Digital Technologies in Healthcare: A Systematic Review and Bibliometric Analysis

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Abstract—Digital technologies hold great promise and have the ability to change healthcare and drug development by changing the way we collect, process, and visualize health data. The implementation of digital technologies in healthcare can make public healthcare more accessible and flexible. This includes patient's treatment, complications, open data on health, latest biomedical research developments, among other things. Medical services and diagnostic tools are becoming more accessible and available, even in less developed economies. However numerous issues concerning digital health technologies, such as safety, testing, reliability, and ethical considerations, remain unresolved. The study aims to discuss and analyze the recent progress in the application of digital healthcare such as ICT, smart/wearable devices, artificial intelligence, big data, and telemedicine in healthcare. Scopus database was used for the publication search. We merged descriptive analysis and bibliometric analysis to determine the temporal evolution, most productive journals, top authors, most productive countries, and co-occurrence of keywords (to identify well-explored topics) in the available scientific literature concerning digital technology in the healthcare field. Using content analysis, we have determined the research hotspots of the scientific publications during the past five years.

Keywords—digital healthcare, digital technologies, digital health, bibliometric analysis, systematic literature review

1 Introduction

Digital technologies and healthcare collaborate to revolutionise global health and improve our health practices even further. Patients now have access to cutting-edge treatments, improved diagnostic tools, and less invasive surgical procedures as a result of technology breakthroughs that have altered the healthcare business. Telemedicine, targeted treatment, remote consultations, and mobile healthcare applications are examples of technological and digital transformations that have aided the development of healthcare [1] [2].

It is well known that clinical use of information technologies (IT) has a high efficiency in reducing the number of complications and adverse outcomes, providing social and economic benefits, and improving the quality of life. Digital platforms can aid in the optimization of patient diagnosis, consultation, and therapy. However, due to a lack of official legislation and recommendations, corporations and governments which are also the major stakeholders, are having difficulty validating and approving new digital health solutions. In this regard, proper scientific research is essential before deploying a digital product for the healthcare sector. Digital technology has created countless opportunities to shape the future of health care and ensure the success of public health initiatives.

Digital health is the implementation of data analytics and digital technologies to understand health-related behaviour of individuals and provide personalized health care resources [3][4]. Digital healthcare can provide important information about disease trends and risk factors, outcomes of treatment or public health interventions, functional abilities, patterns of care, and health care costs and use [5]. The use of real-time data in digital health can help to enhance epidemic prevention and control the dynamic and turbulent nature of epidemics. Decision support systems, wearable monitoring or reporting devices, data registries, electronic medical records, education platforms and electronic therapy are all examples of digital health approaches that have the potential to improve health care access for better integration and personalisation of care. There is growing body of literature that shows that use digital technologies is a useful alternative for traditional healthcare delivery.

The COVID-19 pandemic is favouring digital transitions in many industries and in society. Health-care institutions have swiftly adopted digital solutions and advanced technology tools in response to the Covid-19 outbreak. Digital technologies such as social media, smartphone apps, websites, online discussion forums, and wearable gadgets are now available as tools for young people to understand and enhance their health, physical fitness, and well-being. Community groups, consumers, healthcare professionals, and the overall healthcare industry all benefit from the use of digital health technologies to create and share information about health, medicine, and healthcare. This study discovers the role of digital technologies in healthcare and to answer the following research questions.

RQ1: How has the digital technology literature evolved over time?
RQ2: What the main authors, countries, and journals in the said field?
RQ3: What are the main keywords associated with digital technologies in healthcare research?
RQ4: What are the various themes that the literature on digital technology and digital health revolves around?

2 Methodology

This study uses bibliometric analysis as well as content analysis to give a comprehensive overview of the extant literature on the subject. Many scholars have used scopus database to performa bibliometric analysis [52][53]. We have also selected

Scopus database for the selection of articles to perform this review and bibliometric analysis. We chose the Scopus database because, in comparison to other databases, it offers a wider choice of publications [6]. We used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram to collect data for this systematic literature review. The PRISMA statement consists a 4-phase flow diagram as shown in Figure 1 [7]. A systematic literature review contributes in the improvement of review and meta-analysis reliability [8]. "Digital technologies" AND "healthcare" OR "health care" are the keywords we used in our search query. The number of articles returned as result of search string was 1076, with the oldest article dating back to 1986. We choose publications from the last five years, from 2017 to 2021, for bibliometric analysis. Atotal of 872 articles were published in the past five years. Only 433 of the 872 entries were journal articles. To assure the study's quality, we only included journal publications and did not include conference papers or book chapters. Because only 403 articles were published in English, we have a total of 403 articles in our final dataset.

