Exploration of Digital Health Technologies

Open Exploration

Open Access Original Article

Digital health and mobile health: a bibliometric analysis of the 100 most cited papers and their contributing authors

Andy Wai Kan Yeung[1,2*], Olena Litvinova[2,3], Nicola Luigi Bragazzi[4], Yousef Khader[5], Md. Mostafizur Rahman[6], Zafar Said[7,8,9], Robert S. H. Istepanian[10], Anastasios Koulaouzidis[11,12,13], Adeyemi Oladapo Aremu[14,15], James M. Flanagan[16], Navid Rabiee[17], Sheikh Mohammed Shariful Islam[18], Devesh Tewari[19], Ganesh Venkatachalam[20,21], Giustino Orlando[22], Josef Niebauer[23,24,25,26], Alexandros G. Georgakilas[27], Mohammad Reza Saeb[28], Dalibor Hrg[29,30], Yufei Yuan[31], Muhammad Ali Imran[32], Huanyu Cheng[33], Eliana B. Souto[34,35], Hari Prasad Devkota[36], Maurizio Angelo Leone[37], Jamballi G. Manjunatha[38], Nikolay T. Tzvetkov[39], Maima Matin[40], Olga Adamska[41], Sabine Völkl-Kernstock[2], Fabian Peter Hammerle[2,42], Farhan Bin Matin[43], Bodrun Naher Siddiquea[44], Dongdong Wang[45], Jivko Stoyanov[46], Jarosław Olav Horbańczuk[40], Magdalena Koszarska[40], Emil Parvanov[2,47], Iga Bartel[40], Artur Jóźwik[40], Natalia Ksepka[40], Bogumila Zima-Kulisiewicz[40], Björn Schuller[48,49], Gaurav Pandey[50], David Bates[51], Tien Yin Wong[52,53,54], Benjamin S. Glicksberg[50,55], Maciej Banach[56,57], Cyprian Tomasik[40], Seifedine Kadry[58,59,60], Stephen T. Wong[61,62], Ronan Lordan[63,64], Faisal A. Nawaz[65], Rajeev K. Singla[66,67], ArunSundar MohanaSundaram[68], Himel Mondal[69], Ayesha Juhi[69], Shaikat Mondal[70], Merisa Cenanovic[71], Aleksandra Zielińska[72], Christos Tsagkaris[73], Ronita De[74], Siva Sai Chandragiri[75], Robertas Damaševičius[76], Mugisha Nsengiyumva[77], Artur Stolarczyk[78], Okyaz Eminağa[79], Marco Cascella[80], Harald Willschke[2,42], Atanas G. Atanasov[2,40*]

[1]Oral and Maxillofacial Radiology, Applied Oral Sciences and Community Dental Care, Faculty of Dentistry, The University of Hong Kong, Hong Kong, China

[2]Ludwig Boltzmann Institute Digital Health and Patient Safety, Medical University of Vienna, 1090 Vienna, Austria

[3]Department of Management and Quality Assurance in Pharmacy, National University of Pharmacy of the Ministry of Health of Ukraine, 61002 Kharkiv, Ukraine

[4]Laboratory for Industrial and Applied Mathematics (LIAM), Department of Mathematics and Statistics, York University, Toronto, ON M3J 1P3, Canada

[5]Department of Public Health, Faculty of Medicine, Jordan University of Science and Technology, Irbid 22110, Jordan

[6]Laboratory of Environmental Health and Ecotoxicology, Department of Environmental Sciences, Jahangirnagar University, Dhaka 1342, Bangladesh

[7]Department of Sustainable and Renewable Energy Engineering, University of Sharjah, Sharjah 27272, United Arab Emirates

[8]U.S.-Pakistan Center for Advanced Studies in Energy (USPCAS-E), National University of Sciences and Technology (NUST), Islamabad 44000, Pakistan

[9]Department of Industrial and Mechanical Engineering, Lebanese American University (LAU), Byblos Box 13-5053, Lebanon

[10]Institute of Global Health Innovation, Imperial College, SW7 2BX London, UK

[11]Department of Clinical Research, University of Southern Denmark (SDU), 5230 Odense, Denmark

[12]Department of Surgery, SATC-C, OUH and Svendborg Sygehus, 5700 Svendborg, Denmark

[13]Department of Social Medicine & Public Health, Pomeranian Medical University (PUM), 70-204 Szczecin, Poland

[14]Indigenous Knowledge Systems Centre, Faculty of Natural and Agricultural Sciences, North-West University, Mmabatho 2790, South Africa

[15]School of Life Sciences, College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Durban 4041, South Africa

[16]Division of Cancer, Department of Surgery and Cancer, Imperial College London, SW7 2BX London, UK

[17]Centre for Molecular Medicine and Innovative Therapeutics, Murdoch University, Perth WA 6150, Australia

[18]Institute for Physical Activity and Nutrition, Deakin University, Melbourne 3125, Australia

