Wearable Devices in Healthcare Services. Bibliometrix Analysis by using R Package

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Abstract—Purpose: The current study aims at exploring the theme – wearable devices in healthcare services from 2008 to 2021. It intends to identify the most prominent sources, authors, affiliations, countries, documents, words and trend topics. Methodology: Total 204 records have been extracted from Scopus after applying inclusion and exclusion criteria, and analysed by using biblioshiny software of R-package. Findings: Results of bibliometrix analysis show the prominent sources in 'wearable devices & healthcare' search are IEEE Access and Sensors (Switzerland). Moreover, Lee S. and Shen J. are found be the most productive and prolific authors, King Saud University is leading institutions in producing the articles, China, South Korea, India and USA are identified as the most productive countries and Network Security, Cryptography, Deep Learning, Healthcare Application and Healthcare System are found to be the trending topics and themes in the year 2021. Originality: This study presents the deep analytics regarding wearable devices in healthcare services and it also suggests useful future research avenues and insights for researchers and practitioners.

Keywords—wearable devices, healthcare services, bibliometrix analysis, R-package

1 Introduction

Healthcare services like any other services contain a complex and complicated array of activities. Patients being consumers of healthcare services expect the desired results from the service provided by the healthcare service providers such as doctors, nurses, and support staff. A lot of attention has been put to the healthcare sector because of its importance and effect on the economy and population of countries, reducing health disparities, and provide valuable data and information to the policy makers [1]. Healthcare services have been transformed to different disruptive technologies. Due to these modern technologies, reliance of healthcare services on service providers have been shifted to consumers. Users of healthcare services are much more knowledgeable and aware

of their health than their ancestors. One of the technical advancements is 'Wearable Devices'.

Wearable technology is becoming more popular among consumers as it promises to improve the quality of life in ways smartphones alone cannot. The devices in this category, which include watches, wrist bands, jewellery, glasses, skin patches, electronic garments, and so on, are typically referred to as wearables. Besides letting users check incoming text messages, wearables can also show users urgent information more obviously, conveniently, and naturally than what can be done with a smartphone, which is typically kept in a pocket or bag [3]. Because of its grave importance in healthcare service provision, wearable devices have become and will be the great concern of researchers and practitioners. Therefore, the current paper is mapping the literature of wearable devices in healthcare services by presenting bibliomtrix analysis.

The bibliometrix analysis is a quantitative technique to visualize and synthesize the literature of a particular piece of research work (Khudzari et al., 2018). Different bibliometric studies have been performed on different themes; Service quality in healthcare (Ali et al., 2021), information sharing [8], neuroimaging techniques [4], electronic service quality (Ali et al., 2021), mobile healthcare [10] SERVQUAL & Healthcare (Ali et al., 2021), Community Buying [12], and Wellbeing (Ali et al., 2021). The current study has focused on 'wearable devices in healthcare service'. It intends to achieve following objectives:

RO 1. To identify the publication output of 'Wearable Devices and Healthcare Service' research till 2021.
RO 2. To identify the most prominent and relevant sources their productivity and impact of publications related to 'Wearable Devices and Healthcare Service' research.
RO 3. To identify the most prolific and relevant authors their productivity and impact related to 'Wearable Devices and Healthcare Service' research.
RO 4. To identify the most productive and relevant affiliations and countries related to 'Wearable Devices and Healthcare Service' research.
RO 5. To identify the most frequent and relevant words and the trending topics related to 'Wearable Devices and Healthcare Service' research.

2 Methodology

The current paper presents the bibliometrix analysis of 'Wearabale Devices in Healthcare Services' search from 2008 to 2021. The analysis of the current study is based on documents extracted from Scopus database because it is the largest database [5] and it offers wide-ranging coverage of the subjects than that of MedLine, Web of Sciences and other databases (Ali et al., 2021; Khudzari et al., 2018; Mongeon & Paul-Hus, 2016).

2.1 Search strategy

Inclusion and exclusion criteria are used to screen the records in March 2022. Two main keywords are used to search the literature; *Wearable Devices and Healthcare Services*. The complete search string is given in the Appendix-I. Documents are limited to articles and from journals only. The year 2022 has been excluded from the search, and the language of the documents selected is English only. Total 204 have been screened for analysis. Complete search strategy flowchart is mentioned (Figure 1).

