediction models	Identification of factors associated with inappropriate NSAIDs use, focusing on duration, types of NSAIDs, and associated risks

49	Galozy et al, 2020	Data analysis using EHR and pharmacy records	Patients with chronic diseases	Estimating medication adherence using electronic health records (EHR) and pharmacy data	Different computational methods for adherence estimation	Variability and accuracy of medication adherence estimation
50	Manyazewal et al, 2020	Randomized controlled trial	Patients with tuberculosis (TB) in Ethiopia	Electronic pillbox-enabled self-administered therapy (SAT)	Standard directly observed therapy (DOT)	Medication adherence and sputum conversion improvement, treatment outcomes, cost-effectiveness, usability, and acceptability

HIT: Health Information Technology, PIP: Potentially Inappropriate Prescriptions, PIM: Potentially Inappropriate Medications, PPO: Potential Prescribing Omissions, AUC: Area Under the Curve, NSAIDs: Non-Steroidal Anti-Inflammatory Drugs, TB: Tuberculosis, SAT: Self-Administered Therapy, DOT: Directly Observed Therapy.

pharmacy in providing remote patient care, especially for underserved and remote populations. Similar to a study documenting increased pharmaceutical care access in Serbian rural areas[14]. Similarly, studies revealed the role of tele pharmacy in maintaining good quality of care during the COVID-19 pandemic in the UAE and Middle East, where remote consultations reduced exposure risks and enhanced patient satisfaction[15,19]. While tele pharmacy demonstrates clear advantages, its adoption among older adults and digitally inexperienced users remains limited[18].

Artificial intelligence in pharmacy practice

This review supported AI's contribution to advancing medication safety. AI-based ADR prediction tools, such as the one used in neonatal care were very accurate and could potentially increase patient safety[26]. Equally, studies have shown that AI-powered CDSS resource optimization improved workflow and reduced medication misadventures by flagging at-risk orders[12,27]. It is, in fact, consistent with a review done earlier, which also emphasizes the role of AI in changing the dynamics of health and pharmacy practice by adequate decision support, enhancing patient participation and providing better adherence support[52]. Despite these benefits, our review and other studies, such as Segal et al., highlight alert fatigue and the need for pharmacist training as ongoing challenges to effective AI adoption in pharmacy[5]. Investing in AI training for pharmacists is crucial for maintaining good standards of patient care in increasingly automated pharmacy settings—the role of AI literacy among healthcare providers in maximizing the effectiveness of digital tools[27].

Mobile Health Applications in Pharmacy Practice

mHealth applications significantly support medication adherence, especially in chronic disease management. Our findings demonstrate enhanced adherence among post-transplant patients using a pharmacist-led mHealth intervention[37]. Additionally, the "Smart Pill Sticker," a reminder-based system, effectively increased adherence among elderly patients[38]. Wearable technology demonstrates the potential for improving adherence and patient satisfaction, such as the intelligent pill bottle studied in the Netherlands and the United States[10,11].

Electronic health records integration

The integration of EHRs in pharmacy settings enhances medication safety and workflow efficiency, as demonstrated in the current study. EHR-based DUR systems effectively identify potential drug interactions. However, our study also emphasizes the issue of alert fatigue, which reduces the efficiency of these systems by overwhelming pharmacists with non-critical alerts[40]. Moreover, ML models applied EHR data accurately flag high-risk prescriptions, reducing errors and prioritizing pharmacist interventions[41]. Further, combining patient-accessible health records with EHRs could improve medication accuracy by actively involving patients in managing their health[42].

Wearable devices for medication management

A study in the Netherlands on an intelligent pill bottle reported positive feedback on ease of use and adherence improvements, although issues like connectivity and battery life affected its reliability[11]. Similarly, a smart pill bottle combined with an HIV self-management app in the United States enhanced adherence in patients with chronic conditions. However, participants raised concerns about technical glitches and data privacy[10]. A South Korean study developed a medication behavior monitoring system using IoT and human activity recognition to track medication adherence during the COVID-19 pandemic, though it faced scalability issues due to high setup costs and connectivity requirements[49].

