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Review

Digital health technologies in Kurdistan region of Iraq: a narrative review of enhancing healthcare accessibility and quality

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Abstract
Digital health refers to the use of information and communication technologies to increase healthcare's efficiency and accessibility. Healthcare systems are increasingly recognizing the need to integrate modern technologies to optimize patient outcomes. However, promising innovations and integration into national strategies face challenges, especially in low- and middle-income regions, including Kurdistan. This review describes several digital health technologies in Kurdistan, including software implementation for data management, such as District Health Information Software 2, the establishment of telemedicine services, and the utilization of machine learning algorithms for mortality prediction, particularly during the COVID-19 pandemic. Despite the numerous advantages of digital health technologies, several challenges remain in their widespread adoption, such as the lack of a comprehensive regulatory and legal framework for the free adoption and use of digital technologies, technical challenges, and issues with patient satisfaction. Our key recommendations are the development of a robust digital health infrastructure to integrate digital health innovations, enhancement of healthcare professionals' digital literacy through targeted training programs, and implementation of telemedicine services in remote and rural areas. In conclusion, digital health technologies, including machine learning, telemedicine, and electronic health records, have assisted healthcare accessibility and quality in Kurdistan, particularly in underserved areas, by providing immediate access to patient data and facilitating decision-making through clinical decision support tools, remote consultations, and cost-efficient healthcare services**.**

Keywords Digital health technologies · Kurdistan Region of Iraq · Healthcare system · Telemedicine · Electronic health records · Machine learning

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1 Introduction

Digital health is a rapidly developing technology with great innovation opportunities to enhance healthcare efficiency, delivery, and accessibility by using the power of digital technology to collect, analyze, store, and distribute health data [1]. This growing consensus among the global health community indicates that the strategic and innovative utilization of digital information and communication technologies will be crucial in accomplishing all 17 Sustainable Development Goals (SDGs), as these innovative applications are crucial to ensure that an additional 1 billion individuals utilize universal health coverage (UHC), and more people receive sufficient protection against health emergencies, which further enhances health and well-being [2]. Digital technologies have the potential to increase illness diagnosis and treatment accuracy, improve individual healthcare delivery, and empower patients to take more control of their health and make better decisions [3]. Healthcare organizations are increasingly understanding the importance of incorporating modern technologies to improve patient outcomes from symptom detection to treatment and long-term care. This change has the potential to increase access to healthcare, reduce costs, and provide individualized services [4]. The advancement and execution of digital health vary considerably among countries such as Japan and China, allocating considerable resources to this domain. The World Health Organization (WHO) defines digital health as a comprehensive field that includes electronic health (eHealth) and developing disciplines such as computer science and artificial intelligence (AI) [5]. Mobile health (mHealth), digital decision support systems [6], electronic health records (EHRs) [7], and telemedicine are examples of digital health technologies (DHTs). In terms of therapeutics, the utilization of patient-specific clinical data and EHRs may help patients obtain individualized treatments [4]. EHRs provide a comprehensive digital record of a patient's health across several clinics and experts. This permits the reporting and tracking of adverse medication events, which improves patient safety and the quality of treatment [1, 8]. Furthermore, EHRs can play a pivotal role in the number of surgical outreach trips to low- and middle-income countries (LMICs) by converting critical patient data from paper charts to a digital format to enhance the safety and quality of care during outreach trips [9].

DHTs involving telemedicine enable remote patient monitoring and teleconsultations, such as webcams and mobile devices with cameras and communication capabilities, to play a key role in enhancing healthcare by improving professional knowledge and skills, thereby supporting healthcare evolution [10]. The utilization of telemedicine and telecare systems has markedly increased during the COVID-19 pandemic, leveraging previous successful implementations in the management of infectious disease epidemics including SARS in 2003, MERS in 2015, and Ebola from 2014 to 2016. According to a report from the Langone Health Center in New York City, a significant 683% surge in telemedicine visits has been observed, rising from 102.4 to 801.6 visits on a daily basis within one month [11, 12]. The expense and absence of an adequate medical transport system render telemedicine the sole viable alternative for rural populations to access appropriate medical care [13]. Therefore, certain LMICs, such as India and Lebanon, have established telemedicine platforms that are widely used in the COVID-19 era [14].

The mobile health (mHealth) system is another example of a DHTs that aids in collecting patient data, providing education and assistance, tracking health status, and allowing users to report adverse effects directly from their cellphones. This facilitates a more immediate and convenient way for patients to report problems, leading to the faster identification of safety concerns and enhanced patient engagement and data quality [15]. By 2025, there are expected to be 5.6 billion mobile connections, primarily smartphones, by more than 60% of the global population [16]. In LMICs, mHealth interventions demonstrate considerable potential for mitigating noncommunicable diseases (NCDs) by improving clinical outcomes, fostering healthy habits, and strengthening treatment adherence [17]. Such interventions are effective in Sub–Saharan Africa (SSA) and East Asia for maternal health, in addition to assisting healthcare professionals via decision aids and data collection tools [16]. Digital Health Technologies can increase access to healthcare services, promote direct communication with healthcare providers, and enable complete access to recorded data to facilitate improved surveillance and clinical decision-making by lowering healthcare costs [18]. Despite widespread interest in Adopting DHTs, particularly in LMICs, the integration of appropriate digital health tools faces significant challenges due to limited access to healthcare facilities and skilled healthcare workers, particularly in rural and remote areas [10, 19], with remote access to healthcare services providing a promising solution to bridge this gap and expand healthcare accessibility for underserved populations [1].

