Nine Years of Mobile Healthcare Research:

A Bibliometric Analysis

https://doi.org/10.3991/ijoe.v17i10.25243

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Abstract—The purpose of the paper was to explore the central keyword searched (*e.g., mobile healthcare*). It also aimed at identifying the valuable contributions made by authors, journals, countries, and institutions and their associations in '*mobile healthcare*' search around the world. Data was extracted from 2012 to 2020 by using Scopus database and analysed through VOSviewer software and MS Excel. PRISMA guidelines were used to screen the records. Co-authorship, Co-occurrence, Bibliographic Coupling and Co-citation analysis were executed to identify the links and collaborations among the authors, countries, author keywords and documents globally. Results showed that *Yang X.* had the highest association with other authors and *Sood, S.K.* had published more documents than others. *Australia* was found to have the highest association with other countries, and *India* was leading other countries in publications. *Computers and Electrical Engineering* was found to be the leading journal in publication of documents. This study, to best of our knowledge, was the first of its kind in mapping the '*mobile healthcare*' search which was designed till 2020. This will aid in shaping and understanding the central theme and set the future research directions for the researchers.

Keywords—Mobile Healthcare, m-Health, Electronic Healthcare, Bibliometric Analysis

1 Introduction

The current study presents the bibliometric mapping of 'mobile healthcare'. Mobile healthcare is considered as providing healthcare services by means of technological devices for example, mobile phones, personal digital assistants (PADs), tablet computers, smart devices and so on (ref18). Technological advancement in healthcare enables access to those who cannot receive the services from renowned practitioners around the world.

Pai & Alathur, (2020) analysed the literature on 'mobile health' in Indian context. They used Scopus database for the published works in India between January 2008 to June 2019. They reviewed the methodologies used by the different researchers in mobile health search. Li et al., (2018) reviewed the electronic health literature from 1992 to 2017. They used Web of Science for analysing the foundational knowledge and research hotspots in electronic health. The current study was different from the previous works by extending the analysis till 2020. Also, it was based on bibliometric analysis only by executing all possible tools of VOSviewer software and the focus that was purely on services (e.g., mobile healthcare services). Therefore, the current study of bibliometric analysis was intended to answer the following research questions.

RQ 1. What is the publication output of extracted documents regarding 'mobile healthcare' till 2020?

RQ 2. Who are the most prolific authors and journals in 'mobile healthcare' search?

RQ 3. What are the most prominent countries, and institutions in 'mobile healthcare' research?

RQ 4. What are the links and collaborations among authors, countries, keywords and documents related to 'mobile healthcare'?

2 Method

The bibliometric analysis is one of the quantitative techniques that is helpful in visualizing and synthesizing the literature on a specific searched area [3]–[5]. The search was executed in Scopus database because it was considered as the largest database than others [4]. It also offered wide-ranging coverage of the subjects than that of MedLine, Web of Sciences and so on [4], [6], [7].

2.1 Search Strategy

PRISMA guidelines were followed in screening the records for analysis. Documents were extracted in June 2021. The search was initiated with applying the central theme of the search (e.g., mobile healthcare & m-healthcare). The year 2021 was excluded from the data. Documents were limited to articles only, the source of documents were journals only, and the language of the documents selected was English only. At the end, exact keywords were selected (refer the appendix) to analyze the final documents. Search flow based on PRISMA guidelines was stated in Figure 1. The final number of documents extracted was 35.

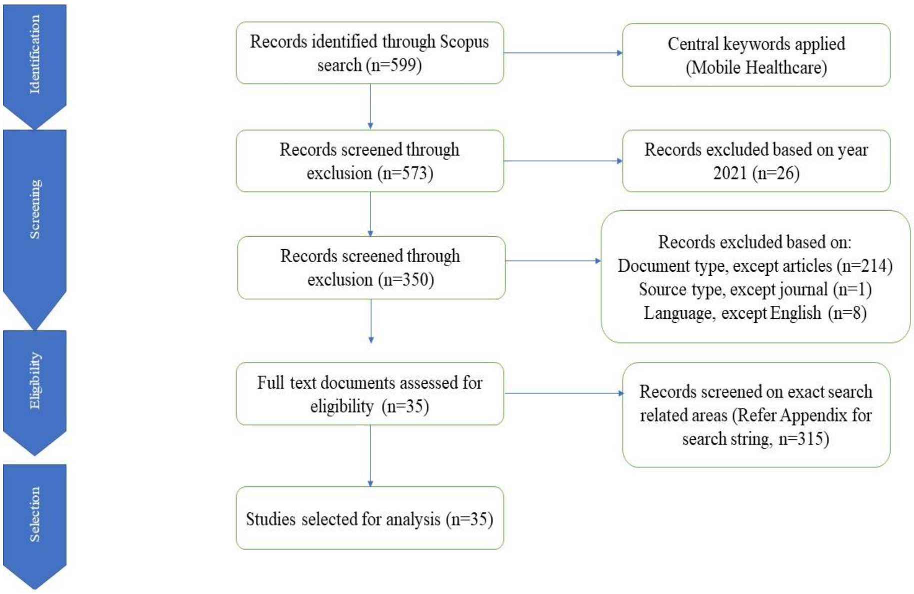

Fig. 1. Search Flow Chart based on PRISMA.