Big Data analytics in pharmacy practice

Big data analytics in pharmacy enhances predictive capabilities for medication safety and adherence but require consistent data definitions, quality management, and targeted HIT education to ensure accuracy and effectiveness. For instance, predictive models help identify high-risk prescriptions and support targeted interventions for older adults with multiple chronic conditions[9,50]. While in Sweden, researchers explored medication adherence using EHR and pharmacy data, noting significant variations in adherence estimates due to inconsistent definitions and data handling. These variations can lead to inaccurate assessments and influence clinical decisions[51] which emphasized the need for standardized definitions and robust data management to improve the reliability of big data analytics in pharmacy.

The opportunities for digital health in Pharmacy Practice

The opportunities for digital health in Pharmacy Practice are vast and continue to expand as technology evolves. For instance, tele pharmacy opens up many possibilities, pharmacists could help patients via a screen or by phone when they can't get into a location. Or maybe there's a small community that struggles to reach a pharmacy. That could be a major opportunity. Another is mobile health apps - that could assist a variety of patients with getting reminders about their medications, checking if they're compliant, tracking their medications or even allowing a pharmacist to access data. Or there are digital health platforms in which pharmacists can use data, patient data and trends, to identify people who are at a high risk, to improve or personalize medication adherence programs for those people and engage in other preventive health measures. Through these platforms pharmacists could collaborate with other health professionals and patients through secure text messages or electronic health records, so there's more connectivity and a better flow of information to enhance patient care. All of these aspects together offer us- pharmacists -unique opportunities to practice pharmacy and fulfill a need that the community is going to be requiring.

The challenges for digital health in Pharmacy Practice

As digital health continues to evolve, some regulatory hurdles remain, necessitating standards for the safe and effective use of technology in pharmacy practice. There are considerable barriers related to incorporating technology into the pharmacy practice that would need to overcome for implementation to be successful. Tele pharmacy, affected by regulatory restrictions and policies, especially in areas that need such innovative forms of medicine[14,15]. Concerns about data privacy and security are prominent across digital platforms, especially for mHealth applications and AI tools, highlighting the need for robust security measures to maintain patient trust[18,37]. Further, infrastructure barriers such as lack of reliable internet access and non-interoperable systems limit the use of technology in adoption especially in the remote areas[21,49]. Another challenge is alert fatigue in AI and EHR systems, where excessive alerts can overwhelm providers, reducing the identification of critical warnings. Prioritizing high-risk interactions and allowing customizable alert settings could help mitigate this issue[12,40]. Training for pharmacists and patients is also crucial; pharmacists must be skilled in AI and EHR technologies, while older patients require guidance on mHealth and wearable devices for practical usage[11,38]. Even with these challenges, the chances for the future of digital health in pharmacy stands a better chance. Technologies such as tele pharmacy and mHealth can help improve accessibility and make it possible for patients to become more involved in their health management[19,20]. With the assistance of predictive analytics powered by AI, medical care tailored to individual patient needs, which reduces the chances of medication mismanagement and associated adverse drug events. This position pharmacists at the forefront of personalized medicine[26,27]. Wearable devices and mHealth applications enable individualized self-management and adherence, especially in chronic disease management[10,37]. The limitations of digital health use in pharmacy practice can be quite significant and can affect both patient care and operational efficiency. Future developments in big data analytics will allow pharmacists to identify and act on patient patterns that can improve their outcomes and reduce overall healthcare expenditure [Manning SE et al. 2023=50]. It will be essential to seek and target the challenges with appropriate policies that ensure enhanced security and provide comprehensive training for the full realization of the benefits of digital health in pharmacy practice.

Summary of evidence

This study focuses on the substantial influence of digital health tools in pharmacy practice, specifically tele pharmacy, AI, mHealth applications, EHR integration, and wearable devices. It reported that these technologies improve accessibility, patient engagement, safety, and operational efficiency in medication management. While they have the potential to improve patient care, challenges included regulatory issues, data security, infrastructure limits, and training requirements, which need addressed to ensure their success [Figure 2].