The Kurdistan region of Iraq (KRI) is an independent area in northern Iraq with four cities: Duhok, Erbil, Sulaymaniyah, and Halabja [20]. The healthcare system in Iraq's Kurdistan region has several significant difficulties that impact the utilization and accessibility of basic medical care. A cross-sectional survey identified a key issue: the

common notion that primary health care (PHC) centers provide inadequate services, with around 83.21% of people avoiding clinics because they believe the services are insufficient. This unhappiness in service quality is a significant barrier to receiving PHC. Overall, patient satisfaction was low, and only 31.4% of patients expressed pleasure with the treatments they received [21]. Moreover, there is a significant shortage of formalized structures for monitoring and addressing physical, mental, and developmental disabilities, including limited rehabilitation services such as speech and language therapy (SLT) and occupational therapy (OT) [22].

The health workforce in KRI has grown in recent years, but remains insufficient in terms of both quantity and quality, with significant imbalances across specialties and geographical locations. Retaining healthcare staff in certain areas and specialties has proven challenging, resulting in heavy workloads for healthcare professionals in underserved regions. Additionally, there is a lack of staff with expertise in planning, management, monitoring, and evaluation, further hindering the efficiency of the healthcare system. Professional development programs are limited, and lack dedicated budgets that discourage professional growth. Additionally, there are no clear financing initiatives to achieve universal health coverage (UHC), and the government's allocated budget for health is insufficient to meet the growing demands of the population, such as shortages of medical supplies and equipment. Another concern associated with challenges in the Kurdistan healthcare system is the administration issue of pharmaceutical sector regulation, inadequate market monitoring, counterfeit drugs, and suboptimal drug quality, which has led to a critical insufficiency of medications for chronic diseases, cancer, and life-saving treatments, consequently leading to barriers in the management of chronic diseases. Issues such as poor staff-patient communication, lack of patient rights implementation, and inequitable access have also been identified [23, 24].

Quality of care in PHC systems is inconsistent and not systematically measured, as most staff members lack training in modern quality improvement methods. Physicians are overburdened with heavy workloads, while nurses remain underutilized and often perform tasks below their potential owing to insufficient training and unclear roles. Health information systems are not effectively utilized, with fragmented and inefficient data collection processes, limited analysis, and virtually non-existent patient record-keeping in ambulatory centers, hindering informed decision-making. Addressing these multifaceted challenges requires the utilization of DHTs for streamlined management and policymaking. This shift could lead to improved health outcomes and reduced costs while promoting more sustainable and equitable health care in Kurdistan [25]. Furthermore, patient satisfaction is a result of public ignorance of hygiene and sanitation standards in private hospitals [26]. Figure 1 shows a summary of the healthcare challenges faced by the Kurdistan region.

Following ISIS's assault on portions of Iraq in 2014, Kurdistan had to accept a huge number of internally displaced citizens, as well as 250,000 Syrian refugees. This puts pressure on KRI's public health system [20]. Since then, attempts have been made to develop digital health projects in Kurdistan, such as the District Health Information Software 2 (DHIS-2) and a health information system platform [20]. These initiatives also included the integration of telemedicine services to improve access to healthcare services in Kurdistan underserved areas. Furthermore, the adoption of the electronic hospital (eHospital) system at Shorsh General Hospital (SGH) in Kurdistan has drastically improved healthcare delivery. This signaled the transition from paper-based to electronic systems, which improved the efficiency and accessibility of patient records, facilitated more effective communication among healthcare providers, and reduced administrative burdens and errors, thereby supporting evidence-based practices by enhancing decision making and improving health outcomes. This successful implementation not only improves medical treatment through better data management but also sets a good model for future eHealth improvements in Kurdistan [27]. The purpose of this review was to identify the possibilities of adopting digital health initiatives to improve medical quality and accessibility in Kurdistan. We explore the potential of implementing digital health tools to address the healthcare gaps in KRI, while addressing the challenges that hinder the effective utilization of DHTs in this fragile area by providing actionable recommendations to enhance the quality of medical care.