3 Analysis and Results

Document were extracted from Scopus and analyzed with the help of MS Excel and VOSviewer. The final number of documents were 35. In our initial analysis, we identified the most influential authors, journals, countries, and institutions that contributed to publishing the documents in the field of mobile healthcare. Our central keyword (e.g., mobile healthcare) contained the similar other keywords such as m-health, m-healthcare, e-healthcare, healthcare applications and electronic healthcare.

3.1 Publication Output

Publication output of our search regarding ‘mobile healthcare’ covered the years from 2012 to 2020 (Figure 2). First publication as per our searched keywords, appeared in 2012. Till 2018, the publication output witnessed decreasing and then increased with increasing rate. The year 2018 showed the highest number of publications (12) in a single year. The publication output decreased after 2018. Surprisingly, 2020 revealed only 03 publications which was the matter of concerns to ponder on.

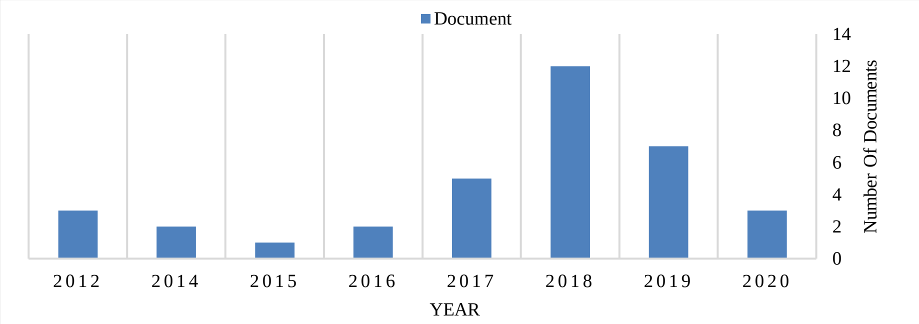

Fig. 2. Graph showing publication output of 'mobile healthcare' search.

3.2 Prolific Authors and Journals

We analyzed the most influential and prominent authors and journals in 'mobile healthcare' search. We acknowledged top ten authors and journals in selected search criteria. Sood, S.K. was leading at the top with 04 total publications with 04 h-index and 114 total citations. He was affiliated to National Institute of Technology Kurukshetra, India. He was followed by Verma, P. (TP, 03; h-index, 03; TC, 110) from India and Sahoo, P.K (TP, 02; h-index, 02; TC, 48) from Taiwan. Other subsequent authors were mentioned in Table 1.

Table 1. List of top ten prominent authors in 'mobile healthcare' search

No	Author	Scopus Author ID	Year of 1st publication*	TP	h-index	TC	Current affiliation	Country
1	Sood, S.K.	35173770300	2018**	4	4	114	National Institute of Technology Kurukshetra,	India
2	Verma, P.	57194110658	2018*	3	3	110	Baba Gulam Shah Badshah University, Rajouri	India
3	Sahoo, P.K.	9738729800	2012*	2	2	48	Chang Gung University, Taoyuan,	Taiwan
4	Abawajy, J.H.	8937496700	2017**	1	1	27	Faculty of Science, Engineering and Built Environment, Geelong	Australia
5	Abbas, H.	57221959316	2017**	1	1	39	National University of Sciences and Technology Pakistan, Islamabad	Pakistan
6	Ahmad, M.	55456467900	2009**	1	0	0	Universiti Utara Malaysia, Sintok	Malaysia
7	Ahmad, M.	57199846726	2019**	1	1	20	Jamia Millia Islamia, New Delhi	India
8	Alelaiwi, A.A.	55546007800	2017***	1	1	27	King Saud University, Riyadh	Saudi Arabia
9	Alex, S.	57219548183	2020**	1	0	0	National Institute of Technology Calicut, Kozhikode	India
10	Baig, Z.	14008320400	2016***	1	1	21	Deakin University, Geelong	Australia

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Computers and Electrical Engineering was the leading journal among others in the list. It published 03 documents and had 7.5 cite score (2019). This journal was published by Elsevier. "An efficient secure communication for healthcare system using wearable devices" was its most cited paper which was cited 20 times. This journal was followed by IEEE Internet of Things Journal from Elsevier and Journal of Medical Systems from Springer. The list of all top journals was mentioned in the Table 2.

Table 2. List of top ten journals.

