

Digital Transformation in Healthcare: Current Trends and Challenges

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ABSTRACT

Background: Digital health technologies have the potential to transform the healthcare delivery landscape by facilitating remote monitoring, improving disease management, and offering more personalized treatment options. The COVID-19 pandemic acted as a catalyst, driving the integration of telemedicine and telehealth solutions into mainstream healthcare practices. In general, digital health technologies offer significant potential to transform healthcare delivery; however, several challenges must be overcome for their successful implementation. Addressing these challenges will require collaboration, investment, and a comprehensive approach to ensure responsible adoption and maximize the benefits of digital health in improving patient care.

Aim: The primary objectives of this review are to discuss the evolving landscape of digital technology in healthcare and its utilization during the COVID-19 pandemic, as well as to highlight the challenges associated with using digital health.

Method: The publication search was conducted using the PubMed, Web of Science, and Google Scholar databases from 2009 to 2024. The terms used for searching were “digital health technologies” or “artificial intelligence” or “machine learning” or “telemedicine” or “wearable devices” or “mobile devices” or “clinical decision support systems” or “blockchain in healthcare” or “virtual reality in healthcare” or “augmented reality in healthcare” or “challenges in digital health technologies”. We identified 7191 papers related to the digital health area. However, the number of papers discussed in the review was limited to 3414 due to the exclusion criteria.

Conclusion: This review summarizes the current state of the art in the field of digital health, encompassing various technologies such as mobile health, wearable tech, EHRs, artificial intelligence, machine learning, virtual reality, and augmented reality, as well as the challenges in the application of digital technology in health care systems.

Keywords: Health care, digital health technologies, wearable devices, mobile apps, artificial intelligence, virtual reality, augmented reality, challenges

1. INTRODUCTION

The phrase "digital health" has become increasingly inclusive over time, encompassing a wide range of electronically recorded data, applications, technical infrastructure, and communications within the healthcare system. Currently, the spectrum of digital health

technologies has expanded from telemedicine, which was developed before the time of digital technologies, to analysis and utilization of big data, comprehensive health record digitization, IoT, wireless and mobile technology/5G, blockchain, artificial intelligence, machine learning, and wearable monitors (biosensors) [1]. These developments offer better results, more patient involvement in their healthcare process, and earlier diagnosis and interventions.

The unprecedented global crisis of the COVID-19 pandemic, caused by severe acute respiratory syndrome

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coronavirus 2 (SARS-CoV-2) in early 2020, has accelerated the development and implementation of both existing and novel digital health technologies through increasing funding, fast-track policy approvals, enhanced governmental priorities, new private-public partnerships, and the pooling, planning, and design of various collaborative research [2]. Countries and healthcare systems worldwide have been forced to quickly adapt to telehealth and digital innovations to reduce the risk of virus transmission. The specific aim of this review was to compile the current trends, challenges, and future directions of digital health, with special emphasis on its accelerated adoption during the COVID-19 pandemic.

The integration of these technologies represents a paradigm shift in the way healthcare is approached. Despite the optimistic potential of digital healthcare, it is important to address the challenges and moral quandaries associated with the use of digital health technologies. These challenges include issues with data security and privacy, as well as ethical concerns and the need for reasonable laws, which will be discussed further in the text.

In this review, we have discussed the key aspects and trends in digital health, encompassing wearable devices, telemedicine and telehealth, blockchain systems, mobile devices and digital apps, artificial intelligence and machine learning, virtual reality, and augmented reality. The review also focused on the utilization of digital health during the COVID-19 pandemic, the challenges of digital health, and the study's future recommendations. The main challenges in these areas are examined and intensively discussed.

Our study closely aligns with the studies conducted by Senbekov et al. [3] and Akhtar et al. [4], which emphasized the transformative potential of digital health technologies in improving healthcare delivery. The COVID-19 pandemic has served as a key catalyst for integrating digital solutions into standard healthcare practices. The methodologies used in all three studies are similar and demonstrate a commitment to rigorous research practices. A comprehensive literature search across multiple

databases was employed, ensuring a broad perspective on digital health technologies. Our study's approach enables a robust examination of the evolving landscape, and the studies reviewed are more recent than those in the other two works. While all three studies emphasize the transformative potential of digital health technologies, they also highlight the challenges that must be addressed for successful implementation. The insights gained from these reviews will provide a foundation for future research to maximize the benefits of digital health innovations in improving patient care.

2. METHODOLOGY

2.1 Search strategy

In this paper, electronic databases such as PubMed, Web of Science, and Google Scholar were searched from 2009 to 2024 to extract pertinent publications on digital technology in healthcare and its utilization during the COVID-19 pandemic, as well as highlighting the challenges of using digital health. The terms used for the search were “digital health technologies” or “artificial intelligence” or “machine learning” or “telemedicine” or “wearable devices” or “mobile devices” or “clinical decision support systems” or “blockchain in healthcare” or “virtual reality in healthcare” or “augmented reality in healthcare” or “challenges in digital health technologies” with various Boolean operators and truncation.

The flow chart summarizing the search process and results is shown in Figure 1. We downloaded the results of the electronic search into a reference manager library. After removing duplicates, both reviewers independently conducted two-phase selection via title and abstract, followed by a full-text evaluation. We retrieved full-text copies of potentially relevant studies and further assessed them against inclusion/exclusion criteria. At both stages, disagreements were resolved through discussion. We read the articles that met all predefined criteria at the end of the full-text review to confirm their inclusions.

2.2 Inclusion and Exclusion Criteria

For review, we included articles related to the digital health area that have been published in the English

language between 2009 and 2024. The selection criteria are summarized in Table 1.

