Bibliometric Analysis of Telemedicine and E-Health Literature

https://doi.org/10.3991/ijoe.v17i12.25483

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Abstract—Emerging technologies such as artificial intelligence, the internet of things, cloud computing, and wearable gadgets have broadened the scope of telemedicine and eHealth in past years. This research aims to investigate the past patterns of telemedicine and eHealth research over the past ten years. Scopus database was used to extract the article information of the selected articles. The research is conducted on 1401 articles in which we investigated the top authors, journals, institutions, countries, and highly cited articles. Our research findings project the growth trend of publications and the pattern of authors and distribution of articles and the core journals. The top 10 authors in the selected field were identified so were the highly cited articles. Co-occurrence analyses of keywords, authors, and countries co-authors analysis and bibliographic coupling of VOS viewer documents were conducted. The limitations and directions for future researchers have also been discussed.

Keywords—telemedicine, eHealth, bibliometric analysis, telehealth, scopus

1 Introduction

The timely and efficient exchange of information can significantly impact different health scenarios, be it an accident or lifetime chronic health condition, or other [1]. Advances in ICT have facilitated the exchange of data successfully, enabling universal access for health products and services to information. Several ICTs have been implemented globally by the health sector to increase information exchange efficiency at all levels of health care [2]. In addition to information exchange, modern ICTs have also facilitated quick, cost-effective clinical and consulting services for medical practitioners. That is typically called e-health, i.e., the use of ICTs to achieve healthcare [3]. eHealth is an interdisciplinary area that uses information and communication technology for health improvement. The objective of e-health is to increase access to, action, and monitor healthcare [4]. Another widely used similar concept is telemedicine. The terms' telemedicine' and 'e-health' are often used interchangeably [5].

Telemedicine plays a significant role in the digital evolution of traditional health care. Telemedicine is a solution for health care providing inaccessible disadvantaged areas and strives to offer the same access to medical care regardless of geographical location [6]. Health care organizations worldwide have increased interest in implementing telemedicine technology to improve care and services [7]. The role of telemedicine has evolved significantly over the last two decades to encompass online physician consultations, intensive care services, monitoring of mental health, managing chronic illness, providing an alternative to traditional visits to hospitals and physicians. Telemedicine is a growing field and identifying the latest developments and growing trends can prove challenging; however, the bibliometric analysis makes it easy to assess a large amount of literature to identify the most prolific authors, articles, keywords, journals, and institutions. Although the word e-health was coined considerably later than telemedicine (and its derivatives), telemedicine is by far the most hot topic in the field [2], [8].

Several literature reviews and bibliometric analysis has been carried out in the telemedicine or e-health area [2], [5], [7], [9]–[16]. Viswanathan et al., [11] focused on authorship trends, while Nwagwu and Onyancha [11] focused on author keywords. Calvo et al., [13] conducted a bibliometric analysis by linking ICT technologies and health with individuals experiencing homelessness. Different researchers have performed their analysis on published literature from different sources, for instance, PubMed [14], Google scholar [12], Web of Science [10], [15] and Scopus [9]. The focus of Fatehi and Wootton [5] was to determine the trend in the use of telemedicine e-health and similar terminologies, while Uribe-Toril et al., [16] studied the telemedicine field concerning social science. However, to the best of our knowledge, this is the first study demonstrating the descriptive statistics and the bibliometric analysis on telemedicine and e-health literature on the Scopus indexed articles from the past decade (2011–2020). This study is unique in its way and incorporates a comprehensive descriptive analysis (influential authors, top journals, institutions, countries, and articles) and bibliometric analysis (co-authorship analysis, co-occurrence analysis, and bibliographic coupling). The main objective of this study is to determine.

1. The publication growth trend of published articles over the past decade.
2. The common aspects including highly prolific journals, institutions, most influential authors, highly cited articles, and the most productive countries.
3. The predominant keywords and authors in the field of telemedicine (eHealth) field by carrying out the co-occurrence analysis of authors keywords.
4. The most influential authors and the most productive countries by carrying out co-authorship analysis of author and countries.

The rest of the paper is structured as follows; Section 2 mentions the methodology. The complete and extensive descriptive analysis is provided in Section 3. The co-authorship analysis by countries and authors, by co-existence of keywords, and bibliometric coupling of documents is performed in section 4. We conducted a complete literature survey in the last few years in the fourth part. Section 5 summarises the findings in order to complete the study. Section 6 states the limitations and future directions of the study.