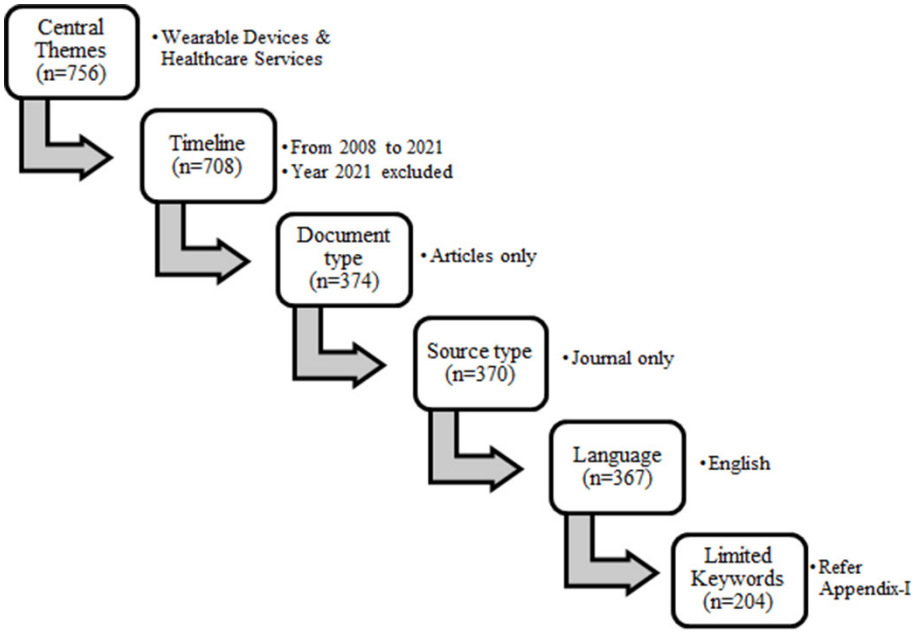

Fig. 1. Search flow chart

3 Results and discussion

Results of the current study have obtained by using *biblioshiny* software of *R-package*. This software gives much more options of analysis than others such as VOSviewer. The main information of the current search contains 204 documents, 722 author's keywords, 774 authors, 3.88 collaboration index and other statistics mentioned in Table 1. Next sections describe the findings of the current study.

Table 1. Main information of screened records

Description	Results
Timespan	2008:2021
Sources (Journals, Books, etc)	123
Documents	204
Average years from publication	3.08
Average citations per documents	23.64
Average citations per year per doc	4.972
References	13432
DOCUMENT TYPES	
Article	204
DOCUMENT CONTENTS	
Keywords Plus (ID)	1871
Author's Keywords (DE)	722
AUTHORS	
Authors	774
Author Appearances	857
Authors of single-authored documents	6
Authors of multi-authored documents	768
AUTHORS COLLABORATION	
Single-authored documents	6
Documents per Author	0.264
Authors per Document	3.79
Co-Authors per Documents	4.2
Collaboration Index	3.88

3.1 Annual scientific production

Annual scientific production regarding 'wearable devises in healthcare service' is growing at 37.42%. It shows the significant growth rate in number of studies published over the years and will increase further as per upward trend mentioned in Figure 2 and Table 2. There is rapid increase in published works after the year 2016. The recent years reveal greater number of publications in searched themes reflecting the importance of wearable devices in healthcare services.

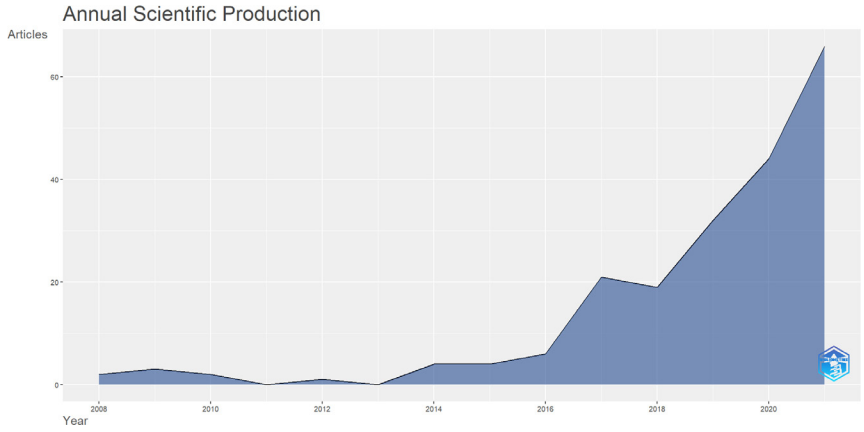

Fig. 2. Annual scientific production from 2008 to 2021

Table 2. Annual production data

Year	2008	2009	2010	2012	2014	2015	2016	2017	2018	2019	2020	2021
Articles	2	3	2	1	4	4	6	21	19	32	44	66

3.2 Prominent sources

Analysis of sources comprises of identifications of the most relevant sources, Bradford's law and Source local impact.