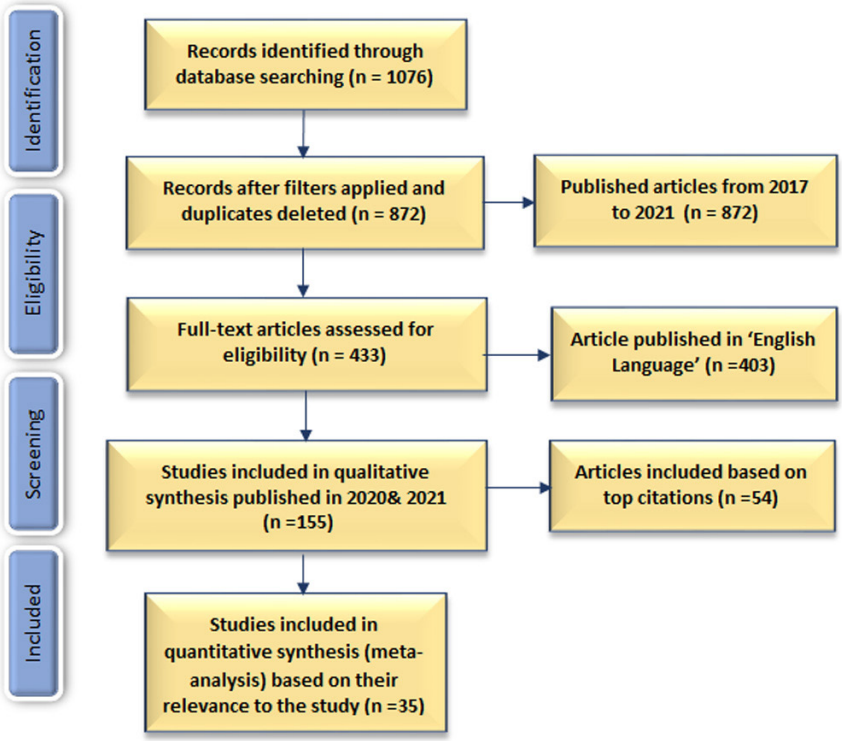

Fig. 1. PRISMA flow chart showing the inclusion and exclusion criteria

It was noticed that 155 articles were published in the year 2020 and 2021. Out of these 155 articles, 54 articles had more than 5 citations which were selected for the systematic review to identify the main themes in the research. We set this limit of 5 citations per article to narrow the scope of the research and to include only the significant articles. For content analysis 35 of the selected articles were selected based on

their relevance to the research questions. The flow chart of research methodology of this study is shown in Figure 2.

