A Bibliometric Analysis of Research papers related to Digital Health

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Abstract

Digital health technology will improve people's lives through increasing knowledge of and understanding of healthcare, expanding the range of healthcare services, and developing a workforce of healthcare workers equipped with these technologies. However, adoption of digital health services is currently progressing very slowly.

The objective of this research is to offer a comprehensive bibliometric analysis of past research related to digital health care publications. The Scopus database was examined to find all currently available and highly cited research papers on digital and mobile healthcare published in English up to 2022. The abstract, title, and keywords were used to build a search strategy that was used to check a title's eligibility using bibliometric criteria. The year of publications, keyword co-occurrence, sources, and authors were calculated using the VOSviewer application.

Out of the 4085 results returned by the search, 2891 publications were used in the study. Since 1992, the average rate of research paper publication has risen by 24%. After 2010, however, there was exponential growth. The primary research areas are telemedicine, mobile healthcare, mobile applications, and use of digital health tools. This study has helped us see earlier work in the field of digital health from a wider angle. Investigations of several aspects of digital health publication, such as publication nations, authors, citations, and bibliographic coupling, were conducted.

Introduction

Primary care is still a crucial component of the healthcare system. Patients are frequently obliged to accept subpar consultation and treatment for early-stage illnesses because of a dearth of professional healthcare services brought on by a weak infrastructure. Ineffective therapy and delayed diagnosis are the results of inadequate access to primary care. Additionally, delaying therapy makes the condition worse. Another issue facing the sector is a lack of healthcare workers. The bulk of contemporary healthcare institutions are found in metro areas because of the resources and opportunities offered there. To improve access to care and provide more advanced therapy, primary healthcare must be

given top priority. Based on a PwC projection, one of India's leading digital healthcare businesses is likely m-health services, with a market size of 2,083 crore INR in 2015 and projected to grow to 5,184 crore INR by 2020. As part of m-health services, a variety of devices, including PCs, tablets, smartphones, and wearable technology, can be used to access knowledge and information. Digital healthcare systems will be improved by newly developed wearable technology, mobile health applications, and other sensor-based technologies. (Fagherazzi & Ravaud, 2019).

PwC asserts that the main obstacles to the diminished impact of digital health care services are insufficient infrastructure, low expectations, a lack of awareness, and manual interventions. However, there are significant obstacles that prevent its widespread deployment, including a lack of user participation and a lack of professional m-health understanding. Bibliometrics is a measurable way of methodically evaluating previously published research papers. According to this approach, several connections between various research articles in terms of authors, keywords, and publishing trends must be found.

The goal of this study is to gain a comprehensive understanding of research being done in the field of mobile and digital health applications. This will increase knowledge of the technology, helping both patients and healthcare professionals. The folks who are less familiar with the idea and are interested in learning more can also benefit from this research.

Research Questions

The expansion of the digital health industry is a direct result of the proliferation of new technologies. It is crucial to look at the broader patterns of publication in this topic, especially in relation to digital health technology uptake and use in India, if you want to comprehend prior research thoroughly. These are the questions that this study aims to answer:

1. How has the area of digital health been publishing recently?

2. For each country, how does the publishing trend stack up against the others?

3. What are the most researched topics or phrases in the history of digital health?

4. Explain the relationships between various publications as they pertain to authorship, citation, and national partnership.

Theoretical Foundation

Data from Burla, India, shows that just 20% of medical staff members regularly use computers. Even though students think computers are an essential component of their medical education, they are rarely used (Chatterjee & Chakraborty, 2021).

According to Desai (2010), the socioeconomic status of the home has a major impact on how frequently people experience common minor diseases, including fever, cough, and diarrhea. Additionally, certain socioeconomic groups bear a disproportionate amount of the burden of illness. Also. A very small percentage of Indians have health insurance.

However, apps were not downloaded for several reasons, including a lack of interest, the cost, and worries about the theft of personal information by unauthorized parties (Krebs & Duncan, 2015). Therefore, it became crucial to comprehend the digital health area in depth. This study was started with the goal of comprehending the major trends in prior research, which would aid in gaining a broad perspective of the field and assisting with future research efforts.