1.1 Kurdistan's digital health landscape

The Kurdistan healthcare system faces significant obstacles and limitations, especially regarding primary care and medical infrastructure, as rural areas are unable to obtain essential medical facilities and specialist doctors. One of the WHO's suggestions for ensuring accurate and consistent data is to computerize the healthcare system. However, Kurdistan lacks a network system for timely information sharing, which causes problems with the structure, precision, comprehensiveness, and accessibility of statistical data [28]. A project was launched to build and deploy a health monitoring and epidemiological surveillance system in Kurdistan, with the goal of collecting data on health determinants,

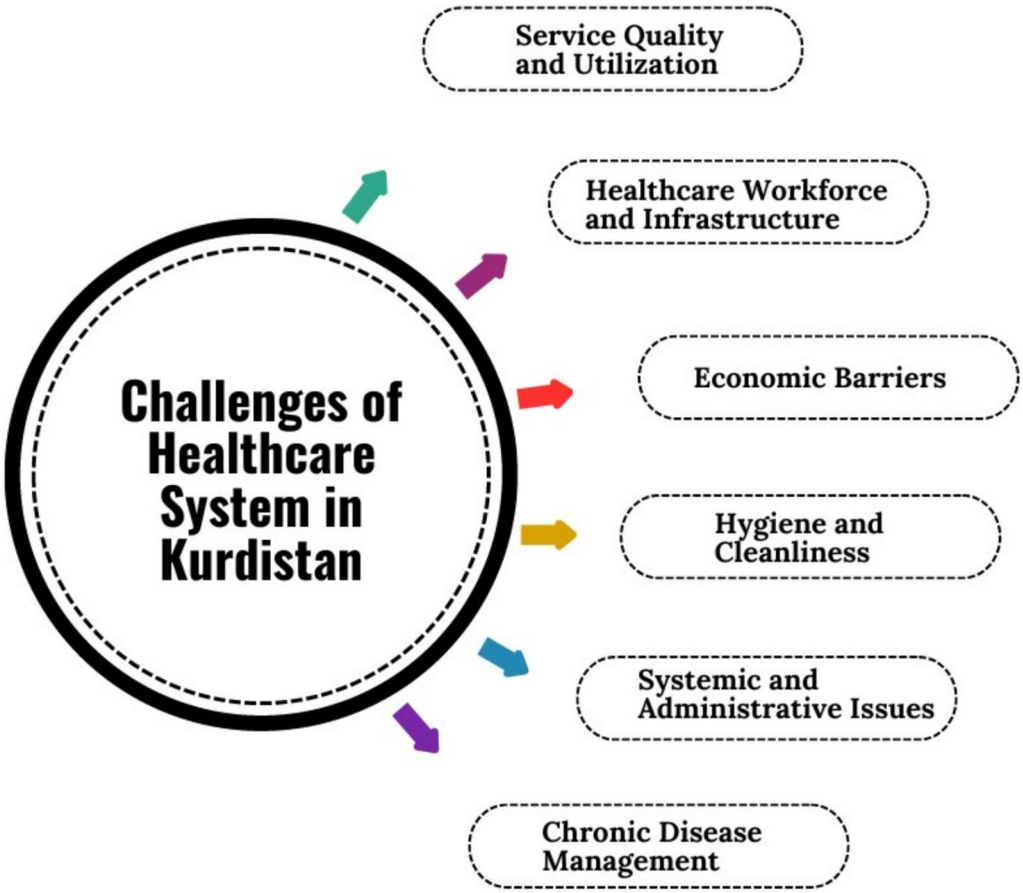

Fig. 1 Primary challenges of the healthcare system in the Kurdistan region of Iraq

births, deaths, and healthcare service performance. The system allows medical professionals to collect, evaluate, and interpret health data using an international code system and improve access to and quality of public healthcare [20]. Patients in rural or remote regions frequently have to travel miles to central facilities for essential appointments due to an enormous disparity in the distribution of doctors, as shown in Fig. 2, the number of suburban experts is significantly lower than that of urban specialists, particularly in Sulaymaniyah city [29].

This difference makes it difficult for residents outside urban centers to obtain prompt medical care, as both patients and their caregivers must stay overnight, resulting in significant expenditures and inconvenience. Nonetheless, the use of electronic health initiatives, such as telemedicine, will ease the delivery of specialist treatment and improve healthcare access for rural patients. Offering specialist consultations near people's hometowns, for example, can be a cost-effective solution because it reduces the need for long-distance travel while increasing availability of specialist physicians [27, 29]. Data collection in statistical departments is generally done on paper, with only a few offices employing simple computer tools to collect local data. Furthermore, the absence of a connection between hospital databases complicates data collection and access, which are frequently disorganized, missing files, or inaccurate/unavailable information, posing a consistent possibility for incomplete and inaccurate health statistics. Entering data into the Kurdistan health information system (HIS) has been proposed as a top priority for improving data collection and analysis. The statistics department workers received technical explanations concerning the eHealth system, followed by instructions on how to enter health information into the system.

The introduction of an Internet-based eHospital system at SGH in Sulaymaniyah exemplified an effective method of managing hospital systems by converting the traditional paper-based system into a totally electronic system. The proposed system proved to be a superior option to paper-based methods. This confirms the technology's ability to improve patient care, increase administrative efficiency, facilitate patient care coordination, and guarantee safety and quality [27]. Thus, this approach can be utilized in other hospitals in Kurdistan, especially in remote areas, as it helps save time through swift data retrieval and a streamlined workflow to decrease the possibility of delaying patient care.