[19]Department of Pharmacognosy and Phytochemistry, School of Pharmaceutical Sciences, Delhi Pharmaceutical Sciences and Research University, New Delhi 110017, India
[20]Electrodics and Electrocatalysis (EEC) Division, Council of Scientific and Industrial Research (CSIR) - Central Electrochemical Research Institute (CSIR - CECRI), Karaikudi 630003, Tamil Nadu, India
[21]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, Uttar Pradesh 201002, India
[22]Department of Pharmacy, University "G. d'Annunzio" of Chieti-Pescara, 66100 Chieti, Italy
[23]Institute of Sports Medicine, Prevention and Rehabilitation, Paracelsus Medical University, 5020 Salzburg, Austria
[24]Research Institute for Molecular Sports Medicine and Rehabilitation, Paracelsus Medical University, 5020 Salzburg, Austria
[25]REHA-Zentrum Salzburg, 5020 Salzburg, Austria
[26]Ludwig Boltzmann Institute for Digital Health and Prevention, 5020 Salzburg, Austria
[27]DNA Damage Laboratory, Physics Department, School of Applied Mathematical and Physical Sciences, National Technical University of Athens (NTUA), 15780 Athens, Greece
[28]Department of Pharmaceutical Chemistry, Medical University of Gdańsk, 80-416 Gdańsk, Poland
[29]Hrg Scientific, 42000 Varazdin, Croatia
[30]Artificial Intelligence and Innovation in Healthcare Lab, AI2H Laboratory, 42000 Varazdin, Croatia
[31]DeGroote School of Business, McMaster University, Hamilton, ON L8P 1A2, Canada
[32]James Watt School of Engineering, University of Glasgow, G12 8QQ Glasgow, UK
[33]Department of Engineering Science and Mechanics, The Pennsylvania State University—University Park, State College, PA 16802, USA
[34]UCIBIO – Applied Molecular Biosciences Unit, Laboratory of Pharmaceutical Technology, Department of Drug Sciences, Faculty of Pharmacy, University of Porto, 4099-002 Porto, Portugal
[35]Associate Laboratory - Institute for Health and Bioeconomy, Faculty of Pharmacy, University of Porto, 4099-002 Porto, Portugal
[36]Graduate School of Pharmaceutical Sciences, Kumamoto University, Kumamoto 862-0973, Japan
[37]Department of Neurosciences, Istituto Di Ricerche Farmacologiche Mario Negri IRCCS, 20156 Milan, Italy
[38]Department of Chemistry, FMKMC College, Mangalore University Constituent College, Madikeri 571201, Karnataka, India
[39]Department of Biochemical Pharmacology and Drug Design, Institute of Molecular Biology "Roumen Tsanev", Bulgarian Academy of Sciences, 1113 Sofia, Bulgaria
[40]Department of Biotechnology and Nutrigenomics, Institute of Genetics and Animal Biotechnology of the Polish Academy of Sciences, 05-552 Magdalenka, Poland
[41]Faculty of Medicine, Cardinal Stefan Wyszynski University, 01-938 Warsaw, Poland
[42]Department of Anesthesia, General Intensive Care, and Pain Management, Medical University of Vienna, 1090 Vienna, Austria
[43]Department of Pharmacy, East West University, Dhaka 1212, Bangladesh
[44]Department of Epidemiology and Preventive Medicine, School of Public Health and Preventive Medicine, Monash University, Melbourne VIC 3004, Australia
[45]Centre for Metabolism, Obesity and Diabetes Research, McMaster University, Hamilton, ON, Canada
[46]SCI Population Biobanking and Translational Research, Swiss Paraplegic Research, CH-6207 Nottwil, Switzerland
[47]Department of Translational Stem Cell Biology, Research Institute of the Medical University of Varna, 9002 Varna, Bulgaria
[48]Department of Computing, Imperial College London, SW7 2AZ London, UK
[49]Chair of Embedded Intelligence for Health Care and Wellbeing, University of Augsburg, 86159 Augsburg, Germany
[50]Department of Genetics and Genomic Sciences, Icahn School of Medicine at Mount Sinai, New York, NY 10029, USA
[51]Department of General Internal Medicine, Brigham & Women's Hospital, Harvard Medical School, Boston, MA 02115, USA
[52]Singapore Eye Research Institute, Singapore National Eye Center, 168751, Singapore
[53]Duke-NUS Medical School, National University of Singapore, 119077, Singapore
[54]Tsinghua Medicine, Tsinghua University, Beijing 100084, China
[55]Hasso Plattner Institute for Digital Health at Mount Sinai, Icahn School of Medicine at Mount Sinai, New York, NY 10029, USA
[56]Department of Preventive Cardiology and Lipidology, Medical University of Lodz (MUL), 90-419 Lodz, Poland
[57]Department of Cardiology and Adult Congenital Heart Diseases, Polish Mother's Memorial Hospital Research Institute (PMMHRI), 93-338 Lodz, Poland
[58]Department of Applied Data Science, Noroff University College, 4612 Kristiansand, Norway
[59]Artificial Intelligence Research Center (AIRC), Ajman University, Ajman 346, United Arab Emirates
[60]Department of Electrical and Computer Engineering, Lebanese American University, Byblos 13-5053, Lebanon
[61]Department of Systems Medicine and Bioengineering, Houston Methodist Cancer Center and T. T. and W. F. Chao Center for BRAIN, Houston Methodist Academic Institute, Houston Methodist Hospital, Houston, TX 77030, USA
[62]Departments of Radiology, Pathology and Laboratory Medicine and Brain and Mind Research Institute, Weill Cornell Medicine, New York, NY 10065, USA
[63]Institute for Translational Medicine and Therapeutics, Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA 19104, USA

[64]Department of Systems Pharmacology and Translational Therapeutics, Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA 19104, USA
[65]Al Amal Psychiatric Hospital, Emirates Health Services, Dubai, United Arab Emirates
[66]Joint Laboratory of Artificial Intelligence for Critical Care Medicine, Department of Critical Care Medicine and Institutes for Systems Genetics, Frontiers Science Center for Disease-related Molecular Network, West China Hospital, Sichuan University, Chengdu 610212, Sichuan, China
[67]School of Pharmaceutical Sciences, Lovely Professional University, Phagwara, Punjab 144411, India
[68]School of Pharmacy, Sathyabama Institute of Science and Technology, Chennai 600119, Tamil Nadu, India
[69]Department of Physiology, All India Institute of Medical Science, Deoghar, Jharkhand 814152, India
[70]Department of Physiology, Raiganj Government Medical College and Hospital, Raiganj 733134, West Bengal, India
[71]Independent Researcher, 71000 Sarajevo, Bosnia and Herzegovina
[72]Department of Biotechnology, Institute of Natural Fibres and Medicinal Plants, National Research Institute, 60-630 Poznan, Poland
[73]European Student Think Tank, Public Health and Policy Working Group, 1058 DE Amsterdam, Netherlands
[74]Independent researcher, 700019 Kolkata, West Bengal, India
[75]Department of Pathology, University of Oklahoma Health Sciences Center, Oklahoma City, OK 73104, USA
[76]Faculty of Applied Mathematics, Silesian University of Technology, 44-100 Gliwice, Poland
[77]Independent Public Health Consultant, Kigali 4278, Rwanda
[78]Orthopaedic and Rehabilitation Department, Medical University of Warsaw, 02-091 Warsaw, Poland
[79]AI VOBIS Center for Artificial Intelligence in Medicine & Imaging, Stanford University School of Medicine, Stanford, CA 94305, USA
[80]Department of Anesthesia and Critical Care, Istituto Nazionale Tumori - IRCCS, Fondazione Pascale, 80131 Naples, Italy

***Correspondence:** Andy Wai Kan Yeung, Oral and Maxillofacial Radiology, Applied Oral Sciences and Community Dental Care, Faculty of Dentistry, The University of Hong Kong, Hong Kong, China. ndyeung@hku.hk; Atanas G. Atanasov, Ludwig Boltzmann Institute Digital Health and Patient Safety, Medical University of Vienna, 1090 Vienna, Austria. atanas.atanasov@dhps.lbg.ac.at

Academic Editor: Zhaohui Gong, Ningbo University, China
Received: October 6, 2023 **Accepted:** December 6, 2023 **Published:** April 22, 2024

Cite this article: Yeung AWK, Litvinova O, Bragazzi NL, Khader Y, Rahman MM, Said Z, et al. Digital health and mobile health: a bibliometric analysis of the 100 most cited papers and their contributing authors. Explor Digit Health Technol. 2024;2:86–100. https://doi.org/10.37349/edht.2024.00013

Abstract

Aim: This study aimed to identify and analyze the top 100 most cited digital health and mobile health (m-health) publications. It could aid researchers in the identification of promising new research avenues, additionally supporting the establishment of international scientific collaboration between interdisciplinary research groups with demonstrated achievements in the area of interest.

Methods: On 30th August, 2023, the Web of Science Core Collection (WOSCC) electronic database was queried to identify the top 100 most cited digital health papers with a comprehensive search string. From the initial search, 106 papers were identified. After screening for relevance, six papers were excluded, resulting in the final list of the top 100 papers. The basic bibliographic data was directly extracted from WOSCC using its "Analyze" and "Create Citation Report" functions. The complete records of the top 100 papers were downloaded and imported into a bibliometric software called VOSviewer (version 1.6.19) to generate an author keyword map and author collaboration map.

Results: The top 100 papers on digital health received a total of 49,653 citations. Over half of them (n = 55) were published during 2013–2017. Among these 100 papers, 59 were original articles, 36 were reviews, 4 were editorial materials, and 1 was a proceeding paper. All papers were written in English. The University of London and the University of California system were the most represented affiliations. The USA and the UK were the most represented countries. The *Journal of Medical Internet Research* was the most represented journal. Several diseases and health conditions were identified as a focus of these works, including anxiety, depression, diabetes mellitus, cardiovascular diseases, and coronavirus disease 2019 (COVID-19).