Methodology

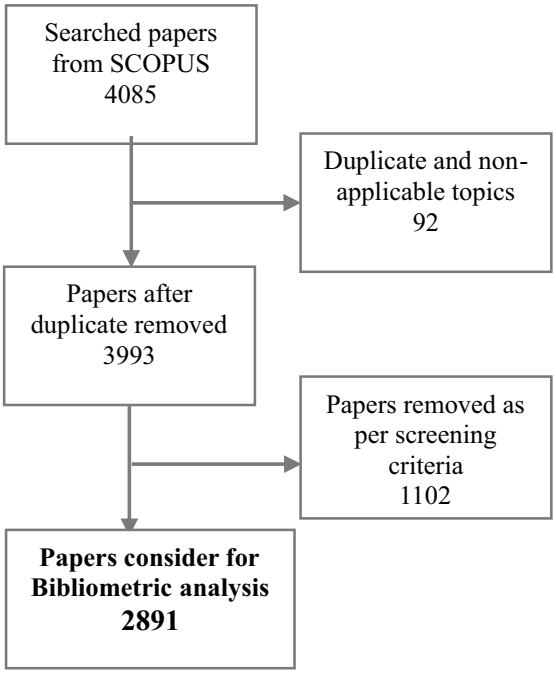
Based on the preliminary literature analysis, we have begun looking for pertinent research papers in the renowned database SCOPUS (Donthu, Kumar, Pandey, et al., 2021). We searched SCOPUS extensively for keywords. This investigation has given a thorough insight into how digital technology, and mobile applications have been used up until December 2022 (Fahimnia et al., 2015).

The following keywords were searched :

- Digital health
- Mobile health
- mHealth

SCOPUS received registrations for 4085 papers in total between January 1992 and December 2022. The research papers that were collected were screened by removing duplicates and selecting pertinent works that contained the word "health" in the title or key words column. Initially, 92 duplicate papers were reviewed. Following that, 1102 documents were removed based on the previously indicated standards. Finally, 2891 research publications were picked for analysis. Making use of the PRISMA flowchart (Moher et al., 2009), Figure 1 shows the research selection strategy.

Figure 1. Research paper screening process



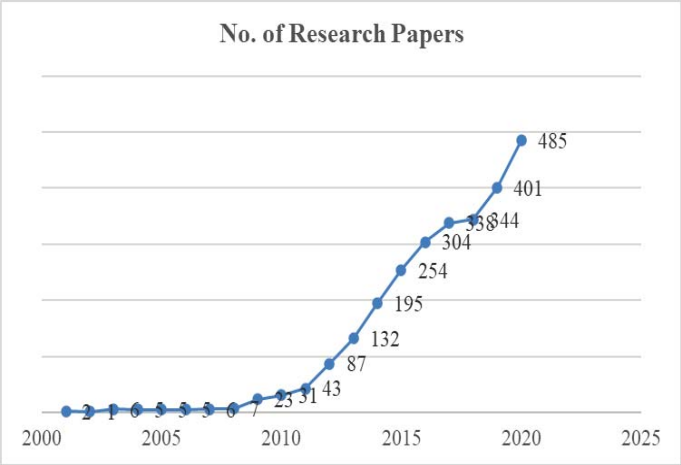
Analysis techniques:

Bibliometrics is a method of literature research that enables the quantitative extraction of data from previously published content to show a variety of patterns and insights (Donthu, Kumar, Mukherjee, et al., 2021). We have used VOSviewer as one of many analytical tools for bibliometric analysis. VOSviewer software was used to upload SCOPUS data that had been extracted and apply various visualization techniques to examine literature.