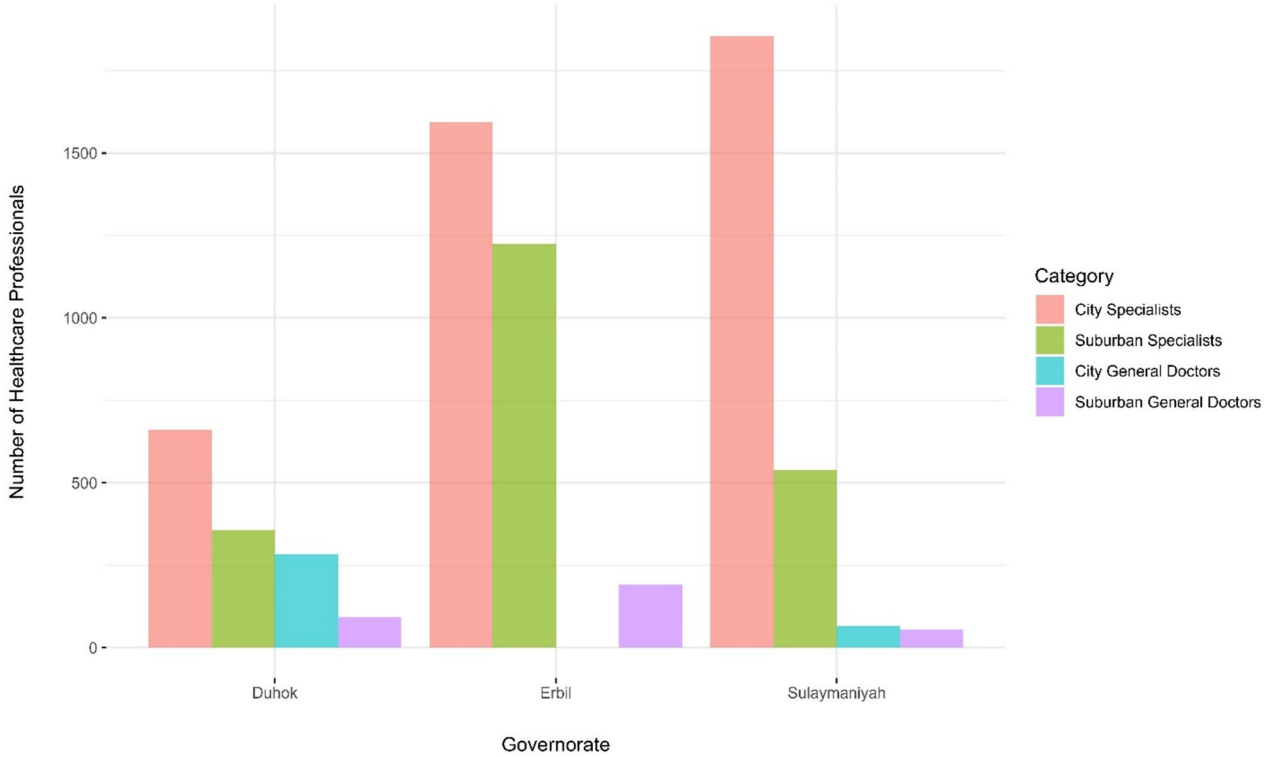

Fig. 2 Distribution of healthcare professionals across the cities of the Kurdistan Region of Iraq [29]

Moreover, it reduces costs by lowering expenses for paper, storage, and administrative errors while improving efficiency and resource allocation in healthcare delivery. A questionnaire was created to assess the feasibility of establishing telemedicine in Duhok. Of the respondents, 58.8% expressed a strong interest in using such a platform, especially in the setting of medical emergencies like COVID-19 [30]. Similarly, a survey of 350 physicians and nurses examined the adoption of telemedicine in Kurdistan, presented an implementation strategy, and evaluated healthcare providers' acceptance and utilization in hospitals. This study identified elements affecting telemedicine adoption, such as usability, utility, personality characteristics, and external influences. The findings underscored the necessity for centralized databases and training of healthcare personnel to improve implementation [29]. Therefore, bridging the gaps in the implementation of DHTs can assist in providing better health quality across Kurdistan countries.

1.2 DHT applications in enhancing healthcare accessibility and quality in Kurdistan

1.2.1 Electronic health records

Electronic health records (EHRs) are digital health tools that can significantly improve healthcare accessibility and quality in Kurdistan. EHRs improve healthcare by providing instant access to patient information, enhancing care coordination, and supporting decision making with clinical decision support tools. EHRs also collect and analyze health data for better practices, engage patients through portals, ensure regulatory compliance, and increase cost efficiency by reducing paperwork [31]. In Kurdistan, EHRs enhanced communication and connectivity between healthcare providers and patients, improving the continuity of care and reducing adverse events. Despite challenges such as patient identification, interoperability, privacy concerns, and infrastructure issues, EHRs have proven beneficial in streamlining administrative processes, ensuring accurate reporting, and providing more efficient healthcare services [32]. A study investigated the integration of maternal and child healthcare services (MCHCS) into the Kurdistan Regional Government Health Information System (KRG-HIS), which enhanced data collection and analysis in 2020, providing reliable data for planning, policy implementation, and health monitoring with more than 15,000 paper files retrieved from storage and entered into the system. Scaling up the KRG-HIS continues to deliver updated maternal and child health statistics, enabling

policymakers to identify strengths and weaknesses and implement measures to improve health outcomes by producing reliable health information [28].