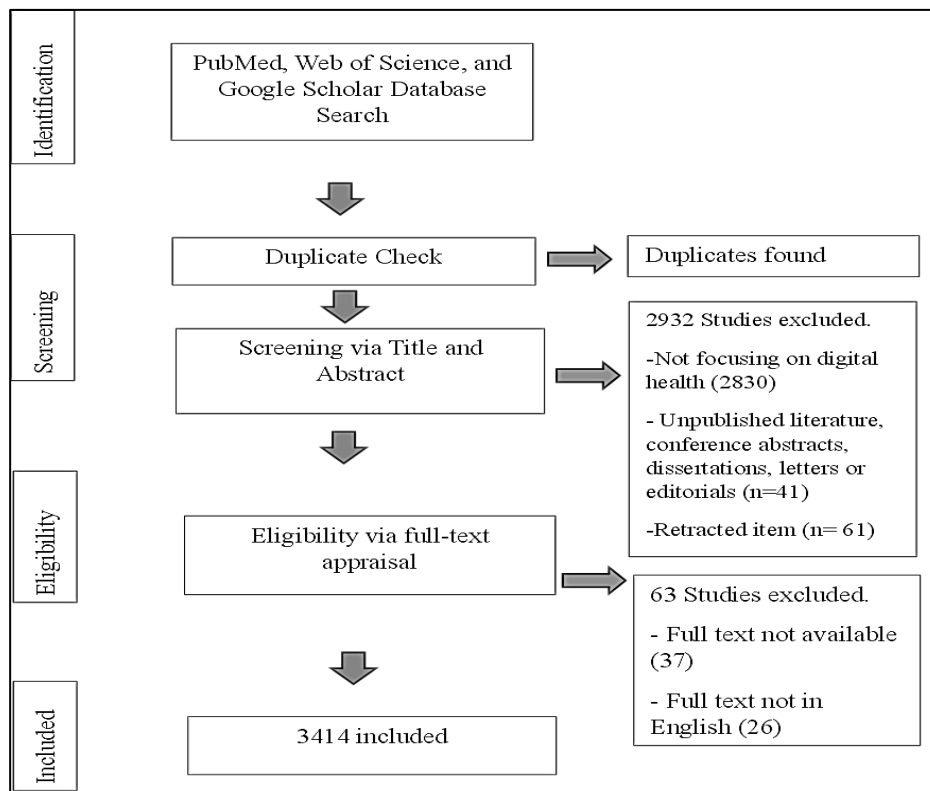


Figure 1. Flow chart summarizing the search process and results

Table 1. Inclusion and exclusion criteria

	Inclusion Criteria	Exclusion Criteria
Language	Studies were conducted in English.	Studies in other languages than English
Timeframe	Publications between 2009 and 2024 were accepted.	Duplicates of the same study
Study design	Empirical papers or review articles where conceptual frameworks were either developed or assessed	Unpublished literature, conference abstracts, dissertations, letters or editorials, white papers
Intervention	Studies were researching the use of digital technology in health care.	a. Reviews that mainly focus on educating healthcare practitioners on the use of digital technology b. Lack of thematic focus where “health” or “digital” were not the main focus
Others	Full-text articles available online	Retracted items

In the following sections, we provide a review and analysis of key aspects and trends in digital health, as well as the challenges of digital health applications and the problems related to the vital and main aspects of digital health technologies, which remain unsolved.

3. DIGITAL HEALTH

3.1. Key Aspects and Trends in Digital Health

3.1.1. Wearable Devices

Wearable technology for consumers has become increasingly common, with gadgets that can be found on wristwatches, gloves, inner soles, headgear, and rings. These wearables, which come with inbuilt sensors, can collect physiological data passively and translate it on the device or when it's linked to a smartphone app. The proliferation of wearable technology has produced physiological data that physicians can use, frequently more than what is accessible on traditional EHRs but dispersed over several apps. There has been a discernible shift in the design of wearables from their initial focus on fitness goals and metrics to early disease detection, monitoring, and intervention [5]. These tools track several health indicators, promote healthy habits, and provide valuable information to patients and medical professionals. Major tech corporations have recognized the considerable income potential in this industry, as evidenced by their substantial investments. With a 24 percent rise in the smartwatch market in 2021, these gadgets have had strong year-over-year growth, with over 40 million units being delivered in the fourth quarter alone [6]. Apple currently holds 34.1 percent of the market, with Xiaomi and Samsung following closely behind [7]. This pattern highlights the increasing popularity and widespread use of wearable technology, indicating a growing reliance on these devices for health management and monitoring.

When new symptoms appear, people under the traditional healthcare paradigm usually consult General Practitioners (GPs) for checkups and medical advice. However, with the growing popularity of reasonably

priced wearables for consumers, this approach is changing. With the use of these gadgets, consumers can now access real-time healthcare data, ushering in a relatively new trend known as Quantified Self (QS) [8]. This shift alludes to a future in which people actively employ wearable technology to monitor and manage their health, replacing the traditional reactive healthcare model with a more proactive and self-aware approach.

Furthermore, it has been shown that consumer wearables have the potential to serve as "secondary," patient-driven diagnostic tools, particularly in the case of chronic illnesses. These devices provide a realistic and continual supply of complete longitudinal data, allowing to track patients' progress without resorting to more complex, expensive, and unpleasant solutions. Wearables, for example, can readily track aspects such as conversation frequency, physical activity levels, and sleep duration to provide insight into the severity of symptoms when treating chronic conditions such as depression [9]. A small wearable that uses tissue vibration to measure heart rate, breathing volume, and snoring may be able to diagnose sleep apnea quickly and enhance the quality of sleep [10]. Consumer wearables also add to a more comprehensive understanding of "predictive preventive diagnostics." This is evident in the sense that these devices may analyse micro-level bodily movement data to detect early indications of illnesses such as Parkinson's disease. In light of this, it can be said that these gadgets have the ability to create a platform for the more accessible and customised at-home care of chronic long-term illnesses [11].

Wearables address some of the shortcomings of stationary computerised solutions, which have facilitated positive behaviour change for medical issues like obesity [12], anxiety [13], panic disorders [14], post-traumatic stress disorder (PTSD) [15], and asthma [16,17]. Static computerised solutions, such as web-based services, electronic self-reports, and feedback via emails, have also helped patients with these conditions. Instant feedback from wearables ensures prompt action and a customized

strategy, while still being useful [18]. They overcome the shortcomings of computerized therapies that were stationary, namely high patient attrition rates and delayed self-reporting [16].