The limitations of digital health use in Pharmacy Practice

This Systematic review relies on data from diverse studies and covers broad uses of digital technologies, limiting the ability to generalize conclusions about each type of use.

Key messages

- **Expanded Healthcare Access:** Tele pharmacy and mobile health tools allow patients, especially those in remote areas, to easily access pharmacy services and consultations.
- **Enhanced Safety, Efficiency, and Engagement:** Artificial Intelligence (AI), electronic records, and wearable devices improve medication safety, streamline workflow, and boost patient adherence.
- **Implementation Challenges:** Adoption barriers include regulatory, privacy, and infrastructure issues.

CONCLUSION

The current systematic review highlights that while technologies such as those described above increase accessibility and help medication management for patients and pharmacy professionals, ongoing problems related to regulatory limitations and data privacy remain significant hurdles to the widespread adoption of

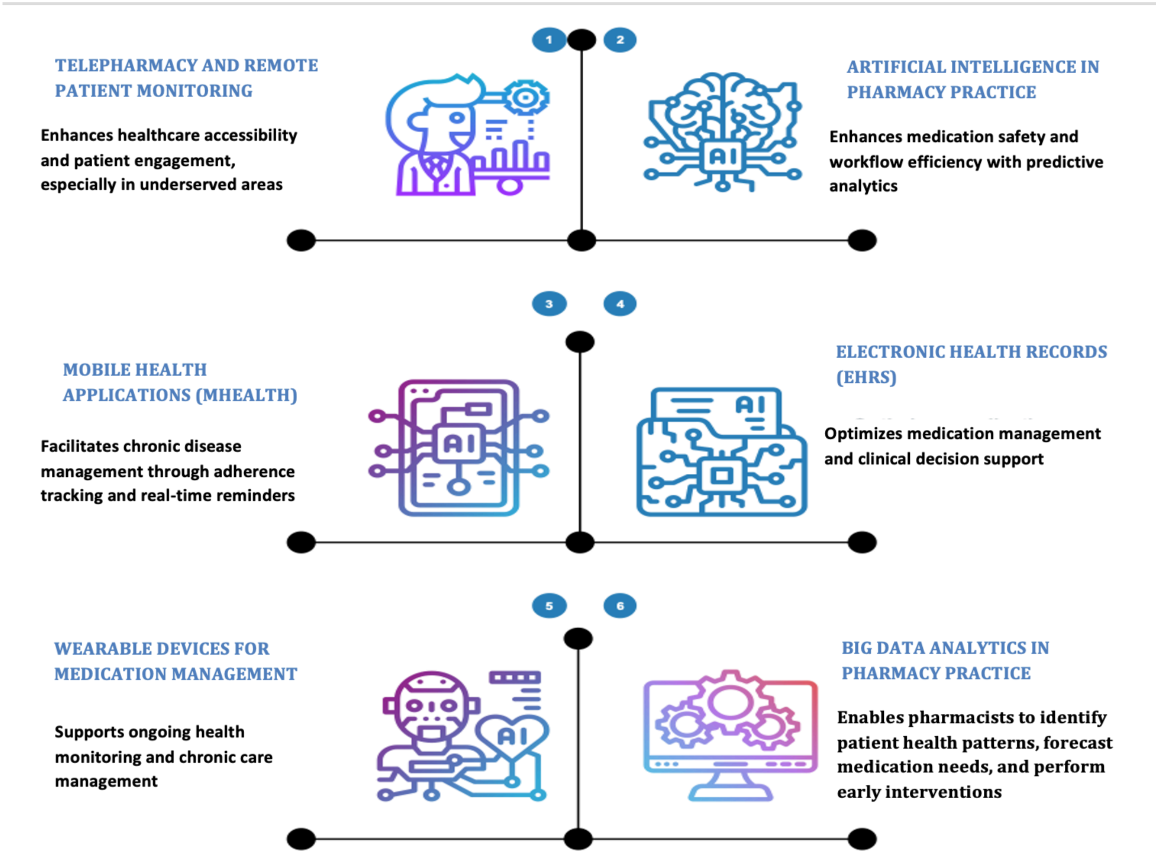

Figure 2: Summary of the Impact of Digital Health on Pharmacy Practice

these innovative digital health solutions. While digital health shows promise in many areas, we still have an insufficient body of high - quality research demonstrating its effectiveness in pharmacy practice over the long term in improving patient outcomes.