Another study that explored physicians acknowledged that hospital management would likely support the implementation of EHRs systems, but they voiced concerns regarding the potential impacts on their autonomy and the doctor-patient relationship. Despite this concern, this study found that physicians felt that hospital management would provide adequate support, including involvement in the process, effective training, and a user-friendly system. Additionally, they believed that EHR systems would enhance care quality and improve work schedules [33]. Similarly, in Uganda, the locally developed EHR platform Streamline offered essential functionalities, including patient monitoring, stock-level management, early warning notifications, and the ability to detect prescription errors, which considerably contributed to the improvement of healthcare delivery for over 60,000 vulnerable patients in the rural region of Southwestern Uganda. [34, 35]. In Rwanda, OpenMRS played a crucial role in improving healthcare services by efficiently managing patient records, supporting informed decision-making, and providing timely alerts and reminders to healthcare professionals, most of whom utilized EHRs and perceived it as well accepted, appropriate, and effective despite infrastructure limitations of 25% [35, 36]. Therefore, these technologies improve the way healthcare is delivered overall by streamlining administrative work and offering quick access to medical treatments in fragile states, including Kurdistan.

1.2.2 Health monitoring system

Establishing a health-monitoring system is achievable even in regions with socio-political tensions, relying on partnerships among multiple stakeholders. In the KRI, a public health surveillance system was successfully developed during the pilot phase, connecting 29 health facilities and training over 250 healthcare professionals. The system has recorded over 400,000 disease events from primary healthcare centers and 200,000 from hospitals, making it one of the largest sentinel surveillance systems in the region. Its epidemiological monitoring capabilities provide accurate and timely health information that is essential for effective policymaking and health practices. Data stored in the central database, currently based in Italy, are anonymized and include user IDs, demographics, diagnoses, and other statistical details [20]. Furthermore, a functional health monitoring system, such as DHIS-2, is required for the routine and timely gathering of health information. One study explored the role of DHIS-2, a JavaScript-based platform that gathered and maintained health records by directly obtaining data from peripheral sources and transferring it to central servers for analysis and management [28], while also allowing for temporary data backups in a local database owing to network problems or missing data [20]. The platform played a major role in improving public health by supporting evidence-based decision making through visual dashboards and reports.

Additionally, a case study explored the development of a user-friendly database created using Java with registration and login forms for patients, doctors, and pharmacists. Patients can create health cards that track their medical history, which doctors can use to review past conditions and treatments. Doctors and pharmacists also accessed and managed patient data and viewed prescriptions to ensure that the appropriate treatments were provided. The findings showed improvements in efficiency, data storage, time savings, and security, confirming that it worked well for everyday use. This system helps doctors make accurate diagnoses, avoid prescribing the wrong medication, and improve overall healthcare in the region [37]. Three other case studies described the implementation of a health-monitoring system in Iraq. The study described the successful implementation of a health monitoring system in 59 primary care centers, in which the authors highlighted the importance of establishing multiple stakeholder partnerships for the success of such project implementation [38]. Similarly, a pilot implementation of the DHIS2 routine immunization (RI) module in Kano State, Nigeria resulted in substantial enhancements in data reporting quality. Within a year, National Health Information Management System (NHMIS) reporting attained 95% for completeness and timeliness of the module, demonstrating the effectiveness of ongoing strategy execution. Systematic reviews conducted by the DHIS2 Core Group facilitated the identification of deficient health facilities, which led to a decrease in data transmission and entry inaccuracies. Considering barriers including restricted training resources, inadequate internet access, and personnel turnover, the pilot yielded better reporting accuracy and superior data quality. Therefore, the achievements and insights gained were implemented for expansion across all states in Nigeria [39].

1.2.3 Telemedicine and mHealth

Telemedicine has the potential to significantly enhance the quality and accessibility of healthcare in Kurdistan by using information and communication technology to bridge the disparity between patients and healthcare practitioners.

During the COVID-19 pandemic, telemedicine has enabled individuals to receive medical guidance and therapy without having to visit a doctor in person, allowing for the delivery of timely, safe, and cheap care [40]. With about 1.05 billion mobile connections by 2025, the widespread use of mobile devices will not only facilitate the deployment of telemedicine services worldwide but also enable the delivery of personalized healthcare [41]. Telemedicine improves long-term health outcomes and preventative care access, particularly for individuals with financial or geographical constraints, by minimizing the need for in-person visits, promoting patient accessibility, and encouraging patient involvement [42]. It also helps with decision-making, remote monitoring, and collaborative patient management [43]. In Duhok City, a team provided remote training during live surgeries at the Azadi Teaching Hospital of Duhok (ATHD) and virtual eye consultations at the Domiz Syrian refugee camp. The VSee system's simplicity and portability enabled over 26 virtual consultations at Domiz and 7–10 telesurgery trainings and demonstrations per day for three days at ATHD. These findings show that VSee is effective for telesurgery and remote consultation, indicating that it may be used in a variety of elements of patient care and health education in the city [44]. As a result, by using telecommunications for healthcare services, telemedicine can assist in overcoming obstacles to inadequate healthcare in remote areas [27].