While wearables can provide large datasets, as shown by early clinical research, their efficacy in detecting disease has been comparatively low. For example, the nearly 400,000 participants in the Apple Heart Study demonstrated that only 0.52 percent of individuals had an abnormal heartbeat detected by their smartwatch, and only 0.16 percent had atrial fibrillation that was subsequently confirmed [19]. The study population, which was predominately wealthy and showed a low baseline prevalence of disease together with few risk factors, may be to blame for this poor detection rate. The fact that early

adopters of wearables typically represent a group with generally better health and fewer pre-existing health conditions partially explains the poor results from such studies. However, as this population ages, wearables may eventually be more effective in detecting a higher incidence of illness. Wearables may become increasingly helpful in disease identification as they become more widely used and integrated into the community at large, which encompasses people with a variety of risk factors and health profiles. Future wearable technology research and developments, along with a more representative study group, could provide more thorough insights into wearables' diagnostic potential. Table 2 provides a list of examples of the functions of wearable devices in healthcare.

Table 2. Functions of wearable devices in healthcare

Functions	Examples
Screening	Early COPD deterioration screening [20] Atrial fibrillation screening [21]
Detection	Neurological disorder detection [22] Seasonal influenza detection [23]
Monitoring	ECG monitoring [24] Blood pressure monitoring [25]
Prediction	Prediction of COVID-19 infections [26] Prediction of sleep quality [27]

3.1.2. Telemedicine and Telehealth

The use of technology to provide medical services remotely is known as telemedicine. It includes the use of various telehealth platforms, virtual consultations, and remote patient monitoring. Contrarily, the term "telehealth" is more inclusive and refers to the provision and support of health and health-related services, such as medical care, patient and provider education, health information services, and self-care, all made possible by digital communication technologies and telecommunications.

In remote and rural locations, where accessing healthcare services can be challenging, telemedicine

appears to be a promising solution to healthcare issues [28]. It provides patients with access to top-notch medical care regardless of where they live. Real-time video conferencing or specialised online services can be used to accomplish this. Through the use of wearable technology, television, and medical technology, healthcare providers can interact with patients remotely and perform tasks such as vital sign checks, condition assessments, diagnosis, and prescription writing [29]. This method greatly reduces the need for needless and expensive travel by facilitating quick communication and feedback from patients. Additionally, the use of telemedicine has been shown to be beneficial in

lowering hospital admissions and mortality rates for patients with diabetes and cardiovascular illnesses [30,31].

Since the 1950s, telehealth has been supporting patient care; it is not a novel concept. Recently, telehealth use has increased significantly on a global scale, especially when the COVID-19 epidemic started. The global health crisis led to a greater acceptance of telemedicine and telehealth, as these solutions were essential for delivering healthcare services with reduced requirements for face-to-face interaction. The adoption of telemedicine and telehealth solutions into standard healthcare procedures was sped up by the COVID-19 pandemic. This change not only addressed the pandemic's issues, but also demonstrated how telehealth and telemedicine can improve accessibility, convenience, and the effectiveness of healthcare delivery [32].

The trend away from predominantly rural clinics, which emerged after the COVID-19 pandemic, is gradually shifting back to a more traditional service paradigm. However, there has been a significant shift in the methods by which healthcare is delivered. This change implies that virtual treatment, which patients have shown to tolerate well and, in some cases, even enjoy, is a possibility [33]. Medical professionals have attested to its efficacy and, in certain instances, concluded that it outperformed conventional care approaches [34]. A hybrid paradigm that combines virtual care with more conventional healthcare paths has the potential to be developed. Such a hybrid approach is attractive because it combines the best aspects of traditional treatment with the benefits of virtual care, like patient comfort and a lower carbon impact. Finding a balance between the two could result in a healthcare system that offers people convenient, high-quality treatment while also being more ecologically friendly.

3.1.3. Cloud-based Electronic Health Records (EHRs) and Blockchain in Healthcare

Cloud-based electronic health records (EHRs) have garnered significant interest over the last decade, as they facilitate remote patient monitoring. Healthcare 4.0 has

gained significance by using cloud computing and Internet of Things (IoT) components for remote medical operations. Healthcare 4.0, based on the concept of Industry 4.0, marks a revolutionary era in healthcare delivery characterized by intelligent and interconnected healthcare systems. Periodic medical data sensing, aggregation, transmission, sharing, and storage are among the primary components of Healthcare 4.0.

Because cloud computing offers storage and processing power on demand, it is essential to Healthcare 4.0. The cloud, which functions as a distributed web-based data centre across several central servers, makes data storage and accessibility convenient and available from any device at any time. Cloud-based technology integration and management in healthcare supports the handling of massive data files, including genetic data, pictures, and electronic health records (EHRs), by offering vast on-demand storage capacity that traditional healthcare systems cannot access. Cloud computing enhances the operation of the healthcare system by enabling the monitoring and analysis of diagnostic data, as well as facilitating data sharing and remote access for medical personnel. The exchange of medical data between healthcare and research institutions has been made easier by the shift of medical records to cloud-based platforms. This has made it possible to exchange data more quickly and easily than was previously possible [35], which has facilitated collaboration on a variety of projects, from analysing novel therapeutic approaches to gaining fresh perspectives on current treatments to enhancing population health management.

While there are advantages to outsourcing healthcare data to cloud service providers (CSPs), such as increased accuracy in disease detection and progress in medical research, there are also serious security risks. Because health data is sensitive, robust security measures are necessary to protect it from potential breaches and unauthorized access. It is recommended that Searchable Symmetric Encryption (SSE) be employed in conjunction

with effective key management to mitigate security vulnerabilities in Electronic Health Records (EHRs). Nonetheless, there are still issues. For example, the majority of SSE schemes are centralized, and EHRs struggle to be shared because there is no verification on both the client and server nodes [36]. Keeping private patient data safe from cyberattacks makes it challenging for e-healthcare systems to store, retrieve, and exchange medical data securely in the cloud. To overcome these security issues, several cryptographic methods have been developed. However, conventional approaches have struggled to strike a balance between strong security, user-side verification without requiring a third party, computational efficiency, and service-side verification. Achieving safe and effective medical data sharing, access, and storage in cloud service providers requires developing solutions that successfully handle these issues.