Most relevant sources. Results reveal top 20 relevant sources that have published the works of wearable devices in healthcare services. IEEE Access and Sensors (Switzerland) are at the top by producing 13 and 12 documents respectively, followed by Journal of Ambient Intelligence and Humanized Computing (05), Applied Sciences (04) and others mentioned in Figure 3.

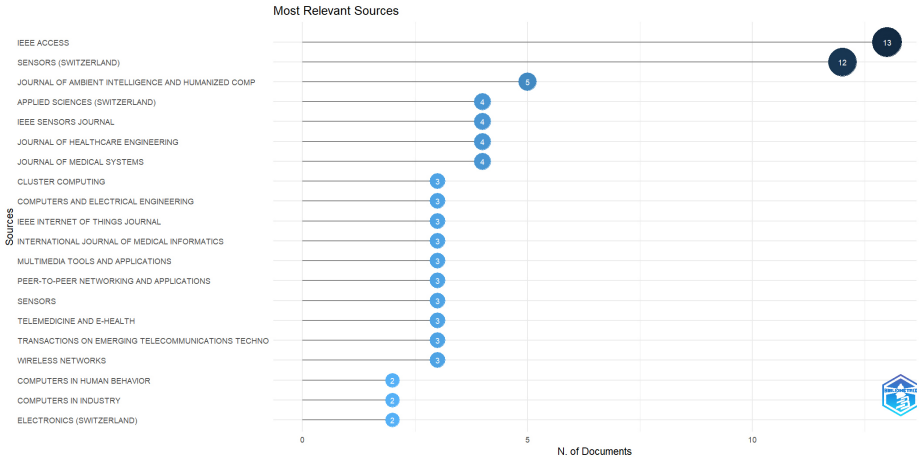

Fig. 3. Most relevant sources

Bradford's Law. Bradford's Law suggests the most significant sources in which first 50 articles can be revealed. It divides the sources in different zones. First zone is considered as core sources where most of the relevant articles fall and it is for first 50 articles of the search. Among top 20 sources, from IEEE Access to Telemedicine and E-health journals fall in zone 1 which means these are the core sources where the relevant searched can be made (Figure 4 & Table 3).

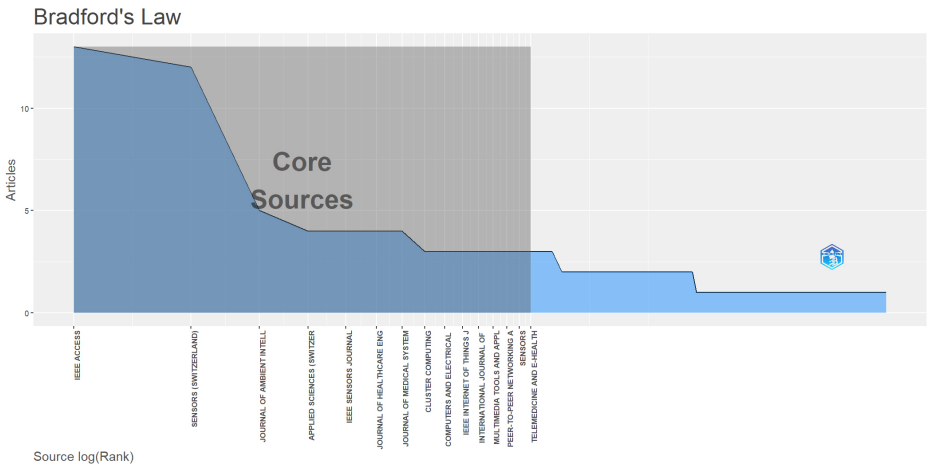

Fig. 4. Most reliable sources by Bradford's Law

Table 3. List of most reliable sources by Bradford's Law

Source	Rank	Freq	CumFreq	Zone
IEEE ACCESS	1	13	13	Zone 1
SENSORS (SWITZERLAND)	2	12	25	Zone 1
JOURNAL OF AMBIENT INTELLIGENCE AND HUMANIZED COMPUTING	3	5	30	Zone 1
APPLIED SCIENCES (SWITZERLAND)	4	4	34	Zone 1
IEEE SENSORS JOURNAL	5	4	38	Zone 1
JOURNAL OF HEALTHCARE ENGINEERING	6	4	42	Zone 1
JOURNAL OF MEDICAL SYSTEMS	7	4	46	Zone 1
CLUSTER COMPUTING	8	3	49	Zone 1
COMPUTERS AND ELECTRICAL ENGINEERING	9	3	52	Zone 1
IEEE INTERNET OF THINGS JOURNAL	10	