No	Journal	TP (%)	CiteScore 2019	The most cited article (reference)	Times Cited	Publisher
1	Computers and Electrical Engineering	3	7.5	An efficient secure communication for healthcare system using wearable devices	20	Elsevier
2	IEEE Internet of Things Journal	2	14.9	An efficient and privacy-preserving disease risk prediction scheme for E-healthcare	10	Elsevier
3	Journal of Medical Systems	2	7.1	Security Attacks and Solutions in Electronic Health (E-health) Systems	21	Springer
4	Cluster Computing	1	3.1	Cloud-assisted IoT-based health status monitoring framework	27	Springer
5	Computer Methods and Programs in Biomedicine	1	7.7	Cloud-assisted mutual authentication and privacy preservation protocol for telecare medical information systems	36	Elsevier Top of Form
6	Computer Networks	1	8.1	Contextual activity-based Healthcare Internet of Things, Services, and People (HIoTSP): An architectural framework for healthcare monitoring using wearable sensors	22	Elsevier
7	Future Generation Computer Systems	1	13.3	Cloud and IoT based disease prediction and diagnosis system for healthcare using Fuzzy neural classifier	106	Elsevier
8	Human Centric Computing and Information Sciences	1	8.6	Trusted and secure clustering in mobile pervasive environment	30	Springer
9	IEEE Access	1	4.8	T Privacy Preservation in e-Healthcare Environments: State of the Art and Future Directions	39	IEEE Access
10	IEEE Transactions on Dependable and Secure Computing	1	13.9	A Provably-Secure Cross-Domain Handshake Scheme with Symptoms-Matching for Mobile Healthcare Social Network	63	IEEE Access

3.3 Prominent Countries and Institutions

Following the most prominent authors and journals, we also identified the most influential countries and institutions which contributed significantly in 'mobile healthcare' search. Results exhibited the top fifteen countries and institutions. Among the top countries, India was leading all with total publication (TPC) of 12 documents. It was followed by China with 10 publications. List of top fifteen countries were shown in Table 3.

Guru Nanak Dev University of India led other institutions with 04 total publications (TPI). It was followed by Chang Gung University of Taiwan (TPI, 02) and King Saud University of Saudi Arabia (TPI, 02). Other top fifteen prominent institutions were mentioned in Table 3.

Table 3. List of top fifteen countries and institutions.

Rank	Country	TPC	Institution	TPI
1	India	12	Guru Nanak Dev University	4
2	China	10	State Key Laboratory of Cryptology	1
3	Australia	5	Deakin University	1
4	Taiwan	5	Chang Gung University	2
5	United States	5	The University of Texas at San Antonio	1
6	Canada	3	Sinai Health System	1
7	Malaysia	2	Universiti Utara Malaysia	1
8	Saudi Arabia	2	King Saud University	2
9	South Korea	2	Hankuk University of Foreign Studies	1
10	Sweden	2	Karlstads universitet	1
11	Indonesia	1	Universitas Widyatama	1
12	Macao	1	Macau University of Science and Technology	1
13	Pakistan	1	National University of Sciences and Technology	1
14	Spain	1	Universidad de Oviedo	1
15	United Kingdom	1	Newcastle University	1

3.4 Bibliometric Maps

We mapped the literature of the searched area with VOSviewer. The current study contained 35 documents. We created maps and visualization of co-authorship for authors and countries, and co-occurrence analysis for author keywords, bibliographic coupling for documents and co-citation analysis.

Co-authorship (Authors). Authors who have coauthored the documents can be analyzed with the option of co-authorship of VOSViewer. The co-authorship analysis represented the links between items (e.g., authors). It was denoted with the link strength. Therefore, the total link strength (TLS) displayed the total co-authorship strength of one author with the other [8], [9].

Different threshold values were applied. Maximum number of authors per document was 25. Minimum number of documents of an author was 01. The minimum number of citations was remained 00. All the 111 items (e.g., authors) met the threshold. Results showed that Yang X. had the highest total link strength (TLS) of 14 with o3 documents and 49 citations, followed by Wang L. (TLS, 09; Documents, 03; Citations, 80). List of top 50 authors, based on TLS ranking, found in co-authorship was mentioned in Table 4.

Maps of co-authorship analysis showed both not-connected set (n=111) and connected set of items (n=15). Both maps were created by modifying the values of attraction to 03 and repulsion to -01. We created maps on network visualization and overlay visualization. Map of network visualization for not-connected set (Figure 3) and connected set (Figure 5) showed the prominence of authors having higher TLS as compared to others. Map of overlay visualization for not-connected set (Figure 4) showed the average publication year in which authors published their documents. Weights assigned to the map was set at documents.