Conclusions: The findings underscore key areas of focus in the field and prominent contributors, providing a roadmap for future research in digital and m-health.

Keywords

Digital health, bibliometric, anxiety, depression, diabetes mellitus, cardiovascular diseases, coronavirus disease 2019

Introduction

Digital health is a popular topic that crosses the fields of healthcare, engineering, and computer science. There are numerous definitions of digital health, and it can be defined as “the application of software or hardware, often using mobile smartphone or sensor technologies to improve patient or population health and health care delivery” [1]. The World Health Organization (WHO) defined digital health as “the field of knowledge and practice associated with the development and use of digital technologies to improve health” [2]. The evolution of the concept “digital health” is intricately connected with the closely related concept “mobile health (m-health)” [3]. m-health could potentially accelerate the delivery of healthcare services in the case of both communicable and non-communicable diseases, by augmenting the transformation of the current standard healthcare system towards more digital approach and innovations, making it more accessible and affordable on a global scale [4]. Following digital health transformation from traditional medicine, the point-of-care has shifted from the clinic or laboratory to the patient themselves, and with the vast amount of digital health data collected and stored in various databases, the diagnostic procedure can shift from domination by individual experience towards an evidence-based or analytical data-driven practice [5]. In this context, digital health technologies have also shown promise in addressing challenges related to rare conditions such as spinal cord injuries, offering avenues for personalized treatment and rehabilitation [6]. Moreover, the integration of biobanking data with digital health platforms is emerging as a potent tool for translational medicine, enhancing the scope and efficacy of interventions [7]. Currently, the relevance of the implementation of digital health products and services is due to the increasing number of people on the planet, the increasing life expectancy and aging population, the increasing number of patients with chronic and viral diseases, and the increasing cost of diagnostic and treatment measures. Digital medicine has great potential for diagnosing, preventing, and treating diseases, predicting outcomes, increasing access to medical care, and monitoring the condition of patients. Moreover, digital technologies help reduce costs and improve the quality and efficiency of medical care [8, 9]. Artificial intelligence (AI) improves the quality of medical care and increases patient safety through improved clinical decision-making, process optimization, and risk management [10, 11]. Deep machine learning and robotic process automation are used in many areas of medicine, and new technologies are emerging [12, 13]. According to experts, the AI market in healthcare will reach $1,345.2 billion by 2030 [14]. Big data also has huge potential for digital health development. The global big data market in healthcare is also projected to reach $794.08 billion in 2030 [15, 16]. According to Statista, in 2030, it is anticipated that there will be close to 30 billion Internet of Things (IoT) devices in use worldwide [17]. IoT technologies are actively used in healthcare [18]. Internet of Medical Things (IoMTs) provide ongoing patient monitoring, promote quality improvement, and reduce the cost of care [19]. Telemedicine is also one of the key tools of digital health care. Its use allows for solving both social and economic problems: increasing the availability and quality of medical care, as well as reducing the costs associated with hospitalization and rehabilitation of patients [20]. There is no doubt that the implementation of AI, big data analysis, IoMTs, telemedicine, and remote patient monitoring in healthcare will contribute to improving the level and quality of life of the population, the formation of highly qualified personnel, and intensifying the national economy. For more detailed information on the definitions and scope of the discussed complex concepts, the readers are referred to the following dedicated references: “digital health” [21], “m-health” [22], “innovation” [23], “big data” [24], and “AI” [25].

State entities and international health bodies have underscored their support and called for action to enhance the use of digital health in contemporary healthcare systems during the last decades. In 2020, WHO released a global strategy on digital health for 2020–2025, focusing on capacity building, implementation of national digital health strategies, and access to digital health applications (apps) [2]. In 2023, the United States Agency for International Development (USAID) published a digital health vision for action, underlining strategic priorities for the integration of the existing USAID digital health policy into the global health sector [26]. During the coronavirus disease 2019 (COVID-19) pandemic, the European Union (EU) accelerated the launch of the European Health Union (EHU), a policy initiative intending to strengthen the EU's capacity to respond to health crises and improve the resilience of national healthcare systems. In this frame, the European Health Data Space (EHDS) is a health data-sharing framework with clear rules, common standards, and practices allowing individuals to access and control their personal health data across the EU. This platform leverages interoperability between healthcare and research infrastructure in Europe while providing a paradigm of patient-centeredness and empowerment [27].

In the context of the paradigm shift towards digitalization of healthcare, a rapidly increasing number of studies have been conducted to introduce or evaluate digital health interventions [28, 29]. Although bibliometric studies of the applied categories (i.e., analyses of a specific topic, authors, countries, journals, etc.) were found to have a generally lower citation impact than those studies that actually analyzed author behavior or discussed bibliometric methods, the former group of studies enabled readers to quickly understand the literature landscape of their concerned fields [30]. Moreover, bibliometric analysis may assess the "international influence of scientific work in a reliable, transparent, and objective way" [31]. Subsequently, many bibliometric studies have been published to assess the recurring themes of digital health research, such as digital health behavior change technology [32], the use of AI in digital health [33, 34], digital health literacy [35], the use of digital technology in cognitive assessment and cardiology [36, 37], the use of m-health apps [38], and the app of digital health in pediatric dentistry [39], among others. These previous works clearly demonstrate the merit of bibliometrics research in the target area. Through analysis of large-scale literature data, bibliometrics has a unique role in quantifying scientific knowledge production, at the same time providing a reliable reference for fostering further advancements and a better understanding of future trends in digital health and its related subcategories worldwide [40].

Since so many publications on digital health have been published, it might be difficult for the general audience and researchers alike to quickly identify the most relevant topics and the most influential and cited publications in the field, and who wrote them. As a guide for beginners and the curious, a bibliometric study reporting these pieces of information would be a convenient introduction to the most impactful research in this area. Hence, this work aimed to reveal the top 100 most cited digital health papers and the most productive authors contributing to them. The conducted analysis can be regarded as a compilation highlighting the most impactful (in terms of obtained citations) work in this field that can be a reference for those who wish to understand the types of studies that are conducted and have been highly referenced by the scientific community. Moreover, bibliometric analysis of highly cited articles in the scope of digital health could facilitate researchers to identify promising new research avenues, and establish international scientific collaboration between interdisciplinary research groups with demonstrated achievements in the area of interest, thus providing additional opportunities for the development of new research studies in the field of digital healthcare [41]. The recurring diseases or medical conditions associated with these papers were also identified in this work in order to provide readers with a better understanding of the potential clinical implications associated with the research landscape of this field.

Materials and methods

On 30th August, 2023, the Web of Science Core Collection (WOSCC) electronic database was queried to identify the top 100 most cited digital health papers. The search strategy was adopted from the previous publication of Yang et al. [35]. In brief, the title, abstract, and keywords fields [topic (TS)] of papers indexed in WOSCC were searched. The #1 search string was: TS = ("digital health" OR "digital health care" OR "digital medicine" OR "eHealth" OR "eHealth care" OR "e-medicine" OR "telehealth" OR "tele-health" OR “telehealthcare” OR “tele-healthcare” OR “telemedicine” OR “tele-medicine” OR “mHealth” OR “m-health” OR “mHealthcare” OR “m-healthcare” OR “mobile health” OR “mobile healthcare” OR “mobile medicine” OR “online health” OR “online healthcare” OR “online medicine”). The #2 search string was: TS = (“digital” OR “mobile” OR “app” OR “apps” OR “information technology” OR “Internet technology” OR “artificial intelligence” OR “big data” OR “Internet of Things” OR “IoT” OR “Internet of Thing” OR “blockchain” OR “machine learning” OR “digital learning” OR “deep learning” OR “wearable” OR “robotic” OR “robot” OR “robotics” OR “augmented reality” OR “virtual reality”). The #3 search string was: TS = (“health*”) (* represents any group of characters, including no character). The search was completed as: #1 OR (#2 AND #3). The search yielded 31,555 papers, which were sorted by descending order of citation count. Papers that did not explicitly focus on digital health or m-health were excluded. WOSCC was chosen over Scopus because the former was a more popular choice of literature database to be consulted by researchers [42]. Two authors (AWKY and AGA) independently screened the list to exclude the irrelevant papers, and any disagreements were resolved by mutual discussion to reach a consensus. Subsequently, six papers were excluded from the top 106, to form the final list of top 100 papers.