2 Methodology

The Scopus database is used for this investigation. For numerous reasons, this database has been chosen as a study platform. The Scopus database is one of those with the most complete worldwide and regional coverage of journals, books and conferences, and offers a broad articles coverage [17], [18]. Scopus also supports numerous software programs to obtain information needed in the bibliometric analysis (authors, title, publication year, references, abstracts, institutions and countries) and is user friendly [19]. It also allows for a preliminary examination of the number of quotations and identification of the most cited authors and articles over the years.

Because telemedicine continues to grow rapidly, it might be tough to keep up to date with the latest trends and advancements, but the bibliometric analysis is a helpful quantitative tool for measuring the enormous number of publications in this sector. Bibliometrics are effectively employed for the evaluation of citations in the complete articles database [20], in order to identify the most influential journals and their publication features in the telemedicine sector [5], [7], [21].

The study data was collected from the SCOPUS database on 26 June 2021 and focused on the research that was published from 2011–2020 that is, in the past 10 years. "Telemedicine and ehealth" was the keyword for the research. The search comprised the title, abstract and keywords. Initially, we identified 3051 search results based on research criteria in the SCOPUS database. We did not seek any related terms intentionally to avoid confusions in similar phrases and to keep the study simple to achieve the targeted goals.

We have had 2535 papers after restricting our search to the published work over the previous 10 years. Finally, we only obtained 1457 articles once the document type had been restricted to articles and source type. There were just 1401 articles published in English. Consequently, this bibliometric analysis is performed on 1401 scientific publication published over the last decade. The search criteria and sample collection process are shown in Figure 1.

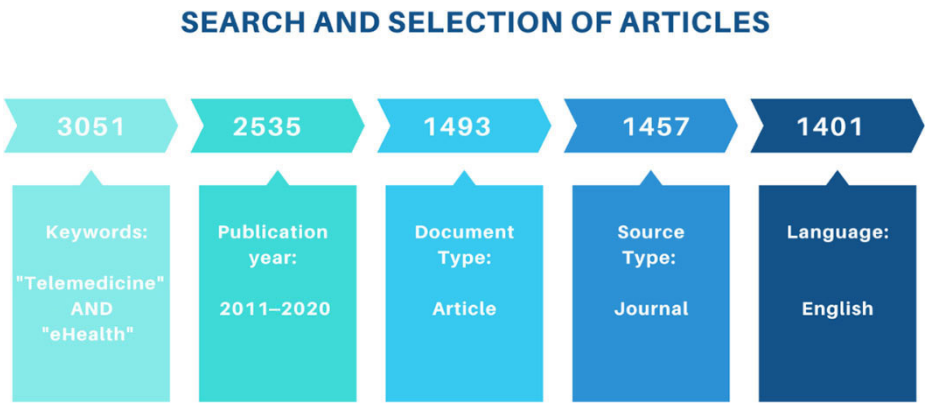

Fig. 1. Search strategy and sample collection

3 Descriptive statistics

Figure 2 shows the growth trend in scientific publications on telemedicine and health. Researchers and academics in this field have shown a growing interest throughout the years. In Figure 2 there is a considerable increase in the number of publications showing growing interest of researchers in the area of telemedicine and ehealth.

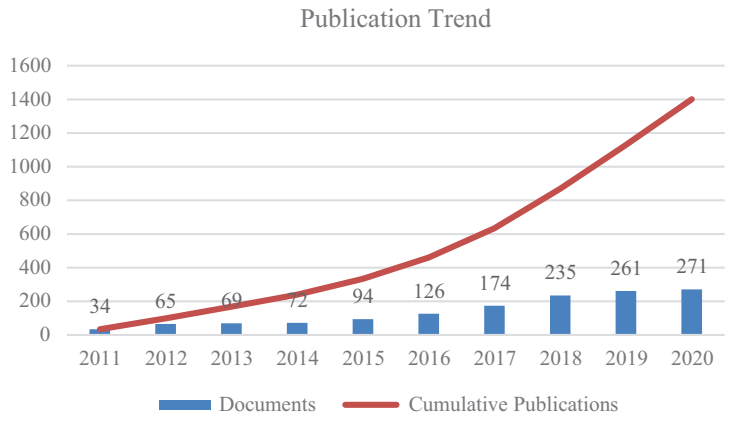

Fig. 2. The publication growth trend

The top-cited journals and most cited articles are shown in Table 1. Journal of Medical Internet Research (6511 citations), Telemedicine and E Health (1692 citations), and International Journal of Medical Informatics (604 citations) are found to be the most productive journals with 309, 148 and 35 publications respectively. The number of citations shows the worth of a published paper, which is why we identified the highly referenced articles. The article becomes increasingly important as the number of citations increases [22]. It is to be noted that TP represents total publications and TC represents total citations of the articles in Table 1.