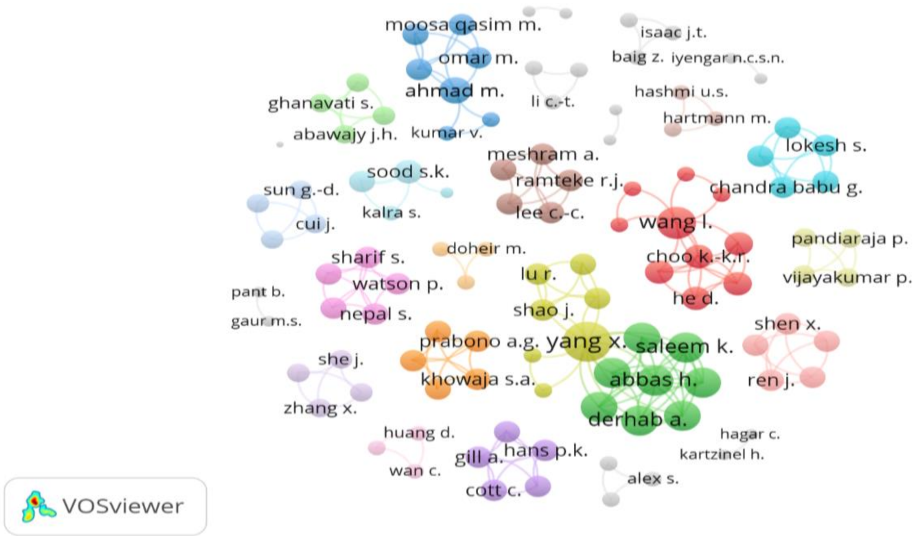

Fig. 3. Screenshot showing network visualization of co-authorship (authors) for all items (n=111).

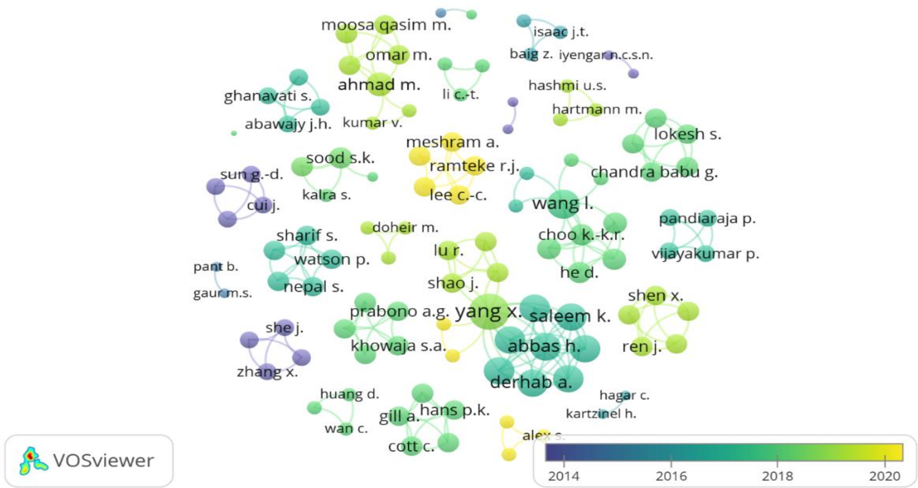

Fig. 4. Screenshot showing the overlay visualization of co-authorship (authors) for all items (n=111).

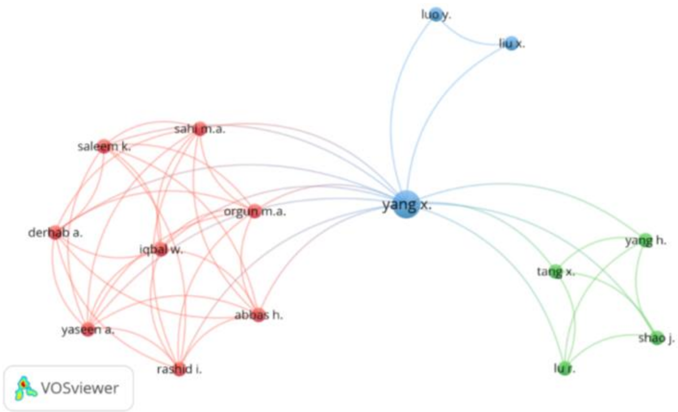

Fig. 5. Screenshot showing the network visualization of co-authorship (authors) for the largest connected set (n=15).

Table 4. List of 50 authors having highest TLS.