The basic bibliographic data was directly exported from WOSCC via its Analyze and Create Citation Report functions. The full records of the top 100 papers were exported into bibliometric software, VOSviewer (version 1.6.19), with default settings recommended by the user manual of the software, to generate author keyword maps and author collaboration maps [43]. In short, the function of “Create a map based on bibliographic data” was used. Then, the analysis of “co-occurrence > author keywords” was used for the former and the “co-authorship > authors” analysis was used for the latter. “Full counting” method was applied. For both maps, a threshold of 2 was applied, meaning that only author keywords appearing in at least 2 papers or authors contributing at least 2 papers were considered, respectively. In each map, the node size represents the number of papers, and the inter-node distance represents the frequency of co-occurrence in the same papers by the nodes. The node color represents the citations per paper (CPP) for the author keyword map and different clusters for the author collaboration map. Moreover, the list of author names from the top 100 papers was compiled and the gender of the authors was identified by genderize.io (https://genderize.io/).

Results

The top digital health 100 papers (Table S1) received a total of 49,653 citations as of 30th August, 2023. Over half of them (n = 55) were published during 2013–2017 (Figure 1). Meanwhile, the annual citation count of these papers experienced stable growth, and collectively they received 7,923 citations in the year 2021 alone. Among these 100 papers, 59 were original articles (CPP = 527.9), 36 were reviews (CPP = 437.6), 4 were editorial materials (CPP = 585.5), and 1 was a proceeding paper (CPP = 414.0). All of them were written in English.

The top 5 most represented authors, affiliations, countries, journals, and journal categories among the top 100 digital health papers are listed in Table 1. University of London (n = 11, CPP = 550.3) and the University of California system (n = 10, CPP = 439.4) were the most productive affiliations. Accordingly, the USA (n = 58, CPP = 513.2) and the UK (n = 20, CPP = 513.5) were the most productive countries. The *Journal of Medical Internet Research* (n = 21, CPP = 459.1) was by far the most productive journal, while both medical informatics (n = 35, CPP = 469.7) and health care sciences & services (n = 33, CPP = 476.4) were the most productive journal categories.

Name analysis from genderize.io indicated that the top 100 papers were authored by 327 men and 184 women (approximately 1.8:1, 36.0% women). The most productive authors among the top 100 digital health papers were examined more closely. The author collaboration map showed that there were 44 authors, each with at least 2 papers among the top 100, distributed in 12 clusters (Figure 2). The most productive authors (Table 1) were clustered as demonstrated in Figure 2. The most productive author, Mohr DC was in the yellow cluster with Schueller SM, a cluster with authors mainly working in the USA. Meanwhile, Spring BJ, Riley WT, West R, and Yardley L were in the red cluster, a cluster with authors based in the USA and the UK. The orange cluster had Chau PYK and Hu PJH showing a collaboration between

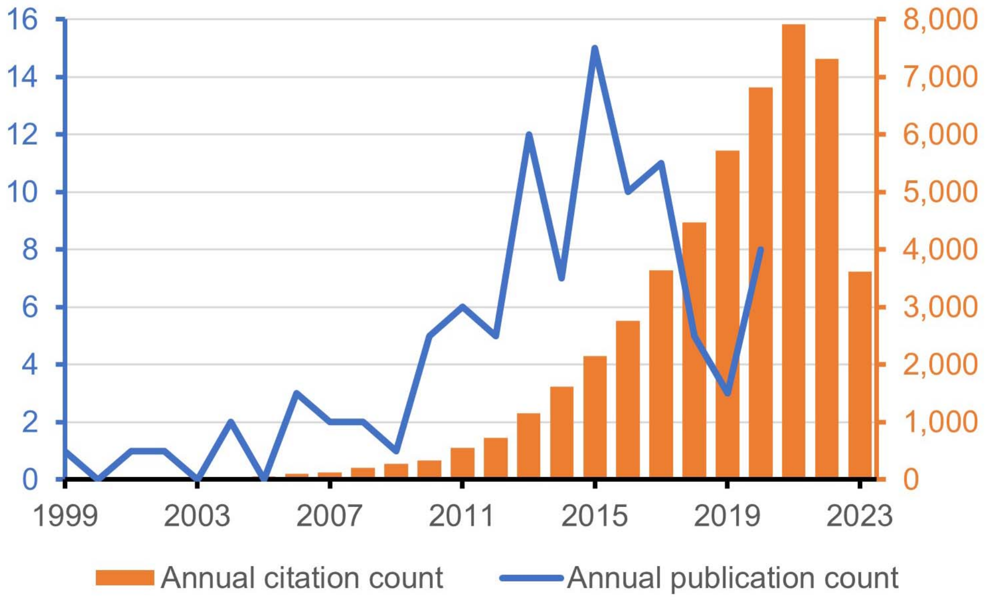

Figure 1. Annual publication and citation counts of the top 100 digital health papers

Table 1. Top 5 most represented authors, affiliations, countries, journals, and journal categories

Entity	Number of publications	CPP
Authors		
Mohr, David C.	6	378.3
Spring, Bonnie J.	4	528.3
Chau, Patrick Y. K.	3	706.3
Firth, Joseph	3	362.0
Hu, Paul J. H.	3	706.3
Nicholas, Jennifer	3	362.0
Ozcan, Aydogan	3	404.7
Riley, William T.	3	506.3
Schueller, Stephen M.	3	353.0
Torous, John	3	362.0
West, Robert	3	392.3
Yardley, Lucy	3	471.3
Affiliations		
University of London	11	550.3
University of California system	10	439.4
Northwestern University	9	425.3
University College London	9	476.3
Harvard University	8	578.0
Countries		
USA	58	513.2
UK	20	513.5
Australia	12	432.2
Canada	9	631.8
China	9	556.4
Journals		
Journal of Medical Internet Research	21	459.1
International Journal of Medical Informatics	5	440.4
American Journal of Preventive Medicine	3	444.3
JMIR mHealth and uHealth	3	728.0
Healthcare Informatics Research	2	355.0
JAMA	2	735.0

Table 1. Top 5 most represented authors, affiliations, countries, journals, and journal categories (*continued*)

Entity	Number of publications	CPP
JMIR Mental Health	2	486.5
Lab on a Chip	2	370.5
PLOS Medicine	2	1104.5
Scientific Data	2	385.0
Translational Behavioral Medicine	2	552.5
Journal categories		
Medical informatics	35	469.7
Health care sciences & services	33	476.4
Medicine general internal	13	605.2
Public environmental occupational health	12	430.7
Computer science information systems	11	547.6

More than 5 names are displayed for authors and journals, due to the equal number of publications for several authors or journals that were ranked in 5th place

China and the USA. The green cluster had Firth J, Nicholas J, and Torous J, who had affiliations with the USA, the UK, and Australia. Finally, the blue cluster had Ozcan A, and authors within this cluster were mostly based at the University of California Los Angeles. Besides those authors listed in Table 1, there were two 3-author clusters: the Singaporean cluster (cyan) and the UK cluster (purple). Other five clusters had 1 or 2 authors each.