Table 1. Top 10 journals

Rank	Journal	TP	Cite Score 2020	No. of Citations	The Most Cited Article	TC	Publisher
1	Journal of Medical Internet Research	309 (22.1%)	6.4	6511	Consort-ehealth: Improving and standardizing evaluation reports of web-based and mobile health interventions	755	JMIR Publications Inc
2	Telemedicine And E Health	148 (10.6%)	4.6	1692	The taxonomy of telemedicine	155	Mary Ann Liebert

(Continued)

Table 1. Top 10 journals *(Continued)*

Rank	Journal	TP	Cite Score 2020	No. of Citations	The Most Cited Article	TC	Publisher
3	International Journal of Medical Informatics	35 (2.5%)	7.1	604	Determinants of physicians' technology acceptance for e-health in ambulatory care	125	Elsevier
4	JMIR mHealth and uHealth	31 (2.2%)	6.2	307	Development and validation of the user version of the mobile application rating scale (uMARS)	113	JMIR Publications Inc.
5	BMJ Open	31 (2.2%)	3.7	153	Person-centred eHealth intervention for patients on sick leave due to common mental disorders: Study protocol of a randomised controlled trial and process evaluation (PROMISE)	47	BMJ Publishing Group
6	International Journal of Environmental Research and Public Health	30 (2.1%)	3.4	104	Prevailing opinions on connected health in Austria: Results from an online survey	17	Frontiers Media S.A.
7	BMC Medical Informatics and Decision Making	30 (2.1%)	3.9	358	Using a mobile health application to support self-management in chronic obstructive pulmonary disease: A six-month cohort study eHealth/telehealth/ mobile health systems	52	Springer Nature
8	Journal of Telemedicine and Telecare	28 (2%)	7.9	357	Participatory design methods in telemedicine research	39	SAGE
9	BMC Health Services Research	21 (15%)	3.5	237	Attitudes towards the use and acceptance of eHealth technologies: A case study of older adults living with chronic pain and implications for rural healthcare Organization, structure and delivery of healthcare	47	Springer Nature
10	Health Informatics Journal	18 (1.3%)	3.2	166	Short message service (SMS) text messaging as an intervention medium for weight loss: A literature review	77	SAGE

Our findings also investigated the top 10 authors (see Table 2) along with their total publications (TP), Scopus Author ID, h-index, current affiliation, year of first publication and total citations (TC). It was found that Chavannes, N.H. (12 publications), De Bourdeaudhuij, I. (10 publications), Crombez, G. (10 publications) are the top authors in the field of telemedicine and ehealth. The table also demonstrates that the most cited author is not always the most productive author Chavannes, N.H is the most productive author but Cuijpers, P. is the most cited author (Table 2).

Table 2. Most prolific authors

No	Author	TP	Scopus Author ID	h-Index	Current Affiliation	Country	Year of 1st Publication	TC
1	Chavannes, N.H.	12	6604023299	40	Leiden University Medical Center–LUMC	Netherlands	2016	64
2	De Bourdeaudhuij, I.	10	57216050218	35	Universiteit Ghent	Belgium	2016	85
3	Crombez, G.	10	7004978351	75	Universiteit Ghent	Belgium	2016	85
4	Mars, M.	9	7005417542	22	College of Health Sciences	South Africa	2012	75
5	Kasteleyn, M.J.	8	55978870300	11	Leiden University Medical Center–LUMC	Netherlands	2017	41
6	Cuijpers, P.	8	7005376994	115	Vrije Universiteit Amsterdam	Netherlands	2015	239
7	Verloigne, M.	8	35621195200	27	Universiteit Gent	Belgium	2017	69
8	van Uden-Kraan, C.F.	8	23468103700	20	Vrije Universiteit Amsterdam	Netherlands	2015	224
9	Poppe, L.	8	56915474300	8	Universiteit Gent	Belgium	2017	69
10	Huirne, J.A.F.	7	6507356903	30	Amsterdam UMC–University of Amsterdam	Netherlands	2014	67

The University of Sydney, UNSW Sydney, and Vrije Universiteit Amsterdam are the most productive universities, according to our research with 36, 32 and 29 publications respectively. Not only that, but we discovered that six of the top ten institutions are from the Netherlands, while the top two are from Australia (See Table 3).