AUTHORS' CONTRIBUTIONS

Yousef Saeed Alqarni: conceptualization, methodology, data collection, validation, and formal analysis، writing and reviewing the final draft of the manuscript.

CONFLICT OF INTERESTS

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ACKNOWLEDGMENTS

I would like to acknowledge Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia, for their valuable support and contribution to this research.

References

1. Digital health recommendations on digital interventions for health system strengthening. [Internet]. [cited 2024 Oct 29].
2. Golder S, Xu D, O'Connor K, Wang Y, Batra M, Hernandez GG. Leveraging Natural Language Processing and Machine Learning Methods for Adverse Drug Event Detection in Electronic Health/Medical Records: A Scoping Review. Drug Saf. 2025 Apr;48(4):321-337. doi: 10.1007/s40264-024-01505-6.
3. Yang X, Bian J, Gong Y, Hogan WR, Wu Y. MADEx: A System for Detecting Medications, Adverse Drug Events, and Their Relations from Clinical Notes. Drug Saf [Internet]. 2019 Jan 21 [cited 2024 Oct 28];42(1):123–33.
4. Dandala B, Joopudi V, Devarakonda M. Adverse Drug Events Detection in Clinical Notes by Jointly Modeling Entities and Relations Using Neural Networks. Drug Saf [Internet]. 2019 Jan 21 [cited 2024 Oct 28];42(1):135–46.
5. Segal G, Segev A, Brom A, Lifshitz Y, Wasserstrum Y, Zimlichman E. Reducing drug prescription errors and adverse drug events by application of a probabilistic, machine-learning based clinical decision support system in an inpatient setting. J Am Med Inform Assoc [Internet]. 2019 Nov 15 [cited 2024 Oct 28];26(12):1560–5.
6. Mohsen A, Tripathi LP, Mizuguchi K. Deep Learning Prediction of Adverse Drug Reactions in Drug Discovery Using Open TG–GATEs and FAERS Databases. Frontiers in Drug Discovery [Internet]. 2021 Oct 27 [cited 2024 Oct 28];1:768792. Available from: https://github.com/scikit-learn-contrib.
7. Nagata K, Tsuji T, Suetsugu K, Muraoka K, Watanabe H, Kanaya A, et al. Detection of overdose and underdose prescriptions-An unsupervised machine learning approach. PLoS One [Internet]. 2021 Nov 1 [cited 2024 Oct 28];16(11).
8. Patel J, Ladani A, Sambamoorthi N, Lemasters T, Dwibedi N, Sambamoorthi U. A Machine Learning Approach to Identify Predictors of Potentially Inappropriate Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) Use in Older Adults with Osteoarthritis. Int J Environ Res Public Health [Internet]. 2020 Jan 1 [cited 2024 Oct 28];18(1):1–16.
9. Xingwei W, Huan C, Mengting L, Lv Q, Jiaying Z, Enwu L, et al. A machine learning-based risk warning platform for potentially inappropriate prescriptions for elderly patients with cardiovascular disease. Front Pharmacol. 2022 Aug 11;13:804566.
10. Cho H, Flynn G, Saylor M, Gradilla M, Schnall R. Use of the FITT framework to understand patients' experiences using a real-time medication monitoring pill bottle linked to a mobile-based HIV self-management app: A qualitative study. Int J Med Inform [Internet]. 2019 Nov 1 [cited 2024 Oct 28];131.
11. Zijp TR, Touw DJ, van Boven JFM. User Acceptability and Technical Robustness Evaluation of a Novel Smart Pill Bottle Prototype Designed to Support Medication Adherence. Patient Prefer Adherence [Internet]. 2020 [cited 2024 Oct 28];14:625–34.
12. Corny J, Rajkumar A, Martin O, Dode X, Lajonchère JP, Billuart O, et al. A machine learning-based clinical decision support system to identify prescriptions with a high risk of medication error. J Am Med Inform Assoc [Internet]. 2020 Nov 1 [cited 2024 Oct 28];27(11):1688–94.
13. Amkreutz J, Lenssen R, Marx G, Deisz R, Eisert A. Medication safety in a German telemedicine centre: Implementation of a telepharmaceutical expert consultation in addition to existing tele-intensive care unit services. J Telemed Telecare [Internet]. 2020 Jan 1 [cited 2024 Oct 28];26(1–2):105–12.