S/No	Item (authors)	Documents	Citations	TLS	S/No	Item(authors)	Documents	Citations	TLS
1	Yang X.	3	49	14	26	Lee C.-C.	1	2	4
2	Wang L.	3	80	9	27	Lee S.-L.	1	22	4
3	Abbas H.	1	39	8	28	Lokesh S.	1	106	4
4	Derhab A.	1	39	8	29	Lu R.	1	10	4
5	Iqbal W.	1	39	8	30	Meshram A.	1	2	4
6	Orgun M.A.	1	39	8	31	Meshram C.	1	2	4
7	Rashid I.	1	39	8	32	Meshram S.G.	1	2	4
8	Sahi M.A.	1	39	8	33	Moosa Qasim M.	1	0	4
9	Saleem K.	1	39	8	34	Nepal S.	1	14	4
10	Yaseen A.	1	39	8	35	Omar M.	1	0	4
11	Ahmad M.	2	20	6	36	Parthasarathy P.	1	106	4
12	Choo K.-K.R.	1	63	5	37	Prabono A.G.	1	22	4
13	He D.	1	63	5	38	Ramteke R.J.	1	2	4
14	Kumar N.	1	63	5	39	Ren J.	1	26	4
15	Sood S.K.	4	114	5	40	Setiawan F.	1	22	4
16	Vinel A.	1	63	5	41	Shao J.	1	10	4
17	Wang H.	1	63	5	42	Sharif S.	1	14	4
18	Bakar J.A.A.	1	0	4	43	Shen X.	1	26	4
19	Chandra Babu G.	1	106	4	44	Steele Gray C.	1	3	4
20	Cott C.	1	3	4	45	Taheri J.	1	14	4
21	Gill A.	1	3	4	46	Tang W.	1	26	4
22	Hans P.K.	1	3	4	47	Tang X.	1	10	4
23	Irfan Khan A.	1	3	4	48	Varatharajan R.	1	106	4
24	Khowaja S.A.	1	22	4	49	Verma P.	3	110	4
25	Kumar P.M.	1	106	4	50	Watson P.	1	14	4

Co-authorship (Countries). We analyzed the co-authorship analysis for countries. It showed the links among countries that had associations and collaborations with other countries in publishing the documents. The closer these countries will be, the stronger their relatedness will be. Also, the thicker links between them, the stronger the link between them [8], [9].

We applied different thresholds while mapping the data. The maximum number of documents of a country was 25. The minimum number of documents of a country was 01. The minimum number of citations of a country was 00. Hence, 16 items (countries) met the threshold.

Analysis showed the prolific association and collaboration from different countries as per their TLS score. Australia was leading other countries with highest TLS (13) with 05 documents and 164 citations. It was followed by China, United States, and others mentioned in Table 5.

The normalization method of analysis was association strength. We created both maps of not-connected set (Figure 6) and connected set (Figure 7). The not-connected set comprised of all 16 items. The layout values were slightly changed as attraction to 06 and repulsion to -01. The largest connected set comprised of 13 items. The layout was set at attraction (02) and repulsion (-01). Both maps showed the dominance of countries which had higher total link strength (TLS) as compared to other countries.

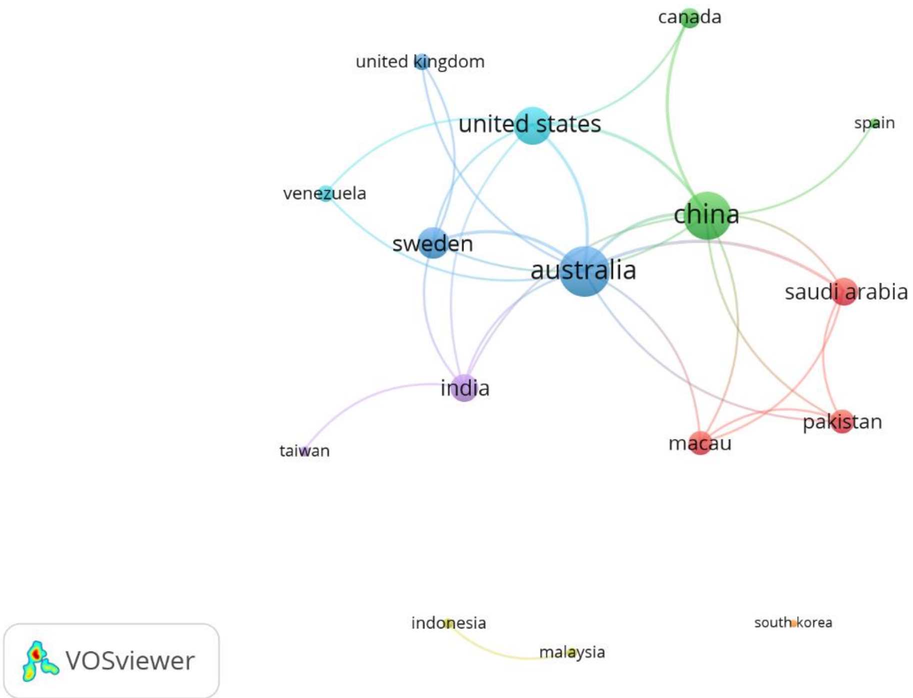

Fig. 6. Screenshot showing the network visualization of co-authorship (countries) for all items (n=16).