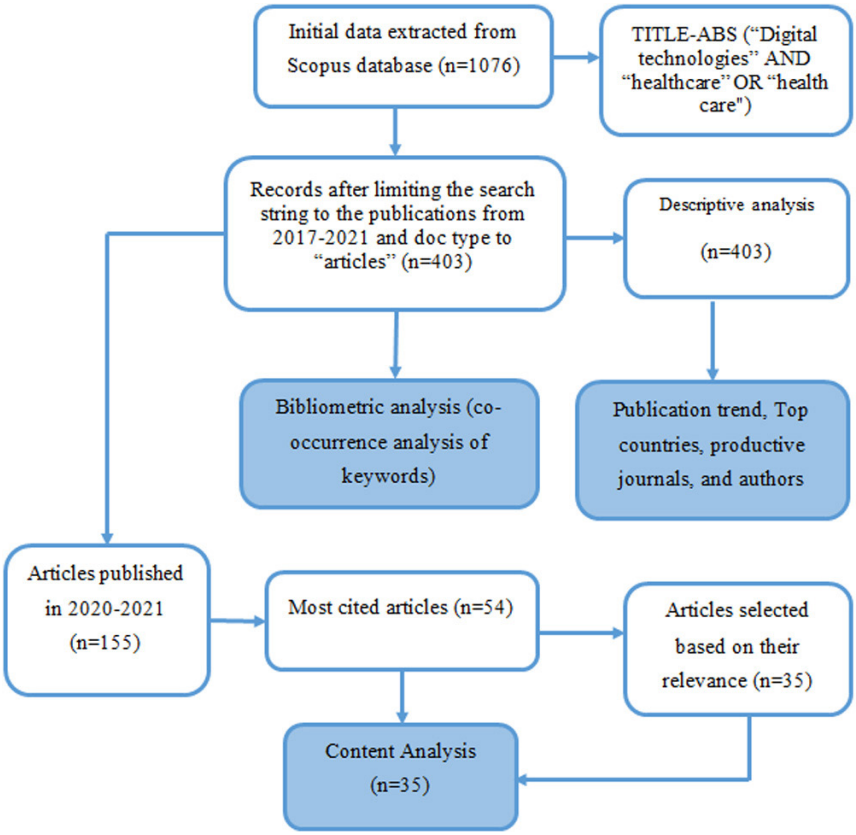

Fig. 2. Flow chart of research methodology

3 Descriptive analysis

To answer the first and second research question, a descriptive analysis was carried out to observe the publication trend of the published scientific articles as well as identify the top countries, journal and institutions actively involved in the research in the said field.

3.1 Publication output

Figure 3 shows that the number of published articles has grown from 37 in 2017 to 147 published articles in 2021. This significant growth reflects the interest of academicians and researchers in the field of digital health care. The growing trends also indicates that this trend will continue to rise in the upcoming years. The highest growth of

articles is observed in the year 2021. One of the main reasons behind this is the recent pandemic and the current scenario.

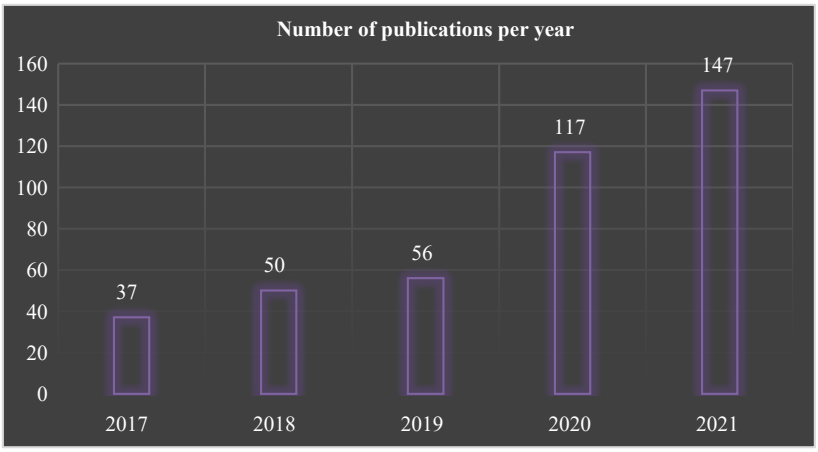

Fig. 3. Publication trend during past 5 years

3.2 Leading countries

Figure 4 shows the top 15 countries actively participating in the research in the field of digital technology in healthcare. It is observed that the top three countries are UK, US and Australia with 101, 92 and 40 publications each in the last five years. It is evident and consistent with the previous investigation that most of the research focusing digital technologies in healthcare has been done in the developed countries as compared to the developing countries [9]. Same is the case with the implementation of digital health [10]. This study provides future researchers a roadmap to conduct similar studies in the less developed and low-income countries.

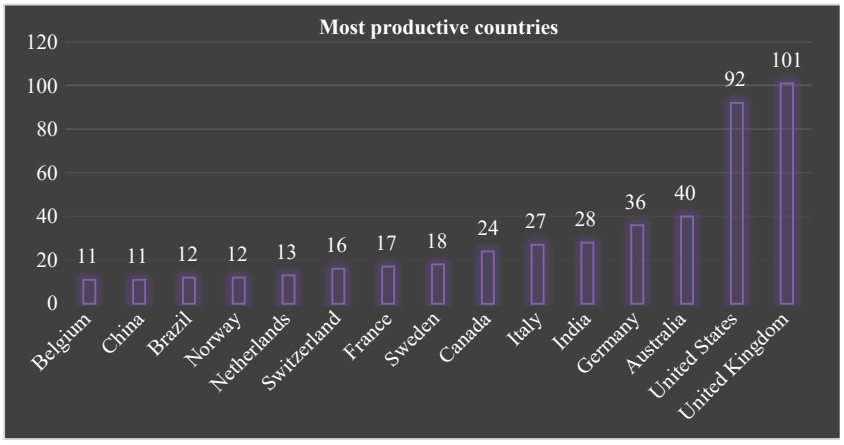

Fig. 4. Leading countries

3.3 Most productive journals

The top 10 journals that has published the article relating digital technologies in healthcare are shown in Figure 5. It is observed that the Journal of Medical Internet Research is the top journal with total 25 publication in the said field followed by JMIR Research Protocols and BMC Health Services Research with 12 and 8 publication each.