Because they can offer strong security for data exchange and storage with minimal computational overhead, blockchain-based security solutions have garnered considerable attention lately. Its potential to increase data integrity, facilitate safe medical record sharing, and enable applications such as supply chain management in the healthcare industry, while enhancing the security and interoperability of health data, has been investigated.

Blockchain works on a decentralised model, in contrast to traditional security techniques that store data centrally [37]. The term "distributed technology" refers to the fact that the same data will be saved in multiple copies across different devices and locations [38]. The distributed structure of blockchain ensures that the security of the original data is not compromised by the loss of any single storage point [39]. Furthermore, the presence of several identical copies of the data ensures that the true information can be retrieved in the unlikely event that an attacker attempts to hack and alter the data at some point [40]. Blockchain essentially groups data into blocks that connect to each other to form a chain, with each block

holding a copy of the same data [41]. Once this chain of blocks is formed, it is nearly hard to change one block without also changing the others [42]. Because of this built-in structure, it is extremely difficult for outside parties to use blockchain technology to jeopardise security. Blockchain's inherent immutability and transparency make it a potentially secure and reliable alternative for handling private health data.

3.1.4. Artificial Intelligence (AI) and Machine Learning (ML)

The ability of digital computers or computer-controlled robots to carry out tasks typically associated with intelligent beings is known as artificial intelligence (AI) [43]. A branch of artificial intelligence known as machine learning (ML) uses data samples to teach computer programmes, or algorithms, associations with predictive value. In essence, it is the computer-assisted application of statistical models to data. Machine learning employs a diverse set of statistical methods that extend beyond those commonly utilised in medicine. As big datasets become more available, machine learning (ML) has grown in popularity because to its adaptability and capacity to manage massive amounts of data. Its versatility makes it suitable for a wide range of applications, including risk prediction, diagnostics, and survival rate forecasting. AI and ML are being utilized in various healthcare applications, including personalized medicine, predictive analytics, drug discovery, and diagnostics. These technologies enhance the medical domain's decision-making processes by analysing massive datasets to gain significant insights.

Data management is a typical application of AI in healthcare. This includes significant procedures for acquiring, storing, normalising, and tracing the data's source, which is an important first step toward revolutionising established healthcare systems. Google's AI research group recently announced the Google DeepMind Health project, which is dedicated to mining medical records data to improve the delivery of speedier and more

efficient health services. The Google DeepMind Health project is now in its early phases, with a focus on collaborating with the Moorfields Eye Hospital NHS Foundation Trust. With the use of AI technologies, the goal is to revolutionise the way professionals carry out eye tests, allowing earlier detection and improving eye therapy [44].

AI will use raw data from sensors for risk assessment and health monitoring, and ML algorithms will be trained to identify patterns in this raw data. These patterns can be recognised as markers of a person's behaviour and state of health. In turn, this helps patients understand and manage their health and makes it easier for them to share relevant information with healthcare professionals [45]. A recent review, published in JMIR, examined literature from 2010 to 2018 and identified 1849 relevant papers that combined AI with the latest technology for diabetes management and decision assistance [46]. Following a comprehensive examination, 141 papers were added to the review. The results demonstrated artificial intelligence's enormous potential to address several important elements of diabetes care. This covers things like anticipating and managing blood glucose levels, identifying unfavorable glycemic events and the risks that accompany them, and tailoring patient therapy. In summary, the study demonstrated how AI, by utilising cutting-edge technology and data-driven insights, is essential to the advancement of diabetes management solutions. The medical industry has made use of a variety of ML algorithms. For example, by taking into account a mix of inherited and environmental factors, it is used in the analysis of optical microscopic images for the diagnosis of malaria [47, 48]. The use of ML in healthcare highlights its potential to transform medical operations by providing advanced analytical tools that enable more precise diagnoses, personalized treatment regimens, and improved prognoses. As technology advances, the integration of AI and ML is projected to have a big impact on the future of healthcare.

In healthcare delivery, there are two primary information processing tasks: treatment and monitoring,

which entail planning, executing, and supervising a multi-step process to achieve a desired future outcome, and screening and diagnosis, which involve categorizing cases based on history, examination, and investigation. These procedures, which are critical for managing the healthcare system and providing healthcare, follow the basic framework of creating hypotheses, testing those hypotheses, and taking action. ML has the ability to improve the generation and testing of hypotheses within health-care systems by revealing previously unknown patterns in data [49]. As such, it has the potential to have a substantial effect on patients individually as well as on the system as a whole.

Additionally, ML advances current statistical techniques by utilizing approaches that do not presuppose certain characteristics of the data distribution. It can identify trends in the data, which can aid in the creation of hypotheses and their subsequent testing. While ML models can produce outcomes in more complex scenarios, they can also contain a higher number of variables and display generalizability across varied data sources, despite being often more difficult to comprehend [50]. ML techniques have been used in research settings, especially for diagnosis, screening, and event prediction.

ML analysis is rapidly progressing in the field of cardiac imaging, particularly in the fields of echocardiography and MRI image acquisition and interpretation [51]. By integrating data from numerous sources, including EHRs, these systems generate rich datasets with the potential for precision medicine, diagnostics, and increased access to key diagnostic testing. This integration allows for a more comprehensive picture of each patient's health, which enhances personalised healthcare and may completely revolutionise how cardiovascular illnesses are recognised and treated. In addition to boosting prediction skills, ML in healthcare offers the potential to lead to more proactive and tailored interventions, which will eventually enhance patient outcomes. The LINK-HF study demonstrates the use of

ML, in which one hundred heart failure (HF) patients had a multisensory patch that continuously recorded their body temperature, accelerometer, thoracic impedance, and ECG signals. A smartphone was used to transfer the gathered data to the cloud, where ML techniques were applied to create unique baselines for every patient. With a median lead time of 6.5 days prior to the actual HF episode, the study was able to predict approaching decompensation with a sensitivity of 88% and a specificity of 86% by using a prognostic machine learning algorithm [52].