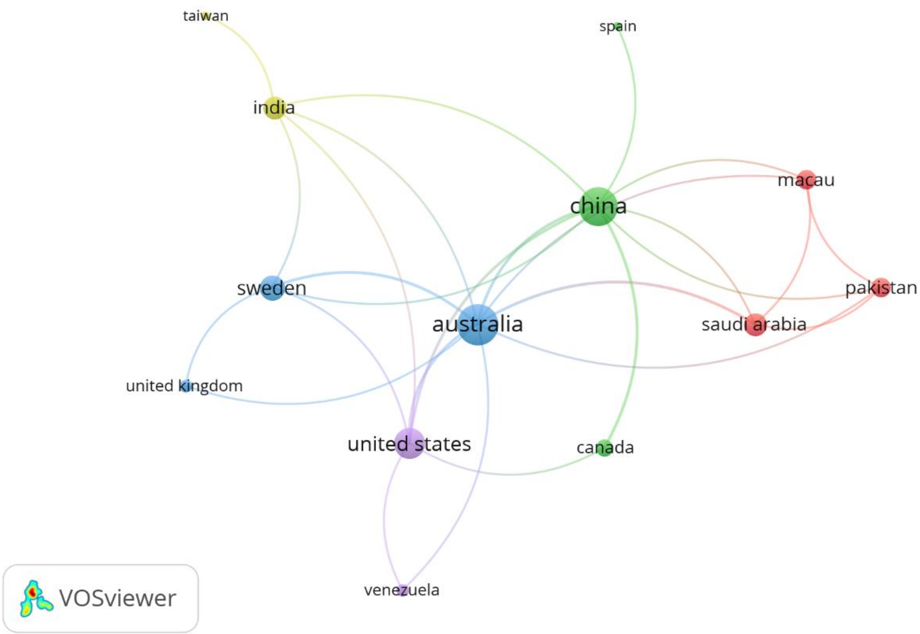

Fig. 7. Screenshot showing the network visualization of co-authorship (countries) for the largest connected set (n=13).

Table 5. List of all countries as per TLS.

S/No	Item (Country)	Documents	Citations	TLS
1	Australia	5	164	13
2	China	10	160	12
3	United States	5	134	8
4	Sweden	2	77	6
5	India	12	360	5
6	Saudi Arabia	2	66	5
7	Macau	1	39	4
8	Pakistan	1	39	4
9	Canada	3	39	3
10	United Kingdom	1	14	2
11	Venezuela	1	21	2
12	Indonesia	1	0	1
13	Malaysia	2	0	1
14	Spain	1	4	1
15	Taiwan	5	94	1
16	South Korea	2	26	0

Co-occurrence (Author Keywords). Author keywords were explored by their occurrence, so co-occurrence analysis was performed. Different threshold was applied while executing co-occurrence analysis. Minimum occurrence of a keyword was set at 01. All 88 items (keywords) met the threshold. Result of co-occurrence revealed some prominent keywords. 'Mobile Healthcare' occurred 20 times with total link strength of 72. This central keyword was finalized by merging similar keywords (e.g., m-healthcare, m-health, e-healthcare). It was followed by 'cloud computing' (occurrence, 10; TLS, 37), 'authentication' (occurrence, 05; TLS, 22), 'internet of things' (occurrence, 05; TLS, 20), 'privacy' (occurrence, 05; TLS, 18), and 'security' (occurrence, 04; TLS, 16).

Map was created by having all connected items based on network visualization. Unit of analysis was association strength and weight assigned to the items was total link strength. Map showed the dominance of keywords having higher TLS as compared to others. Screenshot of the co-occurrence map of author keywords was shown in (Figure 8). Moreover, we identified the underexplored avenues having less occurrence and total link strength. Keywords of 'pulse data processing', 'auto-detection management' and 'blind signature' had least number of occurrence and total link strength.

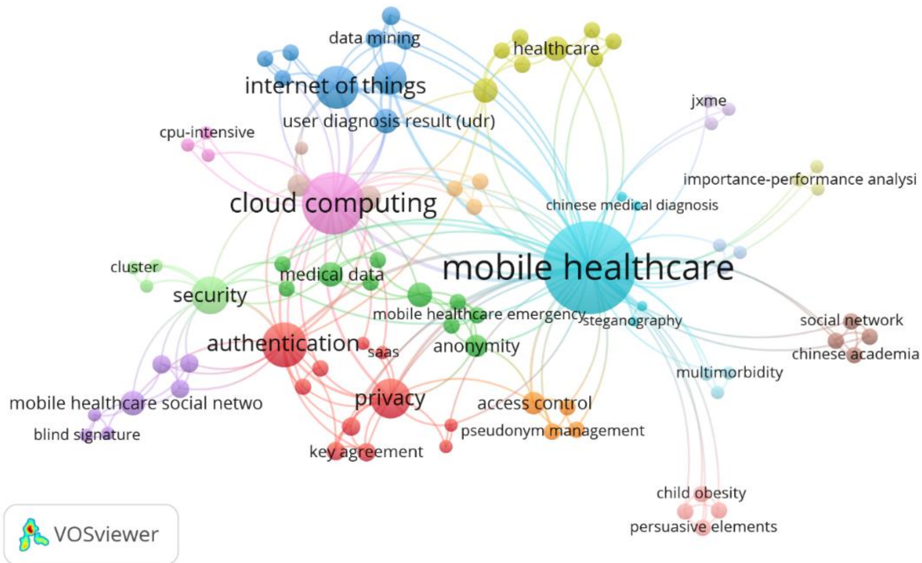

Fig. 8. Screenshot showing the network visualization of co-occurrence (author keywords) for all connected items (n=88).