Results

1. Publication trends: The frequency of research papers published during the last 20 years was identified and displayed against time. This frequency was also used to gauge the growth or decline in research publications (Krishnamurthy et al.,2009)

Figure 2: Publication Trends



The graph (Figure 2) shows a significant upward trend in the number of publications, indicating a growing interest and development in the digital health sector. The data points are labelled for each year, showing a clear trajectory of increasing scholarly activity. In the early 2000s, the number of published papers was limited. Between 2005 and 2010, there was a gradual increase in the number of publications, reaching 43 by 2010. This period can be seen as the nascent stage of digital health research. Post-2010, there is a noticeable increase in the number of publications. In 2011, the number of published papers was 87, which more than doubled to 195 by 2015. This period marks the beginning of significant academic interest and research activity in digital health, possibly driven by advancements in technology and the increasing integration of digital tools in healthcare. The growth becomes exponential during this period. From 195 papers in 2015, the number rose to 485 by 2020. This surge can be attributed to the widespread adoption of digital health technologies, such as telemedicine, mobile health apps, and electronic health records, along with increased funding and policy support for digital health initiatives.

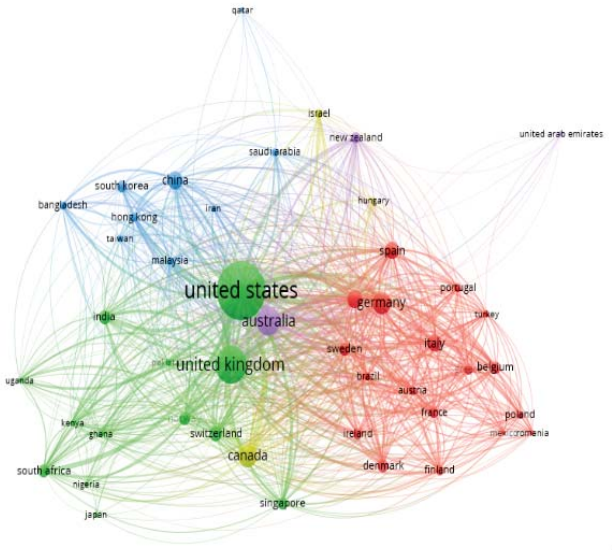
2. Country-wise publications: Cross-country collaborations were shown to be associated with a variety of research papers, according to an analysis of R&D publications conducted by Chahrour et al. (2020), which yielded counts with country specificity.

Table 1: Frequency of research papers published at country level (top 10 countries)

Country	No. of Publications	% of Publications
United States	1324	30%
United Kingdom	544	12%
Australia	318	7%
Canada	205	5%
Germany	182	4%
Netherlands	132	3%
China	121	3%
Spain	117	3%
Italy	114	3%

As per the data from Table 1, the United States leads by a wide margin, followed by the UK, Australia, Canada, Germany, the Netherlands, China, Spain, and Italy. With 1324 publications on digital health, the United States has the largest share (30%) of all countries. This dominance suggests a solid foundation for study, with a particular emphasis on digital health. The strong lead implies that the United States is a prominent center for innovation in digital health, aided by large financial outlays, cutting-edge technology, and a cooperative research atmosphere. With 544 publications, or 12% of the total, the United Kingdom comes in second place. The United Kingdom has placed a strong emphasis on digital health due to its well-established healthcare system, well thought-out government programs, and active involvement in international research collaborations. Notable contributors to the field of digital health research include Canada (205 publications, 5%) and Australia (318 publications, 7%). Both nations have advanced healthcare systems, and they have adopted digital health technologies to enhance the provision of healthcare. Their efforts are indicative of a rising desire to use digital health to solve problems in healthcare, boost system effectiveness, and improve patient outcomes. A large amount of research on digital health is contributed by the Netherlands (132 articles, 3%) and Italy (114 publications, 3%), Spain (117 publications, 3%), Germany (182 publications, 4%), and Spain (114 publications, 3%). These European nations profit from robust research ecosystems, cooperative networks, and enabling policy regimes that promote innovation in digital health. China is becoming a major role in digital health research, with 121 publications (3%). The nation's contributions to this subject are being driven by its large-scale healthcare programs and quickening pace of technical innovation. China's emphasis on digital health is a component of a larger plan to update its medical infrastructure and cater to the demands of its enormous population.