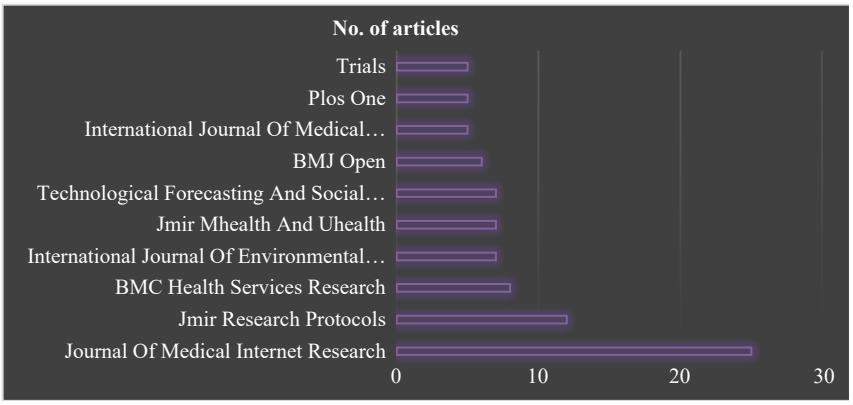

Fig. 5. Most productive journals

3.4 Top institutions

Using the data from Scopus database we identified that the top 3 institutions actively involved in the research focusing on digital technologies in healthcare are University of Oxford with 12 overall publications, and Imperial College London and University College London with 11 publications each. It is worth noting that all three institutions belong to the United Kingdom. The top fourth and fifth institute that is The University of Sydney and University of Melbourne belong to Australia. It is interesting to note that only one institute from United States has made it to the top 10 list which is the Harvard Medical School. Rest of the institutions in the top 10 list are stated in Figure 6.

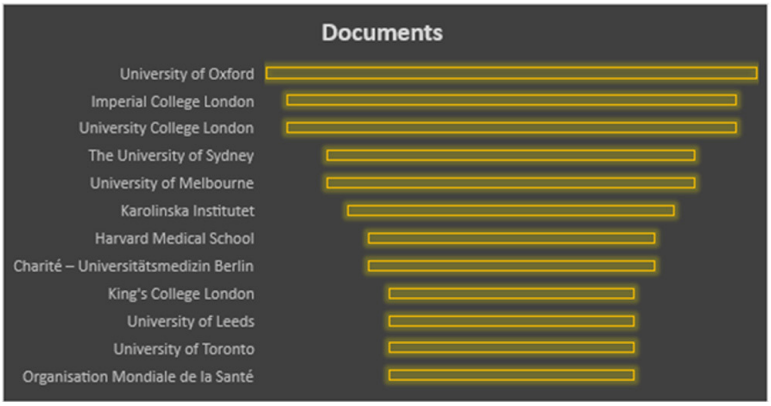

Fig. 6. Top 10 institutions

4 Bibliometric analysis

To answer the third research question, we carried our bibliometric analysis and conducted co-occurrence of keywords analysis to determine the main research areas related to the digital technologies in healthcare research. Bibliometric analysis is a scientific review process that reviews all previous literature on a topic and maps clusters of thematically related published literature. In this study we performed co-occurrence of keywords analysis using the VoS viewer software to identify the core areas of research as well as the emerging topics associated with digital technologies in healthcare research. This will serve as the roadmap for future researchers who are interested in doing research in the same field.

4.1 Co-occurrence of keywords analysis

Through VOS viewer software we have identified the most popular keywords or in other words the most associated keywords used with digital health literature. The results of our findings demonstrate that following are the most used keywords used in the digital technologies are digital health, mhealth, telemedicine, covid-19, ehealth, digital technologies, technology, mobile apps, telehealth, self-management, digital transformation, digitalization, and health literacy (Figure 7). The author keywords in yellow colour demonstrates how recently they have been used in the existing literature. It is evident that mobile apps, digitalisation, digital transformation, public health, health literacy are the most emerging topic in the digital health literature. Figure shows the popular digital technologies that are being used in the healthcare currently, which are mobile apps, ehealth, telemedicine, telehealth, social media, artificial intelligence etc.