14. Ilkić J, Obradović D, Georgiev AM, Marinković V, Tadić I. Implementation of Telepharmacy Services in Community Pharmacy – Pharmacists' Perspective in Republic of Serbia. Indian Journal of Pharmaceutical Education and Research. 2023 Jan 1;57(1):286–94.
15. Jirjees F, Odeh M, Aloum L, Kharaba Z, Alzoubi KH, Al-Obaidi HJ. The rise of telepharmacy services during the COVID-19 pandemic: A comprehensive assessment of services in the United Arab Emirates. Pharm Pract (Granada) [Internet]. 2022 Apr 1 [cited 2024 Oct 28];20(2).
16. Abdulsalam Ali Asseri, Mohab Mohamed Manna, Iqbal Mohamed Yasin, Mashael Mohamed Moustafa, Fatmah Mousa Roubie, Salma Moustafa El-Anssasy, et al. Implementation and evaluation of telepharmacy during COVID-19 pandemic in an academic medical city in the Kingdom of Saudi Arabia: paving the way for telepharmacy. World Journal of Advanced Research and Reviews. 2020 Aug 30;7(2):218–26.
17. Farghali A, Borycki EM, Macdonald S. Pharmacist's perception of the impact of electronic prescribing on medication errors and productivity in community pharmacies. Knowledge Management and E-Learning. 2021;13(4):536–58.
18. Lopez de Coca T, Moreno L, Alacreu M, Sebastian-Morello M. Bridging the Generational Digital Divide in the Healthcare Environment. J Pers Med [Internet]. 2022 Aug 1 [cited 2024 Oct 28];12(8).
19. Mohamed Ibrahim O, Ibrahim RM, Abdel-Qader DH, Al Meslamani AZ, Al Mazrouei N. Evaluation of Telepharmacy Services in Light of COVID-19. Telemed J E Health [Internet]. 2021 Jun 1 [cited 2024 Oct 28];27(6):649–56.
20. Peláez Bejarano A, Villar Santos P, Robustillo-Cortés MDLA, Sánchez Gómez E, Santos Rubio MD. Implementation of a novel home delivery service during pandemic. European Journal of Hospital Pharmacy [Internet]. 2020 Nov 1 [cited 2024 Oct 28];28(e1):e120.
21. Bindler RJ. The Impact of Telepharmacy Services on the Identification of Medication Discrepancies, High-Alert Medications, and Cost Avoidance at Rural Healthcare Institutions. J Int Soc Telemed eHealth. 2020 Jul 2;8.
22. Deas C, Stockton K. Evaluation of Outcomes of a Pharmacist-Run, Outpatient Insulin Titration Telepharmacy Service. Innov Pharm [Internet]. 2019 May 6 [cited 2024 Oct 28];10(2):5.
23. McGinnis B, Padilla E, Garret P, Aziz S. Using pharmacy technicians and telepharmacy to obtain medication histories in the emergency department. Journal of the American Pharmacists Association. 2019 May 1;59(3):390–7.
24. Santos MAD, Herbert J, Cinelli I, Burmann JAL, Soares V V., Russomano T. Development of a Digital Platform: A Perspective to Advance Space Telepharmacy. IEEE Open J Eng Med Biol. 2023;4:168–72.
25. Li H, Zheng S, Li D, Jiang D, Liu F, Guo W, et al. The Establishment and Practice of Pharmacy Care Service Based on Internet Social Media: Telemedicine in Response to the COVID-19 Pandemic. Front Pharmacol [Internet]. 2021 Oct 1 [cited 2024 Oct 28];12:707442.
26. Yalçın N, Kaşıkcı M, Çelik HT, Allegaert K, Demirkan K, Yiğit Ş, et al. An Artificial Intelligence Approach to Support Detection of Neonatal Adverse Drug Reactions Based on Severity and Probability Scores: A New Risk Score as Web-Tool. Children 2022, Vol 9, Page 1826 [Internet]. 2022 Nov 26 [cited 2024 Oct 28];9(12):1826.
27. Bu F, Sun H, Li L, Tang F, Zhang X, Yan J, et al. Artificial intelligence-based internet hospital pharmacy services in China: Perspective based on a case study. Front Pharmacol [Internet]. 2022 Nov 9 [cited 2024 Oct 28];13.
28. Rafiei R, Williams C, Jiang J, Aungst TD, Durrer M, Tran D, et al. Digital health integration assessment and maturity of the United States biopharmaceutical industry: Forces driving the next generation of connected autoinjectable devices. JMIR Mhealth Uhealth [Internet]. 2021 Mar