Figure 3 : VOSviewer chart with networking country as per research publications

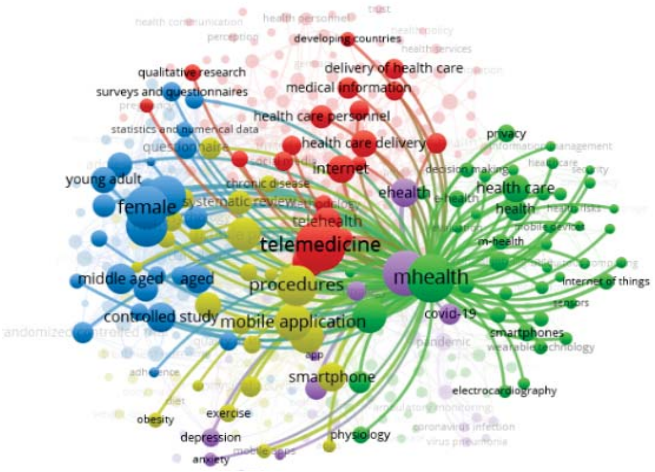


The graph (Figure 3) shows how different countries are working together on digital health research. The lines that connect the nodes reflect cooperative research activities, and each node stands for a nation. The nodes' size is correlated with the amount of research output, while the connections' density and colors show the areas of collaboration and intensity of work. The three most noticeable nodes—the US, the UK, and Canada—indicate their major contributions to the field of digital health research. Due to their significant participation in this subject, Australia, China, and Germany are among the other noteworthy contributors. There are clear geographic clusters on the graph. Europe, for instance, has a high degree of intraregional cooperation due to its extensive connectivity. Comparably, another cluster of Asian nations that emphasizes regional cooperation includes South Korea, Japan, and China. With strong ties to nations in

various regions, the US seems to be a major hub for global digital health research, indicating its critical position in the field. High levels of connectedness are also shown by the United Kingdom, especially with other European and Commonwealth nations. The network clearly demonstrates the increasing involvement of emerging economies in digital health research, including Brazil, South Africa, India, and others. Despite not being as important as the US or the UK, these nations are increasingly collaborating, which suggests a trend towards more inclusive international research initiatives.

3. **Key word analysis:** Research keywords were analysed at three levels, including general, author, and index keywords based on information collected from SCOPUS.

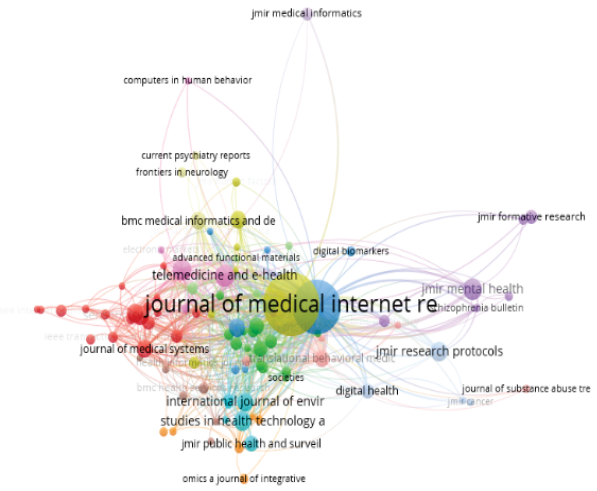
Figure 4: VOSviewer chart with networking key words



Digital health-related research topics and keywords are shown in chart figure 4. The size of the nodes, which stand for various subjects, reflects the amount of research or attention paid to such issues. The relationships or co-occurrences between these topics are represented by the lines that connect the nodes. In the field of digital health research, the various colors stand for different clusters or themes. Huge, center nodes symbolize the ideas of "telemedicine" and "mhealth" (mobile health), which are the graph's primary themes. The importance of these issues in digital health research is highlighted by the high number of connections to other keywords. In addition to "COVID-19," "internet," "mobile applications," and "health care delivery" are important themes that show the breadth of digital health initiatives. Different areas of digital health are depicted by the graph's clusters. As an example, the green cluster is all about mobile health apps and the software that goes along with them. Health care delivery, medical information, and the internet are at the heart of the red cluster, which emphasizes how digital technologies are integrated into health care systems. Blue cluster includes demographic parameters like "female," "middle-aged," and "young adult," highlighting the relevance of digital health research that is particular to populations. Recently, research has shifted its focus to emerging subjects including "COVID-19," "privacy," "decision-making," and "health policy" as a result of the pandemic and the changing digital health landscape. New developments in health monitoring and diagnostics are being represented by the "internet of things," "electrocardiography," and "wearable technology," among other fields. After going through the keyword analysis, the found networks divide into five main categories: m-Health, telemedicine, mobile apps/consumer profiling, COVID research, and related fields. Networking in mHealth Clusters: Using System Dynamics in Their Design and Development (Telemedicine, Mobile App Usage, and Gender Equality)