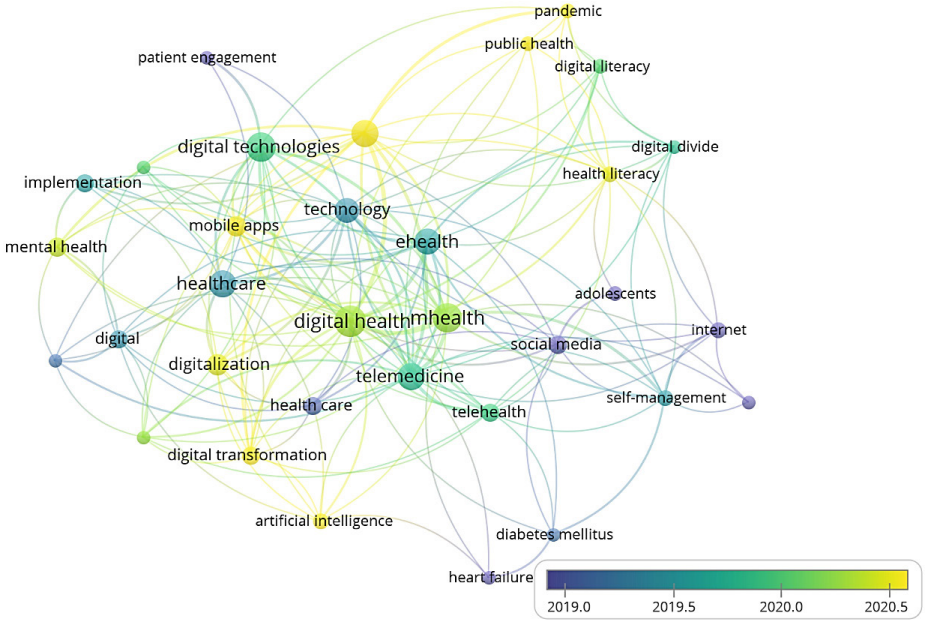

Fig. 7. Co-occurrence analysis of author keywords, online link: https://bit.ly/3n71ZEf

5 Discussion on the main themes in the literature

To answer the fourth research question, we classified the published literature and divided it into six research streams. These research streams are the main areas that have received attention so far in the past five year's research. Following are the major focus areas in the field of digital technologies in healthcare research.

5.1 Digital health literacy

The health-care industry's digital transformation is largely dependent on the skills of its workers. It is very important for the healthcare professional to be aware of the digital technologies that may prove helpful in the healthcare sector. It has been noticed that one the reason that digital health technologies are not widespread is the low level of digital health literacy of healthcare professionals. According to a study, more than 50% of the medical students in Europe considered their digital health literacy as poor or very poor and demanded digital health education in the medical curriculum [11]. There is a huge gap between medical students' willingness to participate in digital transformation and the education they receive in medical schools. Health professionals must digitally train themselves in order to improve our professional performance and thus provide better and better health care that is aligned with the new digital paradigm [12][13].

Digital technologies empower individuals to even focus on their own health. Patient practises, including self-care, have been reframed and reconfigured as a result of this shift. While digital self-care has the potential to increase people's involvement in their own health and healthcare, it also comes with significant risks and costs. In order to avoid misdiagnosis and overtreatment, and to correctly interpret results and manage potential anxiety or fears, digital self-care was generally regarded as a set of practises that could be helpful, but only within the doctor-patient relationship and when accompanied by physician guidance [14]. [2] also points that in order to be effective, digital health must address the variability in digital health literacy among beneficiaries, including populations living in poverty, older and younger people.

Despite the fact that senior citizens are one of the most common health-care consumers they are found to be reluctant to participate in digital health research and this selective nonparticipation in digital health research is linked to age and severity of symptoms. Such systematic selection can lead to skewed research findings that are used to inform research, policy, and practise in ineffective ways [15]. It is imperative for stakeholders to engage in efforts to promote individual's digital health literacy so that people can benefit from what it has to offer.