1 [cited 2024 Oct 28];9(3):e25406.
29. Bazzari FH, Bazzari AH. Utilizing ChatGPT in Telepharmacy. Cureus [Internet]. 2024 Jan 16 [cited 2024 Oct 28];16(1).
30. Sheikh MS, Barreto EF, Miao J, Thongprayoon C, Gregoire JR, Dreesman B, et al. Evaluating ChatGPT's efficacy in assessing the safety of non-prescription medications and supplements in patients with kidney disease. Digit Health [Internet]. 2024 Jan 1 [cited 2024 Oct 28];10.
31. Albogami Y, Alfakhri A, Alaqil A, Alkoraishi A, Alshammari H, Elsharawy Y, et al. Safety and quality of AI chatbots for drug-related inquiries: A real-world comparison with licensed pharmacists. Digit Health [Internet]. 2024 Jan 1 [cited 2024 Oct 28];10.
32. Ong JJ, Castro BM, Gaisford S, Cabalar P, Basit AW, Pérez G, et al. Accelerating 3D printing of pharmaceutical products using machine learning. Int J Pharm X [Internet]. 2022 Jun 9 [cited 2024 Oct 28];4:100120–100120.
33. Naeem M, Coronato A. An AI-Empowered Home-Infrastructure to Minimize Medication Errors. Journal of Sensor and Actuator Networks 2022, Vol 11, Page 13 [Internet]. 2022 Feb 9 [cited 2024 Oct 28];11(1):13.
34. Takase T, Masumoto N, Shibatani N, Matsuoka Y, Tanaka F, Hirabatake M, et al. Evaluating the safety and efficiency of robotic dispensing systems. J Pharm Health Care Sci [Internet]. 2022 Dec 1 [cited 2024 Oct 28];8(1).
35. McCoubrey LE, Elbadawi M, Orlu M, Gaisford S, Basit AW. Machine Learning Uncovers Adverse Drug Effects on Intestinal Bacteria. Pharmaceutics [Internet]. 2021 Jul 1 [cited 2024 Oct 28];13(7).
36. Subramanian G, SreekantanThampy A, Valbosco Ugwuoke N, Ramnani B. Crypto Pharmacy – Digital Medicine: A Mobile Application Integrated With Hybrid Blockchain to Tackle the Issues in Pharma Supply Chain. IEEE Open Journal of the Computer Society. 2021 Jan 5;2:26–37.
37. Gonzales HM, Fleming JN, Gebregziabher M, Posadas-Salas MA, Su Z, McGillicuddy JW, et al. Pharmacist-Led Mobile Health Intervention and Transplant Medication Safety: A Randomized Controlled Clinical Trial. Clin J Am Soc Nephrol [Internet]. 2021 May 8 [cited 2024 Oct 28];16(5):776–84.
38. Kataria G, Dhyani K, Patel D, Srinivasan K, Malwade S, Syed Abdul S. The smart pill sticker: Introducing a smart pill management system based on touch-point technology. Health Informatics J [Internet]. 2021 Nov 1 [cited 2024 Oct 28];27(4).
39. Cobelli N, Chiarini A. Improving customer satisfaction and loyalty through mHealth service digitalization: New challenges for Italian pharmacists. TQM Journal. 2020 Nov 4;32(6):1541–60.
40. Alshehri N, Alanazi A. Pharmacists' Perceptions on Safety Alerts of the Drug Utilization Review (DUR) in Electronic Health Records in a Tertiary Healthcare Hospital. Pharmacy (Basel) [Internet]. 2023 Jul 20 [cited 2024 Oct 28];11(4):119.
41. Balestra M, Chen J, Iturrate E, Aphinyanaphongs Y, Nov O. Predicting inpatient pharmacy order interventions using provider action data. JAMIA Open [Internet]. 2021 Jul 1 [cited 2024 Oct 28];4(3).