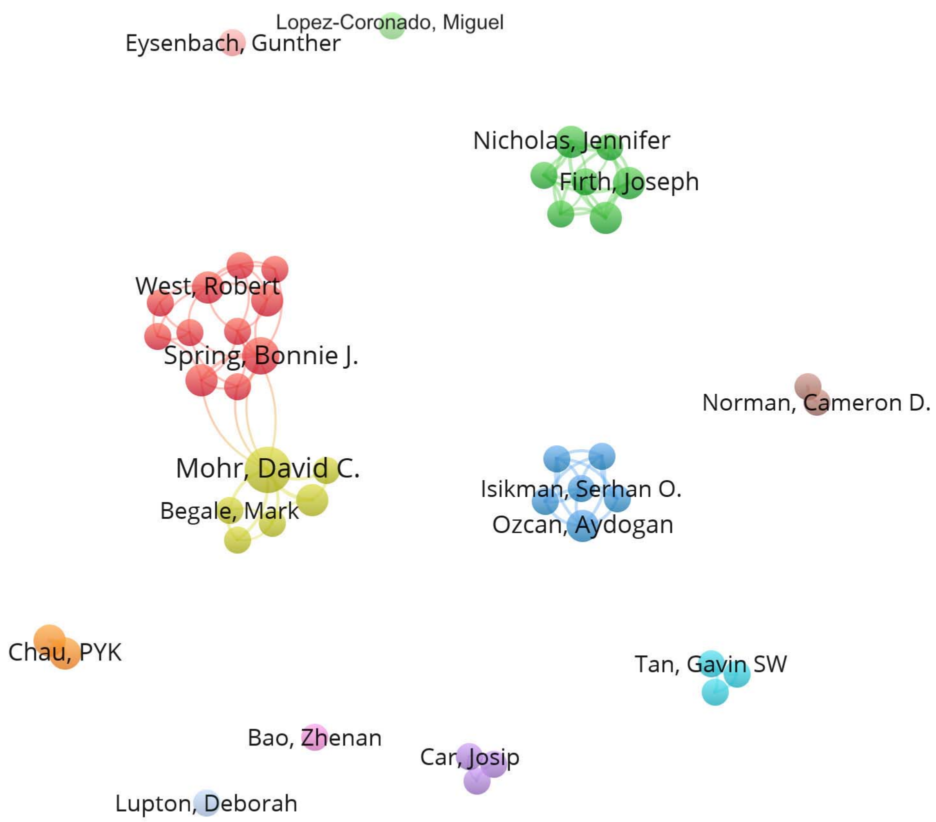

Figure 2. Author collaboration map

At the country level, the extent of international collaboration was explored. For the 69 papers with authors based in the USA and the UK, international collaborations were observed with China ($n = 8$), and to a lesser extent with the following: Australia and Germany (each $n = 4$); Canada, Singapore, and Sweden (each $n = 3$); Brazil, India, Netherlands, South Korea, and Switzerland (each $n = 2$). Fourteen collaborators with $n = 1$ were not listed here. Meanwhile, for the 9 papers with authors based in China, international collaborations were observed with the USA (n = 8), and to a lesser extent with the UK, Singapore, and Sweden (each n = 2). Similarly, seven collaborators with n = 1 were not listed here.

Then, the author's keywords were examined to identify recurring themes among the top 100 digital health papers. Several common diseases and health conditions could be observed, such as anxiety (n = 2, CPP = 486.5), depression (n = 6, CPP = 413.3), diabetes mellitus (n = 2, CPP = 342.5), cardiovascular diseases (n = 2, CPP = 360.5), and COVID-19 (n = 2, CPP = 445.5) (Figure 3). Among the recurring authors, keywords were also "public health" (n = 4, CPP = 674.5), "literacy" (n = 2, CPP = 850), "patient education" (n = 2, CPP = 857.0), "consumer health information" (n = 2, CPP = 743.0), and "internet" (n = 8, CPP = 640.0), which all fit into the theme of "digital health literacy", underling the high significance of digital media as an important source of health information for patients with chronic diseases and other health conditions.

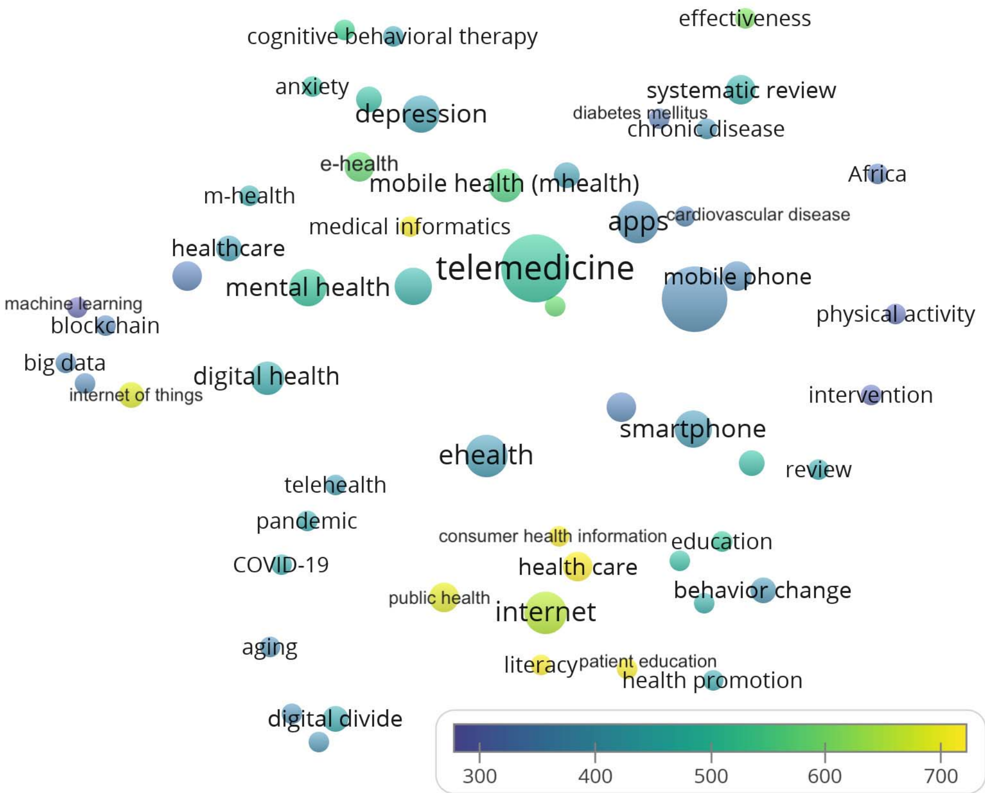

Figure 3. Author keywords map

Discussion

This bibliometric analysis identified the top 100 digital health publications. The article-to-review ratio was approximately 1.6:1. More than half of the publications (n = 55) were published during the middle of the 2010s. The annual citation count of these papers grew steadily, and collectively they received nearly 8,000 citations in the year 2021 alone. The majority of these 100 papers are original articles and reviews. All of them were written in English.