5.2 Digital technologies

Since the 1990s, when the term 'e-health' was developed, digital technology have played a significant role in healthcare organisations [16]. The trend of combining new digital technologies in production systems, including as the Internet of Things (IoT), Big data, and Cloud computing, to connect the virtual and physical worlds is known as Healthcare 4.0 (H4.0) [17][18]. [19] argue that five contingency factors including

hospital ownership and age, number of staff, number of beds, and functionality (such as if it is a teaching hospital or not) effect the adoption of health 4.0 especially in emerging economies. [20] performed an exploratory study to investigate the role of 10 digital technologies derived from health 4.0 and their role of the resilience of healthcare services. They found that Emergency rooms and ICU (intensive care units) benefitted most from the health 4.0 technologies.

Personal mobile gadgets that track heart rate, calorie intake, body weight, and other important data are very popular. An increasing number of businesses are taking this a step further by creating digital platforms to improve the patient experience before, during, and after surgery. This platform's capacity to link patients directly to their physician or physician practise is a major characteristic [21]. To date, smart phones have been the most commonly used platform for eHealth programmes [22][23].

Big data, digital technology, and artificial intelligence (AI) are generating new competitive landscapes in healthcare [24][25]. AI technologies in healthcare are also employed to improve diagnosis and reduce human error [26] as well as to produce value for various stakeholders that is physicians, patients, and policymakers [27]. There is a growing trend using social media, big data analytics and artificial intelligence in the healthcare industry to improve healthcare and medicine awareness [28]

5.3 Digital health for healthcare workers

As the Internet and digital technology have evolved in society and across all productive sectors, health systems have recognised the need to transition to digital/computerized systems that can improve quality and efficiency. Despite technological advancements and rising social pressure to incorporate them into daily clinical practise, digital innovation in the healthcare sector remains limited and slow, mainly because of the digital divide [13]. [13] outlines a set of digital skills for various health care professionals in order to help them make the transition and improve their professional performance using the Internet and related technologies. These skills include Digital Health Literacy, Effective management of scientific-health information Health communication 2.0, Creation of scientific-health digital content, Collaborative network work with health teams, Analysis and data management,

Digital healthcare offers enormous potential for continual development in areas as diverse as information management, communication, research, innovation, teaching, and scientific publication [13].

5.4 Digital health and covid 19

Digital health is defined as "*the cultural transformation of how disruptive technologies that provide digital and objective data accessible to both caregivers and patients leads to an equal level doctor-patient relationship with shared decision-making and the democratization of care*" [29]. Various digital health interventions can be employed to reduce and prevent the spread of contagious diseases such as covid-19 [30][31]. Digital health interventions are interactive, self-directed software solutions that can help to close some of the gaps in treatment access and quality that exist in healthcare

settings around the world [4]. Health IT, mHealth, and eHealth are all examples of digital health. Today, digitalization has pervaded many sectors of life, and it will transform the way we provide and consume medical services as a society. Digital health is a fast-growing medical profession that has a considerable impact on increasing the quality and effectiveness of health treatment, as well as cutting the costs of the health-care system and patients, as well as clinical research.

In the healthcare industry, ground-breaking technologies such as blockchains, artificial intelligence, internet of things, and cloud computing have matured and are being employed more frequently. Medical advances such as genetics, sensors and wearable health products are proving to be increasingly successful in medicine. Medical 3D printing, nanomedicine, and robotics research are all offering to provide targeted, accurate, and rapid medical services [5]. The use of real-time data in digital health can help to improve epidemic prevention and control due to the frequently changing nature of epidemics. DH has potential to improve our readiness towards infectious diseases and pandemics in the future.

5.5 Applications of digital health

Digital health is crucial for curing and facilitating patients with various diseases. For instance, digital technologies can improve the monitoring and care and the quality of life of people with multiple sclerosis but this will require iterative feedbacks of scientist, healthcare professionals as well as digital experts [32].

The digital technologies are widely applicable in facilitating patients with coronary heart disease [33], cancer cure [2], physical fitness and wellbeing [34] psychophysiology [35], telepsychiatry [36], early detection of cancer (oral) [37], Chronic obstructive pulmonary disease (COPD) [38], diabetes [39] etc. Digital diabetes technologies have the potential to improve clinical outcomes and quality of life while also increasing access to care and lowering costs [39]. [40] also discusses the usefulness of digital technologies such and wearable and mobile health technologies in treating the diabetic foot ulcers.