Bibliographic Coupling refers to the referencing of third document by two documents together [8], [9]. We performed bibliographic coupling on documents. Minimum number of citations of a document was set at 00. Therefore, all documents were included. Results showed Meshram et al., (2020) had highest TLS of 37 with 02 citations, followed by Verma & Sood, (2018b) with 32 TLS and 55 citations.

Maps showed not-connected set and connected set of items (documents). Figure 9 and Figure 10 showed the prominence and dominance of documents having higher total link strength. Figure 11 showed the prominence of documents having higher citations in the chosen search area.

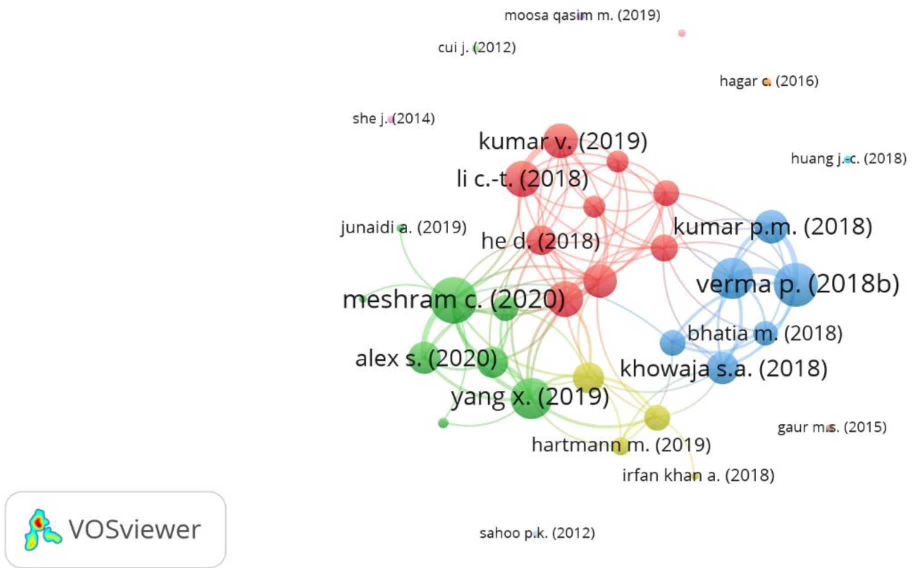

Fig. 9. Screenshot showing the network visualization of bibliographic coupling (documents) for all items (n=35) based on total link strength (TLS).

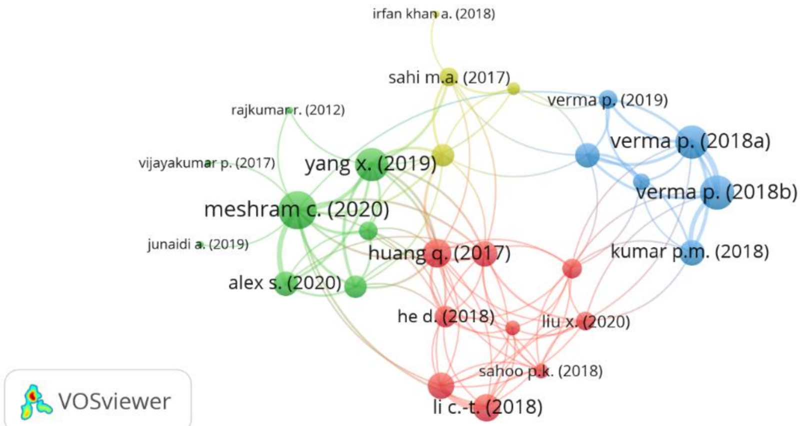

Fig. 10. Screenshot showing the network visualization of bibliographic coupling (documents) for the largest connected set (n=27) based on total link strength (TLS).

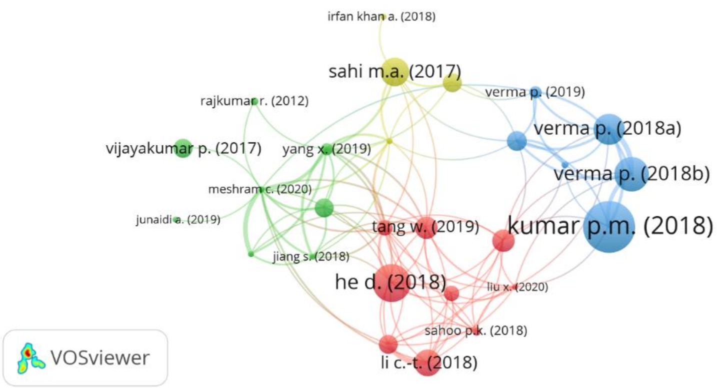

Fig. 11. Screenshot showing the network visualization of bibliographic coupling (documents) for the largest connected set (n=27) based on citations.