4. **Citation analysis:** Citation analysis was performed both by country, documents as well and author level. (Gaviria-Marin et al, 2018). Citations of research in digital health are most commonly coming from the United States, with some also originating from the UK and Australia (Figure 5)

Figure 5: VOSviewer chart with networking citations



Several academic journals and books have made significant contributions to digital health, as seen in the supplied network diagram. A journal's influence or article volume is proportional to the size of its nodes, which in turn reflects the journal's representation in the network. The interconnectedness of the nodes represents the scholarly journals' co-citations or collaborative partnerships. The various hues stand for various groups or topics related to digital health studies. The preeminent node is the "Journal of Medical Internet Research" (JMIR), which is a testament to the journal's pivotal position and substantial merit in the field of digital health research. Journals such as "Journal of Medical Systems," "Telemedicine and e-Health," and "JMIR Medical Informatics" also play an important role in this area. Seen in the graph are multiple clusters, each of which stands for a distinct subfield of digital health. Among the red cluster's publications are some that deal specifically with health technology and medical systems. Broad and integrative health subjects are emphasized by the green cluster, which is centered around public health, telehealth, and environmental health. The blue cluster represents the convergence of healthcare IT with journals pertaining to medical informatics and e-health. "Digital biomarkers," "mHealth," "mental health," and "research protocols" are some of the emerging fields that have recently emerged to reflect the changing character of digital health and the research priorities within it. Journals such as "JMIR Research Protocols" and "JMIR Mental Health" bring attention to the growing significance of digital health studies that employ structured research procedures and the growing importance of mental health.

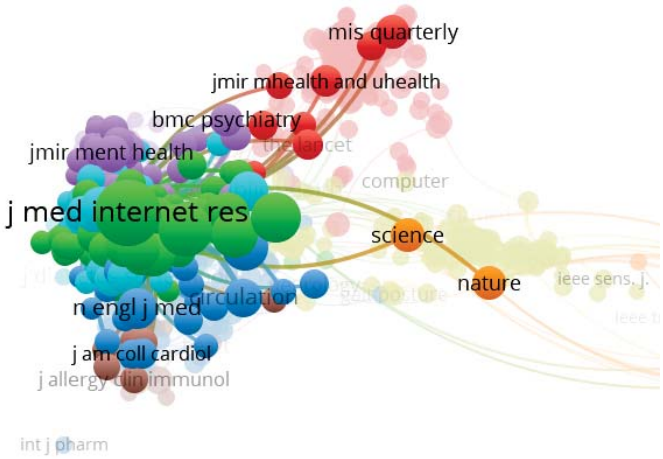
Table 2: Frequency of research paper citations at country level (top 10 countries)

Country	Citations	%
United States	80619	30%
United Kingdom	29586	11%
Australia	18900	7%
Canada	11073	4%
Germany	7486	3%
Netherlands	7895	3%
China	9751	4%
Spain	9030	3%
Italy	6554	2%