The digital technologies are not just helpful in the treatment or cure of an ailment, but it also supports the healthcare industry in many other ways such as remote monitoring, counselling, and some physical examinations and digital record keeping in healthcare organisations. Digital technologies has the potential to empower patient and improve their quality of life as well as facilitate the communication between the patients and the healthcare professions that too with reduced errors and hospitalisation length [41].

Digital technology advancements have opened new possibilities for designing and modelling digital business models. They can be used for digital business models and value co-creation among various stakeholders in the healthcare ecosystem. For example, [42] discussed a digital platform that provided ridesharing services. They believe that there is no need for healthcare organisations to invest in healthcare infrastructure; instead, they argue that arranging ridesharing services is a potentially profitable proposition for the entire health ecosystem. Both healthcare organisations and end users can benefit from ridesharing using simple digital platforms.

5.6 Telemedicine for remote treatment

The recent Covid-19 outbreak has had a significant influence on global healthcare [43] and there has been concerns about the overloading the capacity of healthcare [44]. Medical centres are swiftly embracing digital technologies and tools such as telemedicine and virtual care in response to COVID-19 [45]. At the time of coronavirus outbreak, patients with cancer were at high risk of contracting and suffering from the complications of covid 19. In such a scenario healthcare professional respond to this risk through telemedicine, remote monitoring and home based chemotherapy [46].

Telemedicine technology is widely available, low-cost, and widely accepted by physicians and patients [47] [48]. Telemedicine is the application of information and communication technology that focus primarily on promoting and supporting long-distance medical care. Telemedicine encompasses not only remote healthcare services, but also continuing health education, physician training, and administrative meetings [45]. Telemedicine, mhealth or ehealth has become a necessity during the lockdown due to covid 19 pandemic [49]. The use of digital technology to assess, analyse, and treat substance use disorders (SUDs) is a particularly promising and emerging field of scientific research [50][4]. For instance the use of telecommunication technologies to give long-distance clinical care may potentially allow substance use disorders (SUD) expert physicians to provide care in places with high SUD treatment demands but limited SUD workforce capacity [51].

6 Conclusion

The finding of our analysis has showed that the number of published articles has increased over time and highest number of scientific publications has been seen in the year 2021. One reason behind this is the recent covid-19 pandemic which has resulted in a shift in the existing healthcare practices forcing healthcare organisations and professionals to adopt digital technologies to deal with the current situation. Our investigation revealed that most of the research related to digital technologies in healthcare is done in the UK, US and Australia. Journal of Medical Internet Research is the top journal with most publications in the similar field.

Digital technology has now shown to be the greatest and, in many cases, the only option for providing crucial treatment to patients as the COVID-19 epidemic progresses, despite their reputation for being more futuristic than realistic. Digital technologies provide medical care that is reliable, accessible, and convenient but there is a need for a robust infrastructure for both patients and physicians for efficient implementation of the use of digital technologies in healthcare. While the implementation of digital technologies in healthcare faces a number of challenges, including willingness of healthcare professional and the patients, lack of appropriate infrastructure, insufficient money, and a lack of experience, among others. Therefore, it is critical for stakeholders to improve individuals' digital health literacy in order to raise their awareness of digital health solutions given the numerous benefits they can provide.

Digital health innovations are intended to reduce time, improve accuracy and efficiency, and merge technologies to improve the existing healthcare setup. Digital Health

could help us be more prepared for infectious diseases and pandemics in the future. For this purpose, the participation and dedication of healthcare professionals is very important for the increased awareness among individuals and successful implementation of digital healthcare technologies. The findings of this study can help medical practitioners understand the importance of digital technologies to strengthen their resistance to future health emergencies culminating.

7 Limitations and future directions

Nonetheless, due to the rapidly evolving literature in this field, several studies that have been published are unlikely to have been included in the review. This study has used studies from just one database (Scopus) for analysis. Future researchers could take articles from different databases such as web of science and google scholar and compare the results. Second, the search parameters may not be exhaustive. Future researchers could use few other keywords to select the articles for analysis. Furthermore, to derive the research streams, we used various approaches to divide the scientific publications into our own generated clusters; however, some authors may disagree, culminating alternate clusters and research streams based on their knowledge and understanding.

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