Another study evaluated the usability of telehealth services in Libya during the COVID-19 pandemic via a web-based survey that included 2,512 participants. Approximately 50 percent deemed telehealth services beneficial, with 61.5% regarding them as helpful for communication and healthcare provision. Research has emphasized telehealth's capacity to enhance accessibility, decrease expenses, and mitigate COVID-19 risks [45]. In KRI, mobile health can improve public health and medical practices through the use of mobile devices, and specialized software to support healthcare and public health practices is crucial to emergency management systems. Mobile health applications can assist patients in documenting and communicating possible medical conditions, tracking health information, gaining access to health-related information, automating duties of healthcare practitioners, and interacting with electronic or personal health records [46]. Email and social media platforms can also improve patient involvement and communication, but maintaining the accuracy of health information is still essential for preventing misinformation [47]. Mobile health applications have emerged as a cost-efficient and accessible means of providing high-quality healthcare services, especially in LMICs with vulnerable health systems [41]. For example, a study was conducted to create a smartphone application with offline functionality to detect difficulties in obstetric admissions from refugee camps in Kurdistan. The mobile application was considered a viable tool to enhance communication, optimize referrals, and minimize delays with offline functionality, hence improving healthcare delivery and outcomes in rural areas of KRI [48].

These applications address various issues to enhance healthcare delivery in the area, including infrastructural, cultural, legal, and ethical barriers. They do this by offering a wide range of features such as prescription management, telehealth services, remote monitoring, symptom checkers, and fitness tracking [49]. Likewise, to enhance maternity, neonatal, and child health (MNCH), Malawi implemented a mHealth program called Chipatala Cha Pa Foni (CCPF). CCPF intended to augment health literacy, refine care-seeking behaviors, and improve access to health services for pregnant women, caregivers, and women of reproductive age. It offered a toll-free helpline for medical guidance and referrals, in addition to text and voice reminders regarding MNCH subjects. In four high-mortality districts of Balaka, Nkhota-Kota, Mchinji, and Mulanje, CCPF mitigated healthcare barriers by reducing time and travel expenses. Assessment revealed substantial enhancements, encompassing enhanced antenatal care engagement, prompt breastfeeding initiation and improved maternal health awareness. User satisfaction was elevated, with 94% expressing satisfaction with hotline services and 98% with reminder notifications. Moreover, 75% of calls were addressed without referrals, alleviating the strain on rural health centers [50].

1.2.4 Machine learning algorithms in health

Machine learning (ML) can contribute to the enhancement of care quality and accessibility in Kurdistan by allowing for more precise diagnoses and tailored treatment programs [51]. Through predictive analytics and medical imaging analysis, machine learning models can help with early condition detection, increase patient outcomes, and reduce strain on healthcare institutions [52]. The use of ML to predict the death rate of infectious diseases, including COVID-19, through the development of machine learning algorithms such as decision trees (DTs), was developed using the dataset discovered in Sulaymaniyah city of Kurdistan for coronavirus death and recovery rates from the outbreaks. As a result, the DT algorithm achieved the highest classification accuracy (96.7%) to determine which factor had a major effect on patient death among COVID-19 patients. This helped medical personnel prioritize high-risk patients, improve treatment protocols, and guide targeted preventive measures [53]. Another study demonstrated the efficacy of deep learning algorithms in forecasting long-term COVID-19 symptoms throughout the recovery period, attaining an accuracy of 99.83% on the

testing set. The study further introduced the Kurdistan Long-Term COVID Dataset (KLTCD), which includes data from 3500 COVID recovery patients in Erbil City. The findings indicated that deep learning can proficiently forecast both normal and abnormal occurrences in these datasets, underscoring its potential for forecasting long-term COVID outcomes [54]. Furthermore, a study proposed a combined prediction model for diagnosing gestational by utilizing a dataset from the Kurdistan region. Several machine learning models have been employed, including k-means clustering for data reduction, the elbow method to determine the optimal k value, the Mahalanobis distance to identify relevant clusters, and various classification methods, such as decision tree, random forest, SVM, KNN, logistic regression, and Naïve Bayes. The results showed that combining these techniques significantly improved the prediction accuracy of gestational diabetes [55]. Similarly, one study applied four machine learning techniques in Nigeria: Logistic Regression, Random Forest, DT, and Support Vector Machine. The findings revealed the key determinants influencing medical insurance coverage utilizing ML algorithms among individuals to help policymakers improve healthcare access and affordability [56]. Therefore, these ML approaches hold transformative potential for optimizing healthcare delivery and improving patient outcomes.