In terms of research output and influence, the data (Table 2) clearly shows that the United States is far and away the leader, followed by Australia and the United Kingdom. While the top three nations make up the bulk of the contribution, other European nations, including Italy, the Netherlands, and Germany, all make substantial contributions as well. Indications of a more globalized research landscape are given by the presence of China, Spain, and Italy, which implies an increasing impact of these countries in the subject. If nations want to keep or grow their global impact in different areas of study, the evidence shows that they need to work together internationally and spend money on R&D. Thirty percent of all citations (80,619) are from the United States, making it the most cited country. Something substantial has been added to the area of study or research that is being examined. It is followed by the United Kingdom with 29,586 citations, which is 11% of the total. It appears that there has been significant research production and impact in the field. At 18,900, Australia accounts for 7% of all citations. After this, Australia will be remembered as a leading force in this area. Of all the citations, 4,003 come from Canada. Its impact on the research landscape is moderate but noticeable. Between 2% and 3% come from Germany, the Netherlands, and Italy; 7,486 citations from Germany, 7,895 from the Netherlands, and 6,554 from Italy. European countries' contributions are varied but steady. Three countries—China, Spain, and Italy—contribute three to four percent each, with nine thousand seven hundred fifty-one citations going to China. This points to these nations' increasing clout in the academic world.

5. **Co-citation analysis:** Several research publications' citations of the same articles were examined using co-citation analysis (Chai & Xiao, 2012). The Journal of Medicine is only one of many prestigious journals that has shown high levels of co-citation with other prestigious publications.

Figure 6 :VOSviewer chart with networking various sources of co-citation

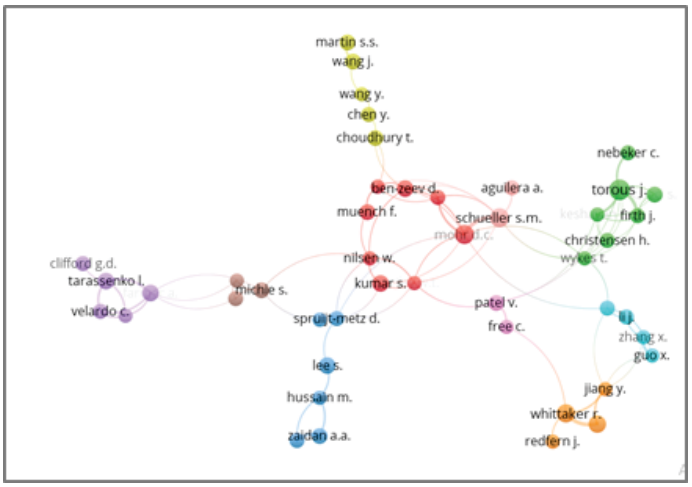


Several research articles and journals pertaining to digital health are interconnected, as seen in the provided network diagram in figure 6. The number of nodes indicates the impact or amount of research published in a certain journal, whereas each node represents a journal. Nodes that are connected to each other show the relationships (such co-citations) among these journals. Colors represent distinct groups or subjects, showcasing the range of digital health research. The preeminent node is the "Journal of Medical Internet Research" (JMIR), which is a testament to the journal's pivotal position and substantial merit in the field of digital health research. Publications such as "JMIR Mental Health," "BMC Psychiatry," and "JMIR mHealth and uHealth" are likewise highly regarded and influential in this area. The network also includes high-impact general scientific periodicals such as "Science" and "Nature," which demonstrate that digital health research is multidisciplinary. Different clusters in the graph stand for different aspects of digital health. The green cluster, for example, is all about telemedicine and medical research conducted online. Management information systems and health informatics journals are organized under the red cluster. The widespread interest in digital health issues among scientists is shown by the yellow cluster, which stands for high-impact scientific journals. Digital health is constantly changing, and new fields like "mHealth," "mental health," and "psychiatry" are cropping up to reflect this. Publications such as "BMC Psychiatry" and "JMIR mHealth and uHealth" document the growing interest in digital mental health and mobile health technology.

6. Co-author analysis:

Networking and linkages in VOSviewer were used to analyze authors who had worked together to write research papers in the field of digital health (Gaviria-Marin et al., 2019).