It is noteworthy that the majority of these top-cited papers were published between 2013 and 2017, indicating a surge in interest and research output during this period. This could be reflective of technological advancements and increased funding in digital health research. Furthermore, the *Journal of Medical Internet Research* emerged as the most productive journal, suggesting that it serves as a central platform for high-impact research in this field. Interestingly, numerous journals with high Journal Citation Reports (JCR) impact factor, which are cherished by the scientific community in the area of digital health (e.g., *Nature Biotechnology*, *Lancet Digital Health*, *Nature Medicine*, *npj Digital Medicine*), were not highly represented in the list of the 100 most cited publications (Table 1). These findings might be due, at least in part, to the larger number of papers published in journals such as the *Journal of Medical Internet Research* in combination with the poor prediction power of journal editors, manuscript reviewers, and submitting authors to judge the future citation-potential of manuscripts at the time of manuscript submission or during peer-review process.

In regard to the analyzed countries with the highest productive output, findings from previous similar studies also indicate that articles from the USA are often among the most cited, although this tendency seems to be changing with the growing publication rates from up-and-coming countries like China and India, depending on the specific domains investigated [44]. Meanwhile, there seemed to be gender disparity in the authorship of the top 100 papers, as 36.0% of authors were women, consistent with previous findings from cardiology-related COVID-19 literature (29.9%) [45] and neuroscience (35.3%) [46]. It was suggested that historical numerical imbalance, socio-psychological factors, and cultural reasons contributed to the gender disparity, and policies to establish a more egalitarian and heterogeneous scientific community should be advocated [47].

Several diseases and health conditions were found among the recurring author keywords, such as anxiety, depression, diabetes mellitus, cardiovascular diseases, and COVID-19. Regarding anxiety and depression, Firth et al. [48] conducted a meta-analysis of randomized controlled trials for each. They found that smartphone interventions could significantly reduce the total anxiety scores compared to control conditions across samples with sub-clinical or diagnosed anxiety disorders (publication ranked 81st in Table S1, 322 citations). They also found that depressive symptoms were reduced significantly more from smartphone apps than control conditions, and cognitive training apps had a significantly smaller effect size on depression outcomes than those focusing on mental health [49] (publication ranked 38th in Table S1, 461 citations). Meanwhile, the most cited randomized controlled trial on anxiety and depression was conducted by Fitzpatrick et al. [50] (publication ranked 20th in Table S1, 599 citations), which found that young adults who received a text-based conversational agent significantly reduced their symptoms of both depression and anxiety over a 2-week study period, whereas those who received a mental health electronic book (eBook) significantly reduced their anxiety but not depression.

The authors of the article "The effectiveness of mobile-health technologies to improve health care service delivery processes: a systematic review and meta-analysis", which ranks second in the citation (1,440 citations) in Table S1, note the modest advantages of using mobile technologies and the need for further research [51]. The high citation of the publication confirms further research in this area and represents the experience of using digital technologies in medicine and their social and economic effectiveness. Further publications citing the work discuss the need for safety and the proven effectiveness of new digital healthcare products.

In the third most cited publication (1,286 citations) in Table S1, an analysis of the security and privacy of the IoT and their impact on the economy and society was carried out [52]. The high citation of this publication confirms the relevance of these issues at this time. It is necessary to conduct clinical research on digital medical devices and services. An increasing number of digital health products are being developed to help reduce morbidity and mortality and increase patient satisfaction with the quality and availability of care.

In the context of diabetes, Ting et al. [53] (publication ranked 7th in Table S1, 1,039 citations) developed a deep learning system that could reliably identify diabetic retinopathy and related eye diseases to facilitate better patient screening. Meanwhile, Cafazzo et al. [54] (publication ranked 50th in Table S1, 392 citations) developed a mobile app to facilitate the self-management of adolescents with diabetes. They found that participants enjoyed the reward system and the microblogging community: the former meant that a user would be awarded "game points" to redeem mobile apps and music if he/she adhered to the preset goals (e.g., 3 or more daily blood glucose tests), whereas the latter meant that users could communicate with one another through a social platform resembling Twitter (recently renamed X).

For cardiovascular disease, Chow et al. [55] (publication ranked 41st in Table S1, 431 citations) found that the use of a lifestyle-focused text messaging service among patients with coronary artery disease led to a modest improvement in low-density lipoprotein cholesterol levels and greater improvement in other cardiovascular disease risk factors such as an increase in physical activity and decrease in smoking, compared with usual care. Meanwhile, the American Heart Association has reviewed and acknowledged the studies on using m-health to manage numerous risk factors of cardiovascular disease, such as weight management, increased physical activity, and smoking cessation [56] (publication ranked 75th in Table S1, 332 citations).

Last but not least, COVID-19 was among the most represented diseases. For instance, the use of telemedicine and virtual care for remote treatment of patients during the COVID-19 pandemic was summarized from 35 research studies [57] (publication ranked 60th in Table S1, 364 citations). Meanwhile, the conceptual framework of telemedicine integration and implementation into the national healthcare system during the COVID-19 pandemic has been discussed and its app was examined for numerous countries [58] (publication ranked 27th in Table S1, 514 citations).

While informative, this study has several inherent limitations. The dynamic character of citation counts is one of them. Because citations build over time, the rankings of the most cited articles are susceptible to change, making these findings reflective of the current research scene. Total citation numbers are also a time-dependent phenomenon that might favor older papers, which had more time to accumulate citations. Furthermore, the specific collection and citation count of the WOSCC database influence the results. Hence, other databases, such as Scopus or Dimensions, may yield different findings. Last but not least, while citation counts were used as a measure of scientific attention, it is important to note that many citations do not always speak to a paper's scientific quality or real-world influence. In essence, papers can be referenced for various reasons, and not all of them will reflect well on the work's content.

This bibliometric research highlights the changing environment of digital health, which is characterized by a convergence of advanced technologies and patient-centered care paradigms. The analysis corroborates the notion that the introduction of digital technologies in healthcare improves access to medical services and their quality, optimizes the use of healthcare resources, and improves patient safety. The prevalence of themes such as anxiety, depression, diabetes mellitus, cardiovascular diseases, and especially COVID-19 demonstrates the versatility and necessity of digital health treatments in treating both chronic and emergent health challenges. Notably, institutions such as the University of London and the University of California are pioneering the way, reflecting worldwide contributions, with the USA and the UK being especially active in this arena. The dominance of journals such as the *Journal of Medical Internet Research* highlights the importance of dedicated channels for disseminating digital health research. As the digital health industry expands, it is critical to evaluate and analyze its bibliometric environment regularly to comprehend evolving paradigms and ensure that technical improvements fit with healthcare demands.

Abbreviations

AI: artificial intelligence

apps: applications

COVID-19: coronavirus disease 2019

CPP: citations per paper

EU: European Union

IoT: Internet of Things

m-health: mobile health

WOSCC: Web of Science Core Collection

Supplementary materials

The supplementary material for this article is available at: https://www.explorationpub.com/uploads/Article/file/101113_sup_1.pdf.

Declarations

Author contributions

AWKY: Conceptualization, Investigation, Writing—original draft, Writing—review & editing. AGA: Conceptualization, Investigation, Writing—review & editing. OL, NLB, YK, MMR, ZS, RSHI, AK, AOA, JMF, NR, SMSI, DT, GV, GO, JN, AGG, MRS, DH, YY, MAI, HC, EBS, HPD, MAL, JGM, NTT, MM, OA, SVK, FPH, FBM, BNS, DW, JS, JOH, MK, EP, IB, A Jóźwik, NK, BZK, BS, GP, DB, TYW, BSG, MB, C Tomasik, SK, STW, RL, FAN, RKS, AM, HM, A Juhi, SM, M Cenanovic, AZ, C Tsagkaris, R De, SSC, R Damaševičius, MN, AS, OE, M Cascella, and HW: Writing—review & editing. All authors read and approved the submitted version.