1.3 Challenges and barriers to the adoption of digital health in Kurdistan

Despite their various benefits, DHTs face several difficulties in mainstream use. These include incorporating novel resources into existing healthcare organizations and maintaining data confidentiality and safety, leading to issues associated with patient data privacy. The income and socioeconomic position of telehealth platform users can also impact its effectiveness. In the Erbil governorate, these issues can be categorized into four primary areas: improper delivery of health services, difficulties with the health workforce, resource shortages, and inadequate information technology [57]. The primary challenges preventing users in Duhok City from adopting telemedicine technology are sudden Internet connection issues and the challenge of acquiring the necessary technical skills [44]. Currently, the primary barrier to the limitless deployment and utilization of digital technology in healthcare is the absence of a comprehensive and outmoded regulatory and legal framework. One of the key concerns for regulatory bodies is ensuring that patients can utilize digital technologies with confidence, ensuring that their privacy and data are secure. The sensitivity of health data raises substantial privacy problems when digitized [58]. A descriptive study in Kurdistan showed that the absence of clear frameworks negatively influenced healthcare professionals to adopt telemedicine [29]. Likewise, a mixed-method study in Ghana revealed that healthcare professionals expressed concerns about DHTs, specifically around patient data security, consent, and system reliability. Despite access limitations, challenges such as credential misuse and unauthorized access persist as substantial threats. While 81% of respondents underscored the necessity for clear authorization requirements, internal security concerns, such as credential sharing and inadequate log-off practices, posed significant challenges. Furthermore, 75% of participants indicated apprehensions regarding external risks including hacking and malware, while 80% of staff reported insufficient training on DHT security. System failures were a significant problem, with 86% voicing doubts regarding unforeseen shutdowns that compromised patient safety [59]. Hence, it is crucial to ensure that providers of digital services follow the best practices to preserve patient data privacy and security [4].

Insufficient digital health literacy in specific social groups, resistance to change among healthcare practitioners, technological difficulties, and resource limitations provide considerable hurdles to the adoption of digital health. The proliferation of non-scientific, biased, and incompatible online health information can mislead people, fostering unreasonable expectations and hindering healthcare decision-making. A cross-sectional study on the adoption of electronic health records in public hospitals in Kurdistan found that healthcare providers felt uncertain about their autonomy when establishing the electronic health records system in public hospitals, raising the issue of healthcare providers and patients being resistant to change and not fully understanding the benefits of DHTs [1, 33]. They stated that EHR may have a negative impact on physicians' attitudes as a result of increasing clinical practice management and surveillance, as well as legal and ethical issues on physicians' autonomy [33]. Similarly, a cross-sectional survey was performed in Taiwan including 1000 randomly chosen physicians from 50 regional acute hospitals. The results suggested that four primary characteristics substantially affect physicians' desire to embrace electronic medical records, with attitude being the most significant one. The research underscored the significance of perceived utility, professional autonomy, and pragmatism in facilitating EHR adoption, demonstrating an explanatory power of 78.4%. The results demonstrated the necessity of acknowledging physicians' professional autonomy and pragmatic considerations while advocating for such systems in clinical settings [60].

The application and assessment of digital health technologies confront obstacles owing to limited resource capacity, such as poor infrastructure, particularly in resource-constrained regions. Digital health literacy in the general community is critical for acceptance of digital health solutions. The scarcity of competent practitioners in digital health hinders the

broad adoption of these applications. Furthermore, the successful implementation of digital health interventions is hampered by insufficient regulations and governance frameworks [61]. The deployment of DHTs is constrained by a severe shortage of competent health staff, lack of reliable health information, and insufficient monitoring and evaluation capability. Significant differences in healthcare access across urban and rural areas and among different socioeconomic categories limit the effective implementation of DHTs in Kurdistan [62, 63].

1.4 Policy recommendations

To promote the adoption and implementation of DHTs, it is essential after identifying the challenges linked to the implementation of these technologies, is to establish a local digital health strategy by the Kurdistan government that emphasizes data security and privacy along with international organizations and stakeholders. Prior establishment of a national eHealth strategy in Kurdistan to increase healthcare efficiency, access and quality, demands further reviewing the current eHealth environment [64]. This is to identify present initiatives and projects, as well as resolve gaps and guide the creation of new digital health solutions by the government and policymakers to promote transparency and involvement in the eHealth strategy to increase return on investment and guarantee that resources are used efficiently. Regular reporting of progress and outcomes will maintain trust and demonstrate the value of digital health initiatives among Kurdish people [65].

This plan should encompass regulatory frameworks, governance systems, human capabilities, and funding by prioritizing the strengthening of local governance and management capacity, along with compliance to global standards such as Global strategy on digital health 2020–2025 by the WHO to enhance efforts for strong health-financing mechanisms, and engaging with the private sector [10, 66]. Thus, the digital Bangladesh initiative as a framework transformed the healthcare sector, contributing to the improvement of service delivery and accessibility during the Covid-19 pandemic, particularly in rural areas of Bangladesh [67]. This experience confirms the similar benefits of having a DHTs action plan to follow in fragile states, such as Kurdistan.