Table 3. The top 10 most productive institutions

Rank	Institution	Country	No. of Publications
1	The University of Sydney	Australia	36
2	UNSW Sydney	Australia	32
3	Vrije Universiteit Amsterdam	Netherlands	29
4	Leiden University Medical Center–LUMC	Netherlands	28
5	Karolinska Institutet	Sweden	27
6	University of Twente	Netherlands	27
7	Radboud University Nijmegen Medical Centre	Netherlands	25
8	Maastricht University	Netherlands	24
9	Universiteit van Amsterdam	Netherlands	23
10	University of Toronto	Canada	22

Considering the geographical distribution of scientific articles the top 10 productive countries are the United States, Netherlands and United Kingdom are the most productive countries with 413, 190 and 151 publications per year respectively (Figure 3). This establishes that among the top ten countries mentioned below, the notion of telemedicine and health is widely known and that the concept is popular exclusively in North America and European countries as compared to the rest of the world.

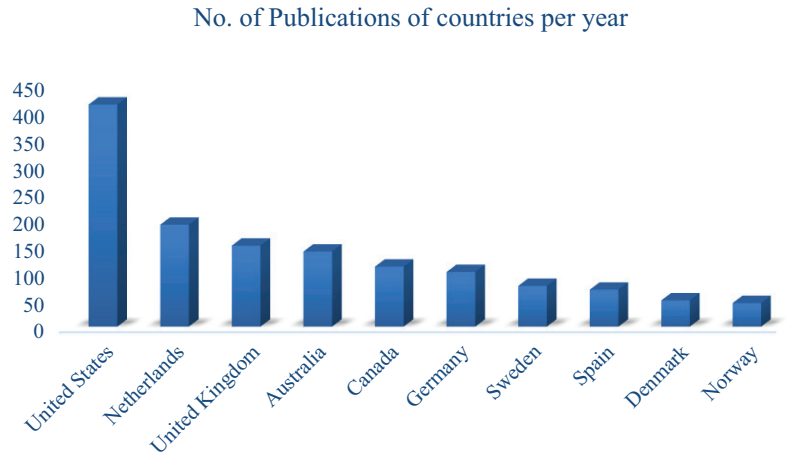

Fig. 3. Leading countries

4 Bibliometric maps

The objective of this study is to map and assess telemedicine and health scientific production using bibliometric analysis. Using bibliometric approaches, we sought to obtain a general picture of telemedicine and health literature that is, its intellectual structure by identifying publication patterns for authors, countries and keywords.

To construct and visualise bibliometric maps, we imported the author publication information from the Scopus database into the VoS viewer. VoS viewer is a bibliometric maps software tool. To analyse the data for this study, bibliometric maps for both author keywords and author-related countries were generated. All the items (nodes) in a map will be connected by an association link (a broad or thin line) that indicates whether they have a strong or weak relationship. A greater number of digits indicates a significant association with another node.

The bibliometric analysis of co-authorship of countries, co-occurrence of author keywords, co-authorship of authors, and bibliographic coupling is described in this section. The total link strength (TLS) in bibliographic coupling refers to the number of commonly cited references shared by two publications. In the case of co-authorship analysis, it displays the number of publications co-authored by two scholars, and in the case of co-occurrence, TLS indicates the number of articles in which any two terms appear together [23].

4.1 Co-authorship (authors)

To perform the co-authorship analysis of authors, the data from Scopus was loaded into the VOS viewer. The minimum number of documents of the author was set to 3 to obtain a combatively larger set of the connected author. As a result, 283 authors out of 6420 were identified who met the threshold. Out of those 283, only 51 authors were well connected as displayed in Figure 4. These 51 authors are divided into 6 clusters which form 113 links with each other and have a total link strength of 278.