42. van der Nat DJ, Taks M, Huiskes VJB, van den Bemt BJF, van Onzenoort HAW. A comparison between medication reconciliation by a pharmacy technician and the use of an online personal health record by patients for identifying medication discrepancies in patients' drug lists prior to elective admissions. Int J Med Inform. 2021 Mar 1;147:104370.
43. Aldughayfiq B, Sampalli S. Digital Health in Physicians' and Pharmacists' Office: A Comparative Study of e-Prescription Systems' Architecture and Digital Security in Eight Countries. OMICS [Internet]. 2021 Feb 1 [cited 2024 Oct 28];25(2):102–22.
44. Peltoniemi T, Suomi R, Peura S, Lähteenoja MNY. Electronic prescription as a driver for digitalization in Finnish pharmacies. BMC Health Serv Res [Internet]. 2021 Dec 1 [cited 2024 Oct 28];21(1):1–9.
45. Foreman C, Smith WB, Caughey GE, Shakib S. Categorization of adverse drug reactions in electronic health records. Pharmacol Res Perspect [Internet]. 2020 Apr 1 [cited 2024 Oct 28];8(2):e00550.
46. Chapman AB, Peterson KS, Alba PR, DuVall SL, Patterson O V. Detecting Adverse Drug Events with Rapidly Trained Classification Models. Drug Saf. 2019 Jan 21;42(1):147–56.
47. Jungreithmayr V, Meid AD, Bittmann J, Fabian M, Klein U, Kugler S, et al. The impact of a computerized physician order entry system implementation on 20 different criteria of medication documentation-a before-and-after study. BMC Med Inform Decis Mak [Internet]. 2021 Dec 1 [cited 2024 Oct 28];21(1).
48. Aung MM, Maneetham D, Chawaphan P. Automatic Pill Dispenser for Pharmacy. International Journal of Engineering Trends and Technology. 2023 Dec 1;71(12):61–8.
49. Roh H, Shin S, Han J, Lim S. A deep learning-based medication behavior monitoring system. Math Biosci Eng [Internet]. 2021 Jan 1 [cited 2024 Oct 28];18(2):1513–28.
50. Manning SE, Wang H, Dwibedi N, Shen C, Wiener RC, Findley PA, et al. Association of multimorbidity with the use of health information technology. Digit Health [Internet]. 2023 Jan 1 [cited 2024 Oct 28];9.
51. Galozy A, Nowaczyk S, Sant'Anna A, Ohlsson M, Lingman M. Pitfalls of medication adherence approximation through EHR and pharmacy records: Definitions, data and computation. Int J Med Inform. 2020 Apr 1;136:104092.
52. Manyazewal T, Woldeamanuel Y, Holland DP, Fekadu A, Blumberg HM, Marconi VC. Electronic pillbox-enabled self-administered therapy versus standard directly observed therapy for tuberculosis medication adherence and treatment outcomes in Ethiopia (SELFTB): protocol for a multicenter randomized controlled trial. Trials [Internet]. 2020 May 5 [cited 2024 Oct 28];21(1).
53. Chalasani SH, Syed J, Ramesh M, Patil V, Pramod Kumar TM. Artificial intelligence in the field of pharmacy practice: A literature review. Exploratory Research in Clinical and Social Pharmacy. 2023 Dec 1;12:100346.