3.1.5. Mobile Devices and Digital Apps

The swift assimilation of mobile devices into clinical practise has been partially fueled by the better quality and increased accessibility of medical software programmes, or "apps." [53]. These applications are computer or mobile application programmes created with a special purpose for use in healthcare environments [54]. As technology develops, more and more of these apps are created, which helps mobile devices integrate seamlessly.

3.1.5.1. Health Record Maintenance and Access

Applications are accessible to support data gathering and retrieval in healthcare environments, making processes like inputting data into patients' Electronic Medical Records (EMR) or Electronic Health Records (EHR) easier. Hospital information systems frequently include features that allow healthcare providers administer EHRs and Picture Archiving and Communication Systems (PACS). These features guarantee safe access to a patient's complete medical history, prescriptions, lab results, imaging scans, consultations, and discharge notes. This type of access can be provided remotely or on-site, giving healthcare professionals more freedom [55]. The iPad and iPhone can now download Epic scheduling, billing, and clinical support apps thanks to a partnership between Epic Systems and Apple [56]. Doctors can also obtain patient clinical data via Apple or Android mobile devices by using PatientKeeper Mobile Clinical Results [55]. For healthcare professionals who need off-site access to patient records, general-purpose record maintenance and access software

like TeamViewer can be loaded on mobile devices and enable remote access to desktop PCs.

Medical imaging scans can also be viewed remotely with specialised apps [57]. As an illustration, consider Mobile MIM, a free iPad and iPhone software that has received FDA approval, allowing users to view x-rays and imaging scans remotely in situations where they are unable to access imaging workstations. This programme can be used with MIMCloud, a HIPAA-compliant server that facilitates the saving and sharing of medical images through a paid subscription or pay-per-use plan [56]. By enabling HCPs to download and examine photos from the cloud in a variety of situations, this technology improves teamwork and patient-provider communication. The utilisation of these applications signifies a notable progression in the role of mobile technology in providing remote access to vital healthcare data.

In some instances, analysing medical image scans remotely via a medical gadget has proven to be just as beneficial as seeing them on a desktop computer. This was demonstrated in a study where participants used their iPhones to identify acute stroke on CT brain scans as accurately as they could with a traditional workstation [56]. This demonstrates the usefulness of mobile devices, especially when access to a workstation is not immediately possible or in emergency situations.

3.1.5.2. Clinical Decision-making

When it comes to facilitating quick and easy access to evidence-based information for healthcare professionals (HCPs) to support clinical decision-making at the point of care, mobile devices are indispensable. In comparison to traditional print resources, doctors now spend twice as much time online (64 percent) searching for information to inform or support clinical decisions. This is according to the Manhattan Research/Physician Channel Adoption Study [59]. Numerous apps with strong evidence supporting them are useful for clinical decision-making at the bedside. Conventional printed medical references, which are frequently used to diagnose diseases, have given

way to mobile device apps that provide thorough details on a range of topics, including diagnosis, therapy, differential diagnosis, infectious diseases, pathogens, and more. Examples of these apps include drug information from Micromedex, Dynamed, UpToDate, CDC antibiotics, and the Johns Hopkins Antibiotic Guide (JHABx).

In addition, the Diagnosaurus app helps prevent the misdiagnosis of alternative conditions, ensuring that common diagnoses are not overlooked or discovered too late [56]. Moreover, apps that help doctors uncover possible diagnostic possibilities, such as 5MCC and Pocket Guide to Diagnostic Tests [55]. The direct administration of fundamental medical assessments, encompassing aspects such as blood pressure, glucose levels, colour blindness, and visual acuity, is now possible with mobile apps. For example, the iPhone app iSeismometer has been reported to quantify tremor frequency, demonstrating performance similar to more expensive and complex equipment used in electromyogram research [60]. Numerous applications are also made to determine the due dates of pregnancies by using the patient's ultrasonography and the date of her most recent menstrual period. Among them, the "Perfect OB Wheel" is noteworthy. These prenatal due date prediction applications are said to work more accurately than conventional paper wheels [59].

Currently, the landscape of clinical decision-making has changed dramatically due to the growing reliance on electronic resources and mobile applications, which provide HCPs with efficiency and accessibility. Incorporating mobile applications into medical examinations not only improves accessibility but also offers affordable substitutes for conventional diagnostic instruments. It is possible to reach a wider audience and enhance overall healthcare outcomes by conducting such examinations with easily accessible mobile devices, which furthers the democratisation of healthcare resources. Apart from that, with the integration of mobile devices and digital health apps, healthcare professionals can make

well-informed judgments about diagnosis and treatment.

3.1.5.3. Patient Monitoring

A useful and efficient solution for remote patient monitoring of chronic illness patients is the use of mobile devices. A plethora of applications with a health theme have been created and are readily available in the market; some of them have even received regulatory body approval. BlueStar is one innovative digital health app that the FDA has certified for the management of diabetes mellitus [61]. Patients are empowered to take charge of their health outside of routine clinic appointments with the use of apps like BlueStar. These applications provide people with diabetes greater flexibility and convenience by simplifying the process of checking blood glucose levels, carbohydrate intake, and insulin dosages.

Another example of how mobile devices and related apps provide individualised and cost-effective healthcare solutions is the AliveCor Heart Monitor. When used with the free AliveECG app, the AliveCor gadget records precise heart rates and electrocardiograms (ECGs), enabling prompt diagnosis of illnesses such as atrial fibrillation [62]. Mobile apps are also being used in various medical fields more frequently, outside diabetes and cardiovascular health. HandBase, a relational database software that complies with HIPAA regulations, is utilized to track hospitalized patients, including their locations, diagnoses, tests, treatments, and billing information [59].