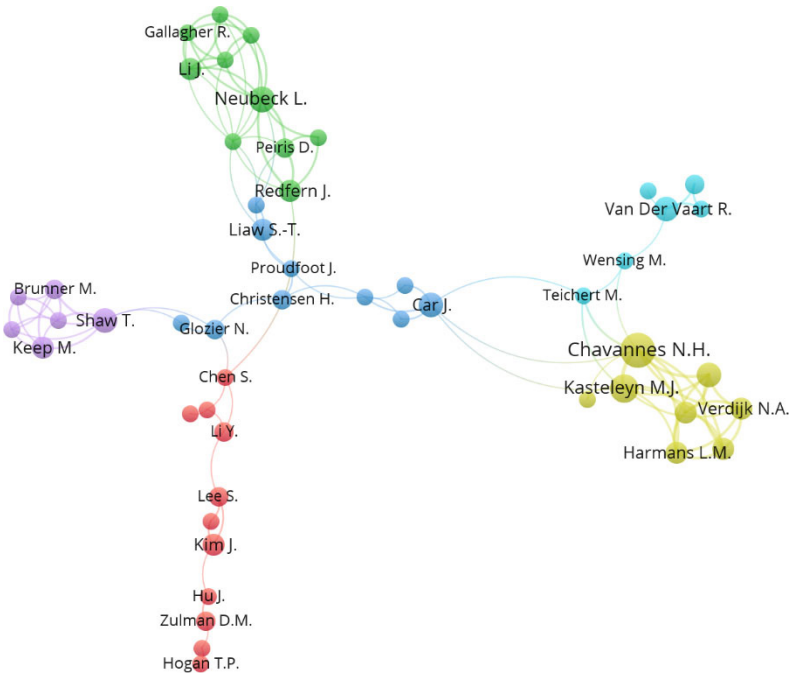

Fig. 4. Snapshot of the bibliometric map representing Co-authorship analysis of authors in network visualisation mode

The top 3 authors as per their total link strength are Chavannes N.H., Verdonck-De Leeuw I.M. and Crombez G. Similarly, the top 20 authors according to their TLS are listed in Table 4.

Table 4. Top 20 authors as per number of TLS

Author	Documents	Citations	Total Link Strength
Chavannes N.H.	12	91	40
Verdonck-De Leeuw I.M.	12	270	38
Crombez G.	10	99	38
De Bourdeaudhuij I.	10	99	38
Giroux D.	6	25	37
Latulippe K.	6	25	37
Poppe L.	8	82	35
Verloigne M.	8	82	35
Carignan M.	4	22	35
Dubé V.	4	22	35
Guay M.	4	22	35
Poulin V.	4	22	35
Provencher V.	4	22	35
Sévigny A.	4	22	35
Tremblay M.	4	22	35
Talboom-Kamp E.P.W.A.	6	41	30
Neubeck L.	7	69	29
Kasteleyn M.J.	8	57	28
Harmans L.M.	5	36	28
Numans M.E.	5	36	28

4.2 Co-authorship (countries)

Scientific collaboration is thought to be a vital component for improving the quality and impact of research [24]. To do so we carried out the co-authorship analysis of countries. While doing the co-authorship analysis of countries, the minimum number of documents per country was set to 5. As a result, out of 103 countries, 45 countries met the threshold resulting in 8 clusters which were then reduced to 7 when arranged manually according to their respective continents. The number of links was 272 representing a total link strength (TLS) of 709. The bibliometric map representing co-authorship analysis of countries is shown in Figure 5.

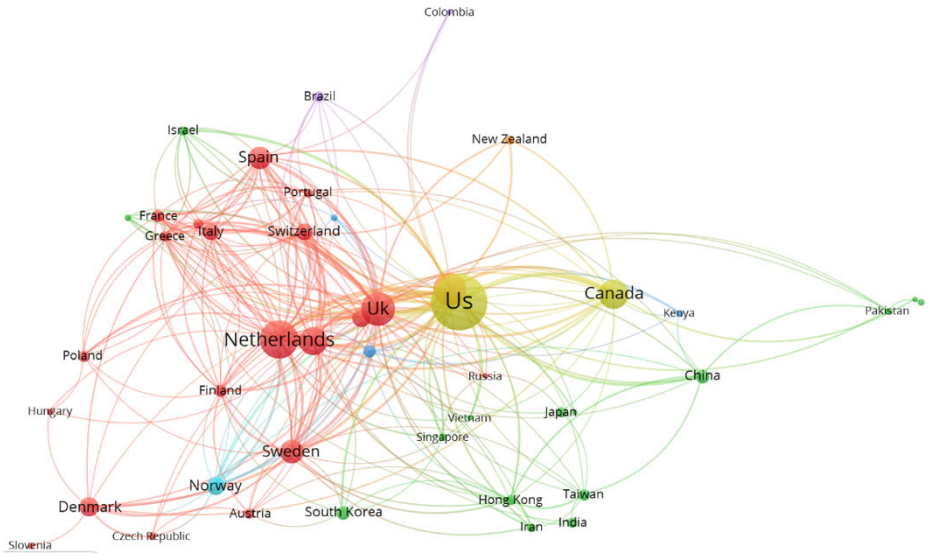

Fig. 5. Snapshot of the bibliometric map representing Co-authorship analysis of countries in network visualisation mode

We discovered that United States has the highest number of TLS of 157 and 7881 citations. It was followed by UK (TLS=147, citations=2404) and Netherlands (TLS=103, citations 3470). Results of the co-authorship analysis of countries is listed in Table 5 as per their total link strength (TLS). This suggests that these countries have the made the most contribution to the intra-country collaborative work.