Conflicts of interest

Atanas G. Atanasov is an Advisory Board member of QluPod AG, a health-tech company aiming for the development of innovative telehealth solutions, and Editor-in-Chief of *Exploration of Digital Health Technologies*. Andy Wai Kan Yeung, Nicola Luigi Bragazzi, Yousef Khader, Md. Mostafizur Rahman, Zafar Said, Robert S. H. Istepanian, Anastasios Koulaouzidis, Adeyemi Oladapo Aremu, James M. Flanagan, Navid Rabiee, Sheikh Mohammed Shariful Islam, Devesh Tewari, Ganesh Venkatachalam, Giustino Orlando, Josef Niebauer, Alexandros G. Georgakilas, Mohammad Reza Saeb, Yufei Yuan, Muhammad Ali Imran, Huanyu Cheng, Eliana B. Souto, Hari Prasad Devkota, Maurizio Angelo Leone, Jamballi G. Manjunatha, Nikolay T. Tzvetkov, Dongdong Wang, Jivko Stoyanov, Emil Parvanov, Gaurav Pandey, Maciej Banach, Seifedine Kadry, Aleksandra Zielińska, and Marco Cascella are Editorial Board members of *Exploration of Digital Health Technologies*. Atanas G. Atanasov and all the Editorial Board members mentioned above had no involvement in the decision-making or the review process of this manuscript. The other authors declare that they have no conflicts of interest.

Ethical approval

Not applicable.

Consent to participate

Not applicable.

Consent to publication

Not applicable.

Availability of data and materials

The dataset analyzed for this study are included in the manuscript and the Supplementary materials.

Funding

Not applicable.

Copyright

References

1. Chen CE, Harrington RA, Desai SA, Mahaffey KW, Turakhia MP. Characteristics of digital health studies registered in ClinicalTrials.gov. JAMA Intern Med. 2019;179:838–40.
2. Global strategy on digital health 2020-2025 [Internet]. World Health Organization; c2021 [cited 2023 Sep 12]. Available from: https://www.who.int/docs/default-source/documents/gs4dhdaa2a9f352b0445bafbc79ca799dce4d.pdf
3. Istepanian RSH. Mobile health (m-Health) in retrospect: the known unknowns. Int J Environ Res Public Health. 2022;19:3747.

4. Inan DI, Win KT, Juita R. mHealth medical record to contribute to noncommunicable diseases in Indonesia. Procedia Comput Sci. 2019;161:1283–91.
5. Meskó B, Drobni Z, Bényei É, Gergely B, Győrffy Z. Digital health is a cultural transformation of traditional healthcare. Mhealth. 2017;3:38.
6. Farris RJ, Quintero HA, Murray SA, Ha KH, Hartigan C, Goldfarb M. A preliminary assessment of legged mobility provided by a lower limb exoskeleton for persons with paraplegia. IEEE Trans Neural Syst Rehabil Eng. 2014;22:482–90.
7. Malmström PU, Agrawal S, Bläckberg M, Boström PJ, Malavaud B, Zaak D, et al. Non-muscle-invasive bladder cancer: a vision for the future. Scand J Urol. 2017;51:87–94.
8. Rodriguez JA, Shachar C, Bates DW. Digital inclusion as health care — supporting health care equity with digital-infrastructure initiatives. N Engl J Med. 2022;386:1101–3.
9. Ibrahim MS, Mohamed Yusoff H, Abu Bakar YI, Thwe Aung MM, Abas MI, Ramli RA. Digital health for quality healthcare: a systematic mapping of review studies. Digit Health. 2022;8:20552076221085810.
10. Wahl B, Cossy-Gantner A, Germann S, Schwalbe NR. Artificial intelligence (AI) and global health: How can AI contribute to health in resource-poor settings? BMJ Glob Health. 2018;3:e000798.
11. Bates DW, Levine D, Syrowatka A, Kuznetsova M, Craig KJT, Rui A, et al. The potential of artificial intelligence to improve patient safety: a scoping review. NPJ Digit Med. 2021;4:54.
12. Sunarti S, Fadzlul Rahman F, Naufal M, Risky M, Febriyanto K, Masnina R. Artificial intelligence in healthcare: opportunities and risk for future. Gac Sanit. 2021;35:S67–70.
13. Deloitte AI Institute. The generative AI dossier [Internet]. Deloitte Development LLC; 2023 [cited 2023 Sep 16]. Available from: https://www2.deloitte.com/content/dam/Deloitte/us/Documents/consulting/us-ai-institute-gen-ai-use-cases.pdf
14. Artificial intelligence (AI) market by offering (hardware, software), technology (ML (deep learning (LLM, transformers (GPT 1, 2, 3, 4)), NLP, computer vision), business function, vertical, and region - global forecast to 2030 [Internet]. MarketsandMarkets Research Private Ltd.; c2024 [cited 2023 Sep 16]. Available from: https://www.marketsandmarkets.com/Market-Reports/artificial-intelligence-market-74851580.html?gclid=CjwKCAjwpJWoBhA8EiwAHZFzfmTHT3YQ9td488Z1HJ0tdc7XOi1wboGOXSkY-BsjEEx7QtEMmuQ-1hoCAyIQAvD_BwE
15. Borges do Nascimento IJ, Marcolino MS, Abdulazeem HM, Weerasekara I, Azzopardi-Muscat N, Gonçalves MA, et al. Impact of big data analytics on people's health: overview of systematic reviews and recommendations for future studies. J Med Internet Res. 2021;23:e27275.
16. Healthcare big data analytics market size worth USD 794.08 billion by 2030 at 24.26% CAGR – report by market research future (MRFR) [Internet]. [cited 2023 Sep 16]. Available from: https://www.globenewswire.com/en/news-release/2023/06/14/2687890/0/en/Healthcare-Big-Data-Analytics-Market-Size-Worth-USD-794-08-Billion-by-2030-at-24-26-CAGR-Report-by-Market-Research-Future-MRFR.html
17. Vailshery LS. Internet of Things (IoT) - statistics & facts [Internet]. [cited 2023 Sep 16]. Available from: https://www.statista.com/topics/2637/internet-of-things/#topicOverview
18. Medtech and the internet of medical things: How connected medical devices are transforming health care [Internet]. Deloitte LLP; c2018 [cited 2023 Sep 16]. Available from: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Life-Sciences-Health-Care/gx-lshc-medtech-iomt-brochure.pdf
19. Yu Z, Amin SU, Alhussein M, Lv Z. Research on disease prediction based on improved DeepFM and IoMT. IEEE Access. 2021;9:39043–54.
20. Barbosa W, Zhou K, Waddell E, Myers T, Dorsey ER. Improving access to care: telemedicine across medical domains. Annu Rev Public Health. 2021;42:463–81.