In a similar vein, the Android software iWander demonstrates how GPS in mobile devices can be utilized to track and monitor patients at risk of wandering in the early stages of Alzheimer's disease. Additionally, smartphone applications have also been used to monitor patients during their recovery. When patients are unable to access typical hospital-based rehabilitation, they may be monitored in their own neighborhoods using a smartphone paired with single-lead ECG equipment via Bluetooth [56]. Apps for patient monitoring have a lot of promise, but their effectiveness may depend on several factors, including GPS and internet connectivity, patient

familiarity with the devices, and other considerations.

3.1.6. Virtual Reality (VR) and Augmented Reality (AR)

By fusing computer-generated elements with the actual environment, AR produces an interactive experience. A variety of sensors, including haptic devices, cameras, microphones, and GPS, are used to create virtual content for computer-generated information. In contrast, people can interact with computer-generated items through the use of haptic devices and other technologies in VR, which immerses users in a fully or partially artificial environment. Applications for AR and VR technologies in healthcare are expanding, with applications ranging from pain treatment and therapy to surgical training. These technologies offer immersive experiences that improve patient care and medical education.

The combination of haptic internet with AR has substantial benefits for the healthcare industry. For

example, one of the primary applications is remote surgery for patients in remote and difficult-to-reach areas where specialists are unable to travel, such as conflict zones. Furthermore, it has been shown that people with diseases like multiple sclerosis are able to walk more easily because to the visual feedback provided by VR technology [63]. Rapid advancements in processing speed, sophisticated software, and detailed graphical representation characterize VR/AR technology. Nevertheless, managing large amounts of data flow and attaining low latency present difficulties for AR/VR apps and other 5G applications that are delay-sensitive. Fog computing and proxy servers at the edge of the network, in particular, provide edge computing as a viable option with an emphasis on improving location awareness and decreasing latency. A list of examples of the VR and AR applications in healthcare is provided in Table 3.

Table 3. Lists of examples of the VR and AR applications in healthcare

Interventions type	Applications	Study Aims	Outcomes	References
VR	VRelax application	To investigate feasibility and immediate effect of VRelax use on perceived stress among ICU nurses during the first wave of the COVID-19 pandemic	The results of this study support that short mental breaks using VRelax can be an effective intervention to reduce immediate perceived stress in ICU nurses providing COVID-19 care.	[65]
VR	Virtual-Fracture-Carving Simulator	To compare trainees' understanding of a complex fracture with the application of either current preoperative techniques or the use of the Virtual-Fracture-Carving Simulator	The use of a Virtual-Fracture-Carving Simulator is feasible, and superior to conventional preoperative planning strategies in terms of quantity and quality of understanding of a spatially complex fracture.	[65]

Interventions type	Applications	Study Aims	Outcomes	References
VR	Immersive VR technology	To evaluate the efficacy of immersive virtual reality (VR) technology in reducing patient’s pain perception	There has been a significant reduction in pain scores with VR across all medical procedures.	[66]
AR	Novel devices based on the emission of near-infrared electromagnetic radiation (NIR) to guide venous puncture.	To compare the new technique with standard venipuncture in a population of elderly patients.	The use of AR reduced the incidence of hematomas and anxiety level.	[67]
AR	AR-based guide for mechanical ventilator setup	The goal is to determine the feasibility and effectiveness of an augmented reality (AR)-based self-learning platform for novices to set up a ventilator without on-site assistance.	Strong confidence and user satisfaction to set up a ventilator using AR systems.	[68]

3.2. Utilization of Digital Health During COVID-19 Pandemic

Globally, the new coronavirus, known as SARS-CoV-2, has had a dramatic impact, altering lives and having a huge influence on healthcare systems. The outbreak began in China and quickly spread worldwide, causing significant disruptions, including mask wearing, social isolation, quarantine regulations, and an unprecedented demand for healthcare resources. As more people rely on the internet and digital devices for access to medical services and treatments, the recent COVID-19 pandemic has highlighted the critical role that digital technologies play in healthcare [69,70]. The necessity to prioritise and integrate "Digital Health" solutions more efficiently has been highlighted by the overwhelming focus that

healthcare systems have placed on COVID-19 patients, as well as the lack of resources in many countries. Digital health, which encompasses a range of technologies including wearables, biosensors, telemedicine, artificial intelligence, and machine learning, is essential to overcoming the obstacles presented by COVID-19.

The healthcare system can combat COVID-19 in several ways through the use of digital health, including primary care and prevention, screening, monitoring, and surveillance. Tracking the spread of viruses and analysing public reactions is aided by social media sites and Google Trends studies [71]. The use of digital health in COVID-19 screening has further reduced ER visits, which has improved the structure of the healthcare system [72]. Digital health has become a frequently used and important

tool as a result of advancements in mobile health (mHealth) and electronic health (eHealth), which have made it easier to design apps and websites for patient screening. Healthcare professionals can quickly assess and classify patients using telemedicine. Additionally, it provides doctors with the opportunity to communicate virtually with patients or those under quarantine, thereby avoiding direct contact with sick individuals. The use of smart gadgets that can directly communicate data on vital bodily functions, such as heart rate and temperature, is also beneficial during the COVID-19 pandemic [73].

Applications for contact tracing and surveillance have become indispensable in the fight against the epidemic. One effective method of controlling the spread of the pandemic is to isolate those who are suspected of being infected and use contact-tracing programmes to identify the pattern of the outbreak. For instance, apps such as Singapore's TraceTogether have been utilised to track and alert those who have come into touch with COVID-19-infected people [74]. Digital health solutions also aid in the triage process, where telehealth assessments are provided during the COVID-19 pandemic, helping to categorize

people before they reach hospitals, which speeds up clinical examination and testing to determine their risk of contracting COVID-19 [75].