Table 5. Results of Co-authorship analysis of countries

Country	Documents	Citations	Total Link Strength	Country	Documents	Citations	Total Link Strength
US	412	7881	157	Singapore	8	171	14
UK	150	2401	147	Iran	11	147	13
Netherlands	190	3470	103	Poland	17	130	13
Australia	140	2471	98	South Korea	26	444	11
Germany	102	1310	89	New Zealand	11	129	11
Canada	112	2098	69	Brazil	16	139	10
Spain	68	774	66	Cyprus	6	68	10
Sweden	76	734	65	Vietnam	5	31	10
Italy	41	486	45	Austria	16	165	9
Switzerland	39	467	42	Czech Republic	9	156	8

(Continued)

Table 5. Results of co-authorship analysis of countries *(Continued)*

Country	Documents	Citations	Total Link Strength	Country	Documents	Citations	Total Link Strength
Belgium	42	539	39	Nigeria	6	92	8
Finland	21	300	39	Pakistan	7	27	8
Greece	16	154	36	Russia	5	113	7
Norway	44	661	34	Kenya	6	53	7
France	23	726	32	Japan	14	259	6
Hong Kong	16	196	28	Bangladesh	5	105	5
Denmark	48	621	27	Colombia	5	52	5
Ireland	15	167	26	UAE	5	123	4
Portugal	11	146	25	Hungary	7	67	4
China	24	268	23	India	16	115	3
South Africa	22	253	23	Saudi Arabia	7	133	2
Israel	11	493	22	Slovenia	6	37	1
Taiwan	18	246	14				

4.3 Co-occurrence (keywords)

Co-occurrence analysis of keywords was performed to investigate the most occurring keywords and themes in the selected set of documents. To do that, the minimum number of occurrences of keywords was set to 10 meaning only those keywords were selected that appeared at least 10 times in the selected documents. This resulted in 86 keywords out of 3039 keywords forming 8 clusters, 978 links and 3651 TLS (total link strength). After this step, the identical keywords were replaced which resulted in a total of 72 keywords with 9 clusters, 765 links and 3459 total link strength.

Some of the most recurring keywords in the telemedicine and ehealth literature are found to be e-health, telemedicine, m-Health, telehealth, internet, ehealth literacy, technology, self-management, digital health, primary health care, mental health and electronic health records. This demonstrates that a substantial amount of research has been conducted and continues to be conducted in the aforementioned areas.

We have also identified the least occurring keywords in the literature and believe that these are the areas that need the attention of future researchers and the gap that needs to be filled. These keywords are barriers, implementation, tele dermatology, anxiety, web-based intervention, self-monitoring, elderly, health communication, usability, oncology, user-centred design, cognitive behavioural therapy, developing countries, health communication, patient-centred care and patient participation. This implies that these are the areas where research is lacking, and a gap must be addressed with additional research. The co-occurrence of keywords is shown in Figure 6.