Figure 7: VOSviewer chart with networking various co authors

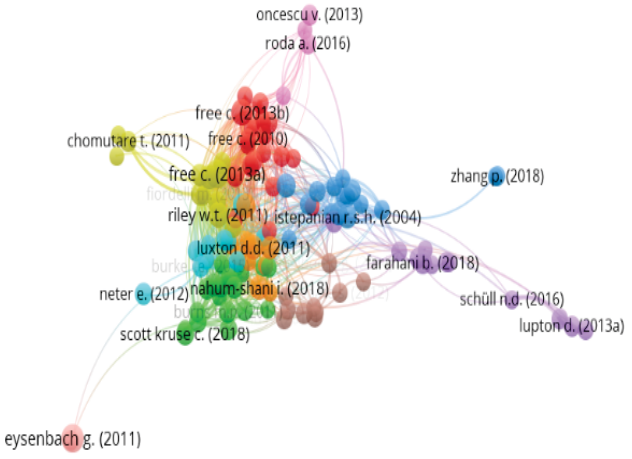


Digital health research appears to be very collaborative, based on the network's clustered in figure 7 and interconnected structure. New ideas and the speedy sharing of research findings are two outcomes that can result from such partnerships. Multidisciplinary studies are necessary for digital health due to the existence of inter-cluster interactions. Improved digital health solutions can be achieved through interdisciplinary collaboration. Newcomers to the field of digital health research and specialized initiatives make up the peripheral nodes. Professors Ben-Zeev, Mohr, and Free all head notable clusters, which is a testament to the importance of their work. In the realm of digital health research, there are a few prominent figures who serve as central nodes, such as Ben-Zeev, Mohr, and Free. They work closely with other scholars, as their central roles suggest. These major nodes serve as gathering places for different sub-networks,

allowing for the free exchange of ideas and information among researchers. Not all nodes in the network are closely linked to the main clusters; some are more peripheral, such as those associated with researchers like Clifford and Velardo. Emerging researchers or niche initiatives in the area can be represented by these tangential nodes. A lack of complete integration into the main collaborative network could be indicated by peripheral nodes, which represent specialized areas of research. Collaborations across disciplines are suggested by the apparent links between various clusters. When it comes to developing all-encompassing digital health solutions, the exchange of ideas and the establishment of these inter-cluster links are paramount.

7. Bibliographic coupling: Bibliographic coupling occurs when the second and third works cited in a research paper are the same (Danvila-del-Valle et al., 2019). One area where bibliographic coupling is consistent is digital health.

Figure 8: VOSviewer chart with networking bibliographic coupling



Researchers in digital health cooperate, as seen in the supplied network diagram figure 8. The size of a node denotes the researcher's influence or the amount of their research output; each node represents a different researcher. Collaboration in research and writing is represented by the lines that link the nodes. Digital health research is inherently collaborative, as the various colors indicate different clusters or groups of researchers. Notable researchers in digital health, like "Ben-Zeev D," "Schueller S.M.," and "Kumar S.", are represented by notable nodes in the network. Others with extensive networks of collaborators include "Nebeker C.," "Torous J.," and "Patel V.," among others. Clusters, depicted by the graph, stand for various study groups or networks of collaboration. Researchers such as "Ben-Zeev D" and "Schueller S.M.," found in the red cluster, are probably engaged in similar endeavors. Members of the green cluster, such as "Nebeker C." and "Torous J.," represent yet another digital health research collaboration. Research collaborations with a narrower emphasis or niche are indicated by smaller clusters, such as the ones in purple and orange. The interconnections between the clusters point to the possibility of multidisciplinary work, in which experts from diverse domains work together to solve difficult problems in digital health. It appears that researchers such as "Kumar S." and "Patel V." are involved in several research initiatives and have a role in promoting interdisciplinary collaboration since they appear to cross multiple clusters.