The use of digital technologies in healthcare surged across various countries during the COVID-19 pandemic. For example, a hospital in Guangdong Province, China, utilized an existing platform to introduce COVID-19 responsive services, including information centers, e-consultation and screening, remote symptom monitoring, and psychological assistance. Users of the web-based system could interact with it easily from websites, phone apps, and social networking sites like WeChat, which is similar to Facebook and Twitter. The hospital reported a significant increase in the use of online services during pandemic lockdowns, and a significant decrease in outpatient visits [76]. In Vietnam, to facilitate case monitoring and surveillance, two smartphone apps—NCOVI and Vietnam Health Declaration—were developed to record electronic health declaration forms for both domestic and international passengers [77]. A list of examples of the reviewed papers discussing the application of digital health tools in the COVID-19 pandemic is provided in Table 4.

Table 4. Application of digital health tools in the COVID-19 pandemic

Applied digital tools	Functions	Purpose of the intervention	Country where the intervention applied	Reference
Web-based systems, GIS technologies	Widespread distribution of information and real-time tracking of transmission	Prevention	China	[78]
CDSS	Severity risk assessment and triage for COVID-19 patients at hospital admission	Diagnosis	China	[79]
Telecommunication system	Allows pathologists to review and report pathology specimens from a remote	Prevention, diagnosis	Unites States	[80]
Videoconferencing	Offering telemedicine to monitor all patients, limit human contact and decrease the risk of COVID-19 dissemination	Follow-up	Italy	[81]

Applied digital tools	Functions	Purpose of the intervention	Country where the intervention applied	Reference
Machine learning	Accurately detect COVID-19 and differentiate it from community-acquired pneumonia and other lung conditions	Diagnosis	China	[82]
Web-based system, mobile apps, digital QR codes	Widespread distribution of information, real-time tracking of transmission, communication platform for patients with COVID-19 to self-monitor their clinical symptoms and enables authorised healthcare personnel to access and manage collected data for clinical monitoring	Screening, prevention, follow-up	Malaysia	[83]

3.3. Challenges of Using Digital Health

Digital health solutions can effectively improve general health and wellness by putting people and processes ahead of technology. These digital health technologies have the ability to totally transform the delivery of healthcare by enabling remote monitoring and improving sickness management. The integration of these digital technologies also allows for the collection of information on patients' vital signs, lifestyles, and medical histories, can result in the development of a personalised medicine model tailored to each patient's specific needs.

The COVID-19 pandemic's urgent need for a "no-touch" emergency state and physical distancing measures has accelerated the adoption of digital health. Patients and healthcare professionals are increasingly turned to digital health solutions. This change has underscored the importance of sharing data and the need for careful analysis and ethical consideration in the rapidly evolving field of digital healthcare.

The impact of digital health policies on system efficiency, cost-effectiveness, and health outcomes is not well-established [84]. There is a dichotomy here: there is no evidence to support implementation, and there is no implementation to support evidence generation. The assessment of the effects of digital health interventions

requires the use of mixed methods in a multidimensional analysis approach to examine the program's effects on patients, healthy individuals, and the health system [85].

Health digitalization has also given rise to privacy concerns, since all digital health domains produce data that needs to be protected. Security, secrecy, discrimination, unauthorised uses of medical information, and patients' right to know how their data will be used are just a few of the many facets of privacy concerns [86]. It is difficult for governments to handle and safeguard this private health information [87]. The risk of re-identification persists despite improvements in anonymization methods, as fresh data must be accurately combined with existing data related to the same person. Digital health platforms are vulnerable to serious security risks due to the possibility of re-identification. Additionally, even if the prices of technology developments that promote digitization are declining, government still confronts substantial challenges in data governance. Although most governments are pursuing digital projects, just 50% of them have privacy policies in place to protect data. As a result, governments must establish guidelines and requirements for efficient data governance. User permission stands out as a critical concern when it comes to ethical challenges in the process of digitalizing health care. Even though the majority of

programmes ask for consent before collecting data from users, users sometimes forget about this part of the process and click the "I accept" button without carefully reading the conditions of use [88]. It's possible that users don't completely understand the terms before accepting them. Ensuring users are aware of data gathering procedures is a crucial step in addressing this ethical dilemma. Establishing public trust and reaffirming a commitment to privacy protection are crucial measures for ensuring the acceptance of digital health projects and their ongoing effectiveness. To gain the trust of stakeholders and the general public, policymakers must carefully consider the long-term sustainability and financial implications of digital care solutions, while placing a strong emphasis on accountability and transparency [89].

In fact, there is a range of challenges related to the integration of these digital technologies into the healthcare system, such as the lack of evidence-based guidelines, privacy difficulties arising from the digitalization of medical records, problems with data management, and moral dilemmas [90]. Conventional evidence-based methodologies provide a solid foundation for assessing the safety and therapeutic efficacy of these technologies. Furthermore, complex systems models offer a more holistic perspective by taking into account the broader impact on healthcare systems, patient experiences, and unintended outcomes. This thorough evaluation method ensures that new technologies not only improve patient care as planned, but also meet legal and ethical criteria.

Addressing these challenges will require collaboration, investment, and a comprehensive approach to ensure responsible adoption and maximize the benefits of digital health in improving patient care.

4. LIMITATIONS OF STUDY

This review highlights the application of digital technology in healthcare, and its associated challenges. It is essential to acknowledge a few limitations of this article, despite the valuable insights it provides on the utilization

of digital technology in the healthcare sector. Firstly, this article primarily focuses on specific aspects of digital health, including electronic health records, artificial intelligence, machine learning, telemedicine, wearable devices, virtual reality, and augmented reality. Given the broad range of digital health technologies, other vital areas of digital health may not be thoroughly explored. Secondly, as the field of digital health is rapidly evolving, some of the information may soon become outdated. Thus, it is essential to stay informed on the latest developments in the field and consider integrating new innovations in future revisions.

5. FUTURE DIRECTION OF DIGITAL HEALTHCARE

5.1. Randomized clinical trials (RCTs)

Traditional RCTs, which are costly, time-consuming, and labor-intensive to conduct, can be made easier and more effective with the help of digital health technology [88]. Although the best use of digital technologies and their full integration into clinical trials has not yet been fully investigated, it is critical to assess their potential to conduct realistic studies that are more effective and practical [91]. It will be easier to comprehend the potential advantages of digital health technology for clinical applications in patient care and research if concerns such as accuracy, reliability, access, confidentiality, and the need for regulations have been addressed. However, it is crucial to recognise that integrating digital technology into therapeutic routes may have certain disadvantages. These could include an unexpected drop in care quality, a paradoxical loss of productivity, and other unfavourable effects. Ensuring that the integration of digital health technology is done intelligently and ethically is imperative in order to maximise its positive influence on clinical trials and healthcare practises. This involves striking a balance between the advantages and negatives.

5.2. Digital health coordinating center

It's not a simple task for primary care physicians to

implement digital healthcare services. The establishment of a Digital Health Coordinating Center (DHCC) as a regional hub is necessary to support primary care physicians who provide digital healthcare services, thereby enabling the smooth implementation of these services [92]. The DHCC is essential in teaching patients about the usage of digital healthcare and digital therapeutics prescribed by doctors in clinical settings, as well as providing pertinent precautionary advice. Users typically only come to the DHCC for the first time, or during their first session, choosing instead to visit primary clinics for any further contacts. The DHCC receives and transmits patient data created and maintained by digital healthcare services in addition to the patients themselves. Here, medical professionals or coordinators can keep an eye on the gathered data, providing patients with feedback and sending their primary care physicians summaries of specific patient situations. This allows primary care providers to focus on in-person patient evaluations at their clinics by using summaries of various measurable data collected from hospitals and supplied by the DHCC. This facility can enhance the knowledge and assistance provided by the DHCC while also reducing the time, expense, and labor burden on primary care physicians.

5.3. Policy suggestions for digital healthcare

Currently, there is increasing pressure on both HCPs and customers due to the free nature of digital health care services. Training staff members who use digital health

platforms in hospitals requires a significant time commitment [93]. In spite of this, insufficient incentives have impeded the implementation of digital healthcare. Therefore, in order to improve the primary areas of medical services, it is imperative to offer incentives to medical staff for digital healthcare. Furthermore, it is essential to completely restructure the laws governing accountability and information protection. This will help provide a stronger foundation for the ethical application of digital health services.

CONCLUSION

Globally, the practices of healthcare professionals as well as patient experiences are being profoundly impacted by the continuous digital transformation in the industry. The adoption of digital tools is expected to have a positive impact on healthcare administration and service standards as technology continues to advance. Keeping up with new trends, such as wearable technology, virtual reality, and artificial intelligence, will enable healthcare workers to thrive in their positions. The ongoing advancement of digital technologies presents an opportunity to enhance the effectiveness, safety, and quality of healthcare. Still, despite all the advantages that come with digitization, the challenges posed by the application of digital healthcare must be overcome to overcome sluggish adoption rates.

Conflict of interest statement

The authors declare that there is no conflict of interest.

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التحول الرقمي في الرعاية الصحية: الاتجاهات والتحديات الحالية

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ملخص

الخلفية: تتمتع تقنيات الصحة الرقمية بإمكانية إحداث تحول جذري في مجال تقديم الرعاية الصحية من خلال تسهيل المراقبة عن بُعد، وتحسين إدارة الأمراض، وتوفير خيارات علاجية أكثر تخصيصًا. وقد مثلت جائحة كوفيد 19- حافزًا قويًا لدمج حلول التطبيق عن بُعد في ممارسات الرعاية الصحية السائدة. وبشكل عام، تُقدم تقنيات الصحة الرقمية إمكانات هائلة. ورغم أنها تُحدث تحولًا في تقديم الرعاية الصحية، إلا أن هناك العديد من التحديات التي يجب التغلب عليها لضمان نجاح تطبيقها. ويتطلب التغلب على هذه التحديات التعاون والاستثمار واتباع نهج شامل لضمان تبنيها بشكل مسؤول وتحقيق أقصى استفادة من الصحة الرقمية في تحسين رعاية المرضى.

الهدف: تهدف هذه المراجعة بشكل أساسي إلى مناقشة المشهد المتطور للتكنولوجيا الرقمية في الرعاية الصحية واستخدامها خلال جائحة كوفيد 19-، بالإضافة إلى تسليط الضوء على تحديات استخدام الصحة الرقمية. المنهجية: أُجري البحث في قواعد بيانات PubMed و Web of Science و Google Scholar للمنشورات المنشورة خلال الفترة من 2009 إلى 2024. وشملت مصطلحات البحث: "تقنيات الصحة الرقمية" أو "الذكاء الاصطناعي" أو "التعلم الآلي" أو "الطب عن بُعد" أو "الأجهزة القابلة للارتداء" أو "الأجهزة المحمولة" أو "أنظمة دعم القرار السريري" أو "تقنية سلسلة الكتل في الرعاية الصحية" أو "الواقع الافتراضي في الرعاية الصحية" أو "الواقع المعزز في الرعاية الصحية" أو "تحديات تقنيات الصحة الرقمية". وقد تم تحديد 7191 ورقة بحثية متعلقة بمجال الصحة الرقمية. ومع ذلك، اقتصر عدد الأوراق البحثية التي نُوقشت في هذه المراجعة على 3414 ورقة بحثية فقط، وذلك بسبب معايير الاستبعاد.

الخلاصة: تُوجز هذه المراجعة أحدث ما توصل إليه العلم في مجال الصحة الرقمية، بما في ذلك تقنيات متنوعة كالصحة المتنقلة، والتقنيات القابلة للارتداء، والسجلات الصحية الإلكترونية، والذكاء الاصطناعي، والتعلم الآلي، والواقع الافتراضي، والواقع المعزز، بالإضافة إلى التحديات التي تواجه تطبيق التكنولوجيا الرقمية في أنظمة الرعاية الصحية.

الكلمات الدالة: الرعاية الصحية، تقنيات الصحة الرقمية، الأجهزة القابلة للارتداء، تطبيقات الهاتف المحمول، الذكاء الاصطناعي، الواقع الافتراضي، الواقع المعزز، التحديات

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