Secondly, investing in digital infrastructure, including data centers, fiber-optic cables, mobile networks, servers, and internet connectivity, enables communication, data access, and digital services which therefore, leads to improving patient outcome through accessibility to essential services and improving connectivity in remote areas [68]. A significant achievement in Saudi Arabia's digital health transformation is the introduction of patient portals. These portals are designed to empower patients to take an active role in managing their health. They served as secure digital platforms that grant patients access to personal health information and enable direct communication with healthcare providers. Thus, studies have shown that these systems promote preventive care and help manage chronic diseases more effectively. Additionally, utilizing patient portal in healthcare settings improves patient involvement, facilitates better communication, and reduces healthcare costs [69]. Currently, building on the success of patient portals, Saudi Arabia is advancing towards the implementation of the Unified Health File system. This initiative aims to consolidate all patient information into a single, comprehensive digital record accessible across various healthcare organizations [70].

Thirdly, improving digital literacy for both healthcare professionals and the general public is crucial through focused initiatives that use real-world case studies to illustrate the implications and applications of DHTs and should be incorporated into educational curricula alongside digital health training programs to enhance staff competence and enable better project management and skill development among healthcare workers [71, 72]. It is essential to establish a continuous evaluation process for the community that enables individuals to assess the usability and effectiveness of advanced medical devices. This participatory approach helps to identify areas for improvement and ensures that technological advancements meet the specific needs of local populations [73].

Furthermore, continuous planning and improvement are necessary for long-term success of eHealth strategies. Tools such as the National eHealth Strategy Toolkit can aid in the progressive development of a strategy, with updates based on emerging needs and technological advancements [49]. A study found eHealth toolkit strategies for 34 African countries, and the quality of strategies varied, with nine countries having strong strategies, while only 17 countries implemented moderate strategies [74]. Hence, the eHealth Toolkit offered promising roles in enhancing healthcare quality and accessibility in underserved regions.

Lastly, collaboration with multiple stakeholders between developed and developing countries, such as institutional support, the Ministry of Health and the Ministry of Information and Communication Technology, medical providers, civil society organizations for the development and consolidation of national digital health strategies, and the implementation of their action plans, usually requires more resources and capabilities [10, 75]. For instance, telehealth in Australia encouraged patients to engage with healthcare practitioners through telephone or video consultations, facilitating

access to medical care, particularly during the COVID-19 pandemic. This technology expanded in March 2020, numerous telehealth programs are now permanently incorporated into Medicare, enhancing accessibility, especially in remote locations, and minimizing travel requirements. The $4 billion governmental investment in COVID-19 telehealth has facilitated over 85 million services for 16 million patients [76]. Australia also promotes partner nations in developing sustainable health systems through investments in leadership, workforce training, infrastructure, and service delivery. The government allocates resources to international health efforts such as the WHO and the Global Fund, promoting equitable services and emphasizing maternal, child, and reproductive health, as well as non-communicable diseases in fragile states [77]. Hence, collaborations with such countries bridge the gap where physical healthcare infrastructure may be limited, allowing people in remote areas of Kurdistan to access essential services like consultations, diagnoses, and follow-ups without needing to travel long distances.

It is critical for Kurdistan to spend heavily on sustainable health care. Infrastructure is the backbone for the successful implementation of DHTs, as well as human resources, including capacity building and competitive pay for healthcare workers, whereas implementation and maintenance issues, which are not limited to telecommunication networks and power supply, are handled by a strong monitoring and assessment system [78]. The development of assistive technologies and user-friendly interfaces for underprivileged communities and persons with disabilities also requires collaboration with technology businesses and development organizations to address concerns about physician autonomy and patient trust [61, 79]. The Kurdistan community leaders should further promote regional efforts in digital health research and development to promote innovative thinking, develop tailored solutions, and contribute to global health advancements [80]. While the findings suggest a positive impact, there is a need for more ongoing and thorough studies to precisely determine the specific strategies in which DHTs can contribute to healthcare improvements in the Kurdistan region of Iraq.

2 Conclusion

Digital health technologies have transformed health care by enabling accurate diagnoses, effective treatments, and improved patient engagement, leading to better outcomes. The use of machine learning, telemedicine, and electronic health records has improved healthcare quality and accessibility in Kurdistan, a region facing many challenges in its health system by providing remote consultations, complete access to digital patient data by healthcare professionals, and cost-efficient healthcare services. Despite these benefits, regulatory and security concerns have yet to be addressed, limiting the use and implementation of such technologies due to technological issues, the absence of legal frameworks, and lack of health infrastructure. Leveraging digital health, such as health monitoring systems, telemedicine, mHealth, and machine learning demands, developing a supporting policy and regulation by collaborating with international and local partners, with effective community participation. Furthermore, by investing in digital health infrastructure and human resources, Kurdistan can attenuate the healthcare burden by utilizing digital health technologies to significantly improve healthcare quality and accessibility, particularly in Kurdistan's rural areas.

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