Discussion

A strong rising trend in the number of publications over the last 20 years is revealed by the findings, suggesting that the digital health industry has been experiencing increasing interest and development. As digital health technologies continue to gain popularity and are more integrated into healthcare systems, this upward trend is in line with predictions (Krishnamurthy et al., 2009). The exponential growth in publications after 2010 indicates a dramatic uptick in academic interest and research, which may be fueled by technological developments and enabling policy settings. The United States ranks first in digital health research when looking at publications by nation. Then comes the UK, then Australia, Canada, and finally Germany. This preeminence is a result of the robust research infrastructures, deliberate government programs, and robust international partnerships exhibited by these nations (Chahrour et al., 2020). Even more proof of the United States' pivotal position in international digital health research is its vast network of linkages to nations all over the world. Because digital health research is a worldwide

phenomenon, the involvement of Asian and European nations in the network highlights the significance of international cooperation in this field. The most common topics covered by digital health studies, according to keyword research, include telemedicine, mHealth, healthcare delivery, and the internet. Emerging themes such as COVID-19, privacy, and mental health demonstrate how the field is adapting to address global health concerns and the changing nature of research. Research in digital health is diverse and interdisciplinary; examples of such clusters include mobile applications, mHealth, and telemedicine. System dynamics is being used to build mHealth clusters, which means that digital health interventions are becoming more structured and based on evidence.

Analysis of citations at the national, and author levels reveals that American sources account for most citations, with the UK and Australia following closely behind. Because of their outsized impact on digital health research around the world and their substantial contributions to the subject, these nations naturally dominate the area. Research is becoming more globalized, as shown by the presence of Asian and European countries in the top 10. Journals such as "Journal of Medical Internet Research" (JMIR) and "JMIR mHealth and uHealth" have a lot of citations in the digital health research network, which means they are important for research dissemination. Digital health research is inherently multidisciplinary, and co-citation analysis shows how different journals and studies are linked. A wider scientific interest in digital health themes is indicated by the inclusion of high-impact general science magazines like "Science" and "Nature" in the network. This study emphasizes the value of collaborative research in digital health and identifies prominent figures and thought leaders in the area, including Ben-Zeev, Mohr, and Free, through its co-author analysis.

Limitations

A potential limitation of the study is that it used only the SCOPUS database, which might not have included all relevant publications. If additional databases, such as Web of Science, were to be included in the search, a more complete picture of the literature may be produced. In addition, the study may have missed some relevant publications because it used a restricted set of keywords. If more synonyms and keywords were used, a wider variety of books could be found. Finally, the study mostly relied on secondary sources of information, which might not be up to date. The most recent findings could be obtained by conducting primary research. The research also didn't consider books and websites, which are kinds of literature that might have contributed significantly or offered new insights. A more complete picture of the subject might be revealed by incorporating these sources into the study. Overall, the bibliometric study is helpful, but it might be much better if we used a broader search technique, conducted more primary research, and included a wider range of literature sources.

Future Research Questions

Through the examination of bibliometric data, trends in digital health research from the past can be revealed, allowing us to pinpoint crucial areas that require further investigation. Research into digital health has skyrocketed in recent years, but adoption rates among both consumers and healthcare providers have been disappointingly low. Within the context of this gap, research into the elements that promote or inhibit the use of digital health technology is necessary. The challenges that low-income nations face in conducting digital health research, such as a lack of infrastructure and limited access to technology, should be the subject of future research. Additional research is needed to determine the strengths and weaknesses of digital health components such as e-health, telemedicine, and mobile health. Finally, collaboration between the scientific communities of high- and low-income nations is crucial to the expansion of digital health around the world.

Conclusion:

The bibliometric analysis of research papers on Digital health suggests that the topic has been experiencing a growth in both interest and innovation. Recent advances in technology and the prevalence of digital technologies in contemporary medicine are the driving forces behind this expansion. Due to their robust research infrastructures and dedicated pursuit of digital health policies, the United States, the UK, Australia, Canada, and Germany spearhead

digital health research. New issues like COVID-19, privacy, and mental health are making headlines, while old favorites like telemedicine, mHealth, the internet, and healthcare delivery still hold sway. According to the citation rankings, the top three countries are the US, UK, and Australia. Research on co-authors and co-citations shows that the area is very interdisciplinary, and that collaboration is crucial. Significant contributions to the dissemination of digital health research have been acknowledged by key people and journals. In conclusion, the results highlight the significance of bringing digital health forward by means of cross-national cooperation, multidisciplinary study, and methods grounded in evidence. Improving healthcare delivery on a global scale and meeting new problems will necessitate sustained research and collaboration in this dynamic subject.

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