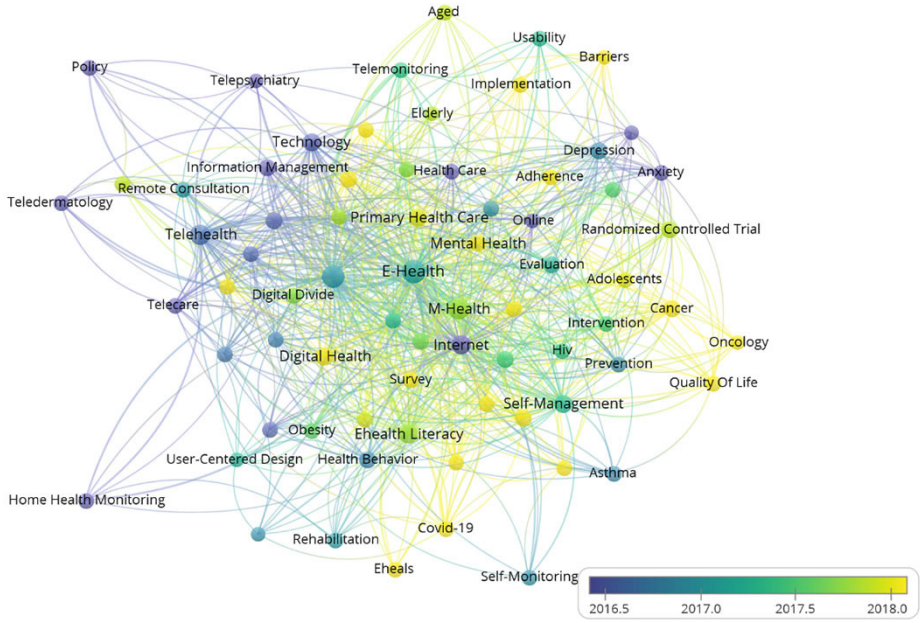

Fig. 6. Snapshot of the bibliometric map representing Co-occurrence analysis of keywords in overlay visualisation mode

Table 6 shows the frequency of occurrence of the keywords as well as their total link strength.

Table 6. Results of Co-occurrence analysis of keywords

Keyword	Occurrences	Total Link Strength	Keyword	Occurrences	Total Link Strength
E-Health	883	1591	Intervention	11	39
Telemedicine	380	829	Patient Participation	11	38
M-Health	228	546	Quality Of Life	18	38
Telehealth	158	399	Hiv	18	37
Internet	113	272	Prevention	16	37
Ehealth Literacy	120	205	Public Health	19	37
Technology	63	171	Obesity	13	36
Self-Management	62	144	Policy	16	36
Digital Health	40	112	Survey	12	36
Primary Health Care	43	96	Remote Consultation	12	35
Mental Health	32	94	Asthma	12	33
Electronic Health Records	38	89	Medication Adherence	12	33

(Continued)

Table 6. Results of co-occurrence analysis of keywords *(Continued)*

Keyword	Occurrences	Total Link Strength	Keyword	Occurrences	Total Link Strength
Depression	28	87	Social Media	15	33
Smartphone	24	82	Health Care	16	32
Health Information Technology	34	80	Digital Divide	15	31
Physical Activity	36	72	Older Adults	15	31
Cancer	23	67	Telemonitoring	13	31
Qualitative Research	26	59	Patient-Centered Care	11	30
Health Behaviour	21	57	Pregnancy	12	30
Information Management	26	57	Rehabilitation	13	29
Randomized Controlled Trial	26	55	Behavior Change	12	28
Telecare	19	55	Teledermatology	11	28
Medical Informatics	18	54	Aged	12	27
Evaluation	22	53	Telepsychiatry	10	27
Health Promotion	20	50	Adolescents	13	26
Chronic Disease	18	49	Oncology	10	25
Self-Care	17	49	Usability	14	25
Anxiety	12	47	Web-Based Intervention	10	25
Adherence	17	45	Barriers	10	24
Covid-19	15	44	Implementation	17	23
Diabetes	16	44	Developing Countries	11	22
Online	10	43	Eheals	14	21
Home Health Monitoring	17	42	Health Communication	10	20
Cognitive Behavioral Therapy	12	41	Self-Monitoring	11	19
Exercise	18	40	User-Centered Design	10	19
Consumer Health Information	14	39	Elderly	10	18

4.4 Bibliographic coupling (documents)

We call it Bibliographic coupling when two publications refer to a common third publication in their bibliographies [25]. A bibliographic coupling connects publications that cite the same articles. We performed a bibliographic coupling of documents in this study. To conduct the biographic coupling, we set the minimum number of citations of a document to 20. This resulted in 313 documents out of 1401 forming 11 clusters, 3076 links having a total link strength of 5650. Though the resulting documents were 313, the largest set of documents connected consisted of 275 documents as shown in Figure 7.