21. Mathews SC, McShea MJ, Hanley CL, Ravitz A, Labrique AB, Cohen AB. Digital health: a path to validation. NPJ Digit Med. 2019;2:38.
22. Nacinovich M. Defining mHealth. J Commun Healthcare. 2011;4:1–3.
23. Kline SJ, Rosenberg N. An overview of innovation. In: Rosenberg N, editor. Studies on science and the innovation process. World Scientific; 2009. pp. 173–203.
24. Favaretto M, De Clercq E, Schneble CO, Elger BS. What is your definition of big data? Researchers' understanding of the phenomenon of the decade. PLoS One. 2020;15:e0228987.
25. Ramesh AN, Kambhampati C, Monson JR, Drew PJ. Artificial intelligence in medicine. Ann R Coll Surg Engl. 2004;86:334–8.
26. Note 2. Advancing national digital health strategies [Internet]. Source: USAID; [cited 2023 Oct 5]. Available from: https://www.usaid.gov/sites/default/files/2023-06/USAID_DHV_TGN2_508_06132023.pdf
27. Gallina S. Preparing Europe for future health threats and crises: the European Health Union. Euro Surveill. 2023;28:2300066.
28. Ahmadvand A, Kavanagh D, Clark M, Drennan J, Nissen L. Trends and visibility of "digital health" as a keyword in articles by JMIR publications in the new millennium: bibliographic-bibliometric analysis. J Med Internet Res. 2019;21:e10477.
29. Atanasov AG. *Exploration of Digital Health Technologies*. Explor Digit Health Technol. 2023;1:1–3.
30. Ellegaard O. The application of bibliometric analysis: disciplinary and user aspects. Scientometrics. 2018;116:181–202.
31. van Raan AFJ. Advances in bibliometric analysis: research performance assessment and science mapping. In: Blockmans W, Engwall L, Weaire D, editors. Bibliometrics: use and abuse in the review of research performance. London: Portland Press Limited; 2014. pp. 17–28.
32. Taj F, Klein MCA, van Halteren A. Digital health behavior change technology: bibliometric and scoping review of two decades of research. JMIR Mhealth Uhealth. 2019;7:e13311.
33. Fosso Wamba S, Queiroz MM. Responsible artificial intelligence as a secret ingredient for digital health: bibliometric analysis, insights, and research directions. Inf Syst Front. 2023;25:2123–38.
34. Shaikh AK, Alhashmi SM, Khalique N, Khedr AM, Raahemifar K, Bukhari S. Bibliometric analysis on the adoption of artificial intelligence applications in the e-health sector. Digit Health. 2023;9: 20552076221149296.
35. Yang K, Hu Y, Qi H. Digital health literacy: bibliometric analysis. J Med Internet Res. 2022;24:e35816.
36. Yeung AWK, Kulnik ST, Parvanov ED, Fassl A, Eibensteiner F, Völkl-Kernstock S, et al. Research on digital technology use in cardiology: bibliometric analysis. J Med Internet Res. 2022;24:e36086.
37. Chen L, Zhen W, Peng D. Research on digital tool in cognitive assessment: a bibliometric analysis. Front Psychiatry. 2023;14:1227261.
38. Peng C, He M, Cutrona SL, Kiefe CI, Liu F, Wang Z. Theme trends and knowledge structure on mobile health apps: bibliometric analysis. JMIR Mhealth Uhealth. 2020;8:e18212.
39. Bastani P, Manchery N, Samadbeik M, Ha DH, Do LG. Digital health in children's oral and dental health: an overview and a bibliometric analysis. Children (Basel). 2022;9:1039.
40. Tian H, Chen J. A bibliometric analysis on global eHealth. Digit Health. 2022;8:20552076221091352.
41. de Oliveira OJ, da Silva FF, Juliani F, Barbosa LCMF, Nunhes TV. Bibliometric method for mapping the state-of-the-art and identifying research gaps and trends in literature: an essential instrument to support the development of scientific projects. In: Kunosic S, Zerem E, editors. Scientometrics recent advances. Rijeka: IntechOpen; 2019.
42. Zhu J, Liu W. A tale of two databases: the use of Web of Science and Scopus in academic papers. Scientometrics. 2020;123:321–35.
43. van Eck NJ, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics. 2010;84:523–38.

44. Ellegaard O, Wallin JA. The bibliometric analysis of scholarly production: How great is the impact? Scientometrics. 2015;105:1809–31.
45. Vasti EC, Ouyang D, Ngo S, Sarraju A, Harrington RA, Rodriguez F. Gender disparities in cardiology-related COVID-19 publications. Cardiol Ther. 2021;10:593–8.
46. Marescotti M, Loreto F, Spires-Jones TL. Gender representation in science publication: evidence from *Brain Communications*. Brain Commun. 2022;4:fcac077.
47. Astegiano J, Sebastián-González E, Castanho CT. Unravelling the gender productivity gap in science: a meta-analytical review. R Soc Open Sci. 2019;6:181566.
48. Firth J, Torous J, Nicholas J, Carney R, Rosenbaum S, Sarris J. Can smartphone mental health interventions reduce symptoms of anxiety? A meta-analysis of randomized controlled trials. J Affect Disord. 2017;218:15–22.
49. Firth J, Torous J, Nicholas J, Carney R, Pratap A, Rosenbaum S, et al. The efficacy of smartphone-based mental health interventions for depressive symptoms: a meta-analysis of randomized controlled trials. World Psychiatry. 2017;16:287–98.
50. Fitzpatrick KK, Darcy A, Vierhile M. Delivering cognitive behavior therapy to young adults with symptoms of depression and anxiety using a fully automated conversational agent (Woebot): a randomized controlled trial. JMIR Ment Health. 2017;4:e19.
51. Free C, Phillips G, Watson L, Galli L, Felix L, Edwards P, et al. The effectiveness of mobile-health technologies to improve health care service delivery processes: a systematic review and meta-analysis. PLoS Med. 2013;10:e1001363.
52. Islam SMR, Kwak D, Kabir MH, Hossain M, Kwak KS. The Internet of Things for health care: a comprehensive survey. IEEE Access. 2015;3:678–708.
53. Ting DSW, Cheung CY, Lim G, Tan GSW, Quang ND, Gan A, et al. Development and validation of a deep learning system for diabetic retinopathy and related eye diseases using retinal images from multiethnic populations with diabetes. JAMA. 2017;318:2211–23.
54. Cafazzo JA, Casselman M, Hamming N, Katzman DK, Palmert MR. Design of an mHealth app for the self-management of adolescent type 1 diabetes: a pilot study. J Med Internet Res. 2012;14:e70.
55. Chow CK, Redfern J, Hillis GS, Thakkar J, Santo K, Hackett ML, et al. Effect of lifestyle-focused text messaging on risk factor modification in patients with coronary heart disease: a randomized clinical trial. JAMA. 2015;314:1255–63.
56. Burke LE, Ma J, Azar KM, Bennett GG, Peterson ED, Zheng Y, et al.; American Heart Association Publications Committee of the Council on Epidemiology and Prevention; Behavior Change Committee of the Council on Cardiometabolic Health; Council on Cardiovascular and Stroke Nursing, Council on Functional Genomics and Translational Biology, Council on Quality of Care and Outcomes Research, and Stroke Council. Current science on consumer use of mobile health for cardiovascular disease prevention: a scientific statement from the American Heart Association. Circulation. 2015;132: 1157–213. Erratum in: Circulation. 2015;132:e233.
57. Bokolo Anthony Jnr. Use of telemedicine and virtual care for remote treatment in response to COVID-19 pandemic. J Med Syst. 2020;44:132.
58. Ohannessian R, Duong TA, Odone A. Global telemedicine implementation and integration within health systems to fight the COVID-19 pandemic: a call to action. JMIR Public Health Surveill. 2020;6: e18810.