Co-citation Analysis refers to the citations of two documents by third document [8], [9]. We extended our analysis to co-citation analysis of 35 documents based on cited authors. We set minimum number of citations of an author at 05 which resulted in 98 authors cited out of 2956. The largest set of connected items (authors cited) comprised of 97 items was shown in map (Figure 12). The map of connected set of co-citation analysis showed the dominance of author cited by other others.

Lin, X. was leading other in being cited by other documents with 37 citations and 1828 total link strength. Subsequently, Shen, X. followed Lin, X. with 32 citation and 1590 total link strength, then Lu, R. (citations, 31; TLS, 1521), Kumar, N. (citations, 21; TLS, 1287), and Liang, X. (citations, 27; TLS, 1269).

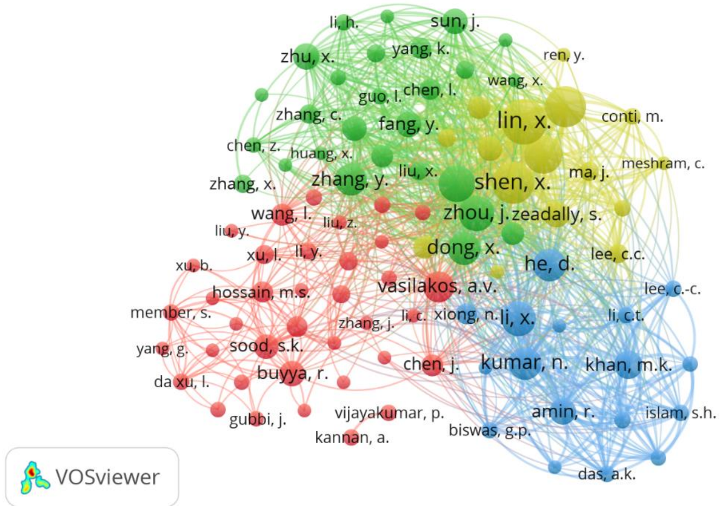

Fig. 12. Screenshot showing the network visualization of co-citation (cited author) for the largest connected set (n=97).

4 Limitations and Future Research Directions

The current study was restricted to specific keywords covering the central keyword (e.g., mobile healthcare) which might not cover all aspects in the literature. Different other keywords could be used instead. To make the results more appealing, different thresholds were applied which limited the findings to lesser number of items and excluded other available items pertaining to authors, countries, keywords which might show different visualizations.

Different avenues for future research were thereby recommended. No association was witnessed from South Korea in mobile healthcare. Lesser number of affiliations and collaborations were revealed from Indonesia, Malaysia, Spain, and Taiwan, therefore more studies were suggested from the researchers of countries mentioned above. Keywords of 'pulse data processing', 'auto-detection management' and 'blind signature' had least number of occurrence and total link strength, therefore, more studies were suggested to link these keywords with mobile healthcare in future.

5 Conclusion

The study was intended to map the 'mobile healthcare' from 2012 till 2020. Bibliometric analysis was conducted on 35 documents extracted from Scopus in the month of June 2021. Publication output was identified throughout the years. Valuable contributions made by productive authors, countries and institutions were identified and recognized. Collaborations and associations were mapped showing the links of authors, countries, keywords, documents, and cited authors through bibliometric analysis of mobile healthcare.

6 Conflict of Interest

No Any.

7 Acknowledgment

Javed Ali gratefully thanks to Sukkur IBA University, Pakistan for sponsoring his studies abroad in Universiti Teknologi Malaysia. Also, he acknowledges the fruitful contributions of co-authors in completing the study.

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Appendix-I

The search string:

Mhealthcare OR *m-healthcare* OR *mobile*healthcare* AND (EXCLUDE (PUBYEAR, *2021*)) AND (LIMIT-TO (DOCTYPE, *"ar"*)) AND (LIMIT-TO (SRCTYPE, *"j"*)) AND (LIMIT-TO (LANGUAGE, *"English"*)) AND (LIMIT-TO (EXACTKEYWORD, *"MHealth"*) OR LIMIT-TO (EXACTKEYWORD, *"Mobile Healthcare"*) OR LIMIT-TO (EXACTKEYWORD, *"Health Care Application"*) OR LIMIT-TO (EXACTKEYWORD, *"E-healthcare"*))

Article submitted 2021-07-04. Resubmitted 2021-08-04. Final acceptance 2021-08-05. Final version published as submitted by the authors.