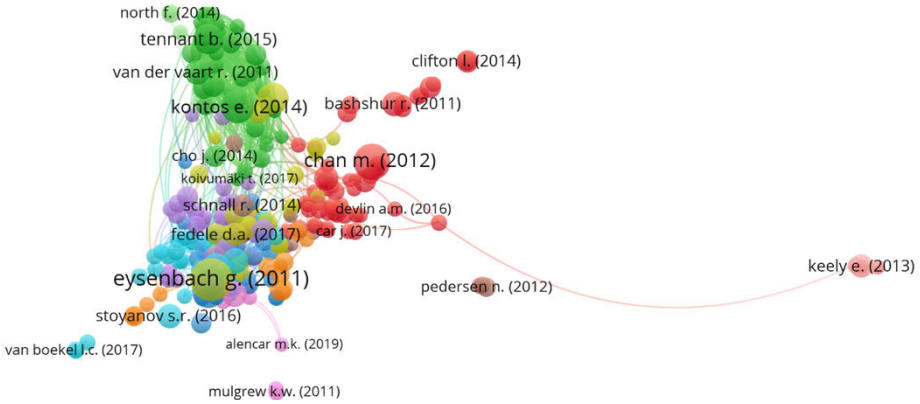

Fig. 7. Snapshot of bibliographic coupling of documents as per citations

It was found that article Eysenbach G. [26], Chan M. [27], and Kontos E. [28] has the highest citations that are, 821, 513 and 387 respectively. The results of the analysis of bibliographic coupling are listed in Table 7 along with their total link strength. In the same way, the Bibliographic coupling of documents of top 20 documents as per citations weight is listed in Table 7.

Table 7. Bibliographic coupling of documents (top 20) as per citations weight

Document	Citations	Total Link Strength
Eysenbach G. (2011)	821	24
Chan M. (2012)	513	26
Kontos E. (2014)	387	129
Mohr D.C. (2013)	328	91
Neter E. (2012)	304	28
Tennant B. (2015)	267	221
Kohl L.F.M. (2013)	203	179
Davies E.B. (2014)	181	80
Vandelanotte C. (2016)	154	139
Hutchesson M.J. (2015)	149	66
Stoyanov S.R. (2016)	142	1
Van Der Vaart R. (2011)	139	117
Dünnebeil S. (2012)	132	48
Bashshur R. (2011)	127	12
Lee S. (2011)	120	0
Mohr D.C. (2017)	112	40
Fedele D.A. (2017)	112	34
Martin S.S. (2015)	111	6
Lee K. (2014)	110	138
Keely E. (2013)	110	1

5 Conclusion and discussion

This bibliometric analysis investigates the progress and developments of trends in telemedicine and ehealth literature over the past decade. It is an emerging field [10] with hundreds of scientific publications every year. Journal of Medical Internet Research is the top journal in the said field with 309 total publications and the most cited article (604 citations). A country-wise analysis was carried out according to which the United States, Netherlands and United Kingdom are the most productive countries with numerous publications in the telemedicine and ehealth area. It was determined that the major authors in telemedicine and health were Chavannes, N.H. (12 publications), De Bourdeaudhuij, I. (10 publications), Crombez, G. The topmost productive institutions were identified as The University of Sydney.

The co-authorship analysis enabled us to identify the top three authors based on overall link strength: Chavannes N.H., Verdonck-De Leeuw I.M., and Crombez G. We discovered the most studied keywords in the field of telemedicine and ehealth using bibliometric analysis: m-health, telehealth, internet, ehealth literacy, technology, self-management, digital health, primary health care, mental health, and electronic health records. We identified the most cited documents by bibliographic coupling, which are by Eysenbach G. (2011), Chan M. (2012), and Kontos E. (2014) [29].

This study provides a complete knowledge base of telemedicine and ehealth literature enabling researchers of the same filed to know it is an emerging discipline and get a knowhow of the most studies and understudied areas for their future research initiative. This study also states the well-known journals to aid researchers and scholars in publishing their work. It has been shown that most research is conducted in the United States, the United Kingdom, and Europe, paving the path for future researchers to perform similar studies in developing countries.

6 Limitations and future directions

First and foremost, this study is constrained by the fact that the literature search was limited to a single database. This suggests that our findings may not be indicative of the entire telemedicine and ehealth literature and that the findings should be interpreted with caution [7], [30], [31].

These least studies keywords were determined in the co-occurrence analysis which implies that these are the areas where research is lacking, and the gap must be addressed with additional research. For instance, future researchers could identify the barriers to telemedicine and health and its implementation. Future researchers could also investigate telemedicine and ehealth research in the context of less developed counties because the said field is less implemented in developing countries. Similarly, oncology, tele dermatology, and reasons for the lack of elderly participation in the telemedicine field are some of the less studies areas in the field. More research into the use and application of telemedicine is needed to help both developing and developed countries' healthcare systems [32]. Recent pandemics especially Covid-19 have highlighted the need for remote healthcare and brought attention to the millions of people who do not have access to it. Telemedicine and use of ehealth may overcome these problems [15], [33].

Thus, future research should consider telemedicine and ehealth research concerning Covid-19 and devise strategies for its successful implementation.

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Article submitted 2021-07-14. Resubmitted 2021-10-19. Final acceptance 2021-10-19. Final version published as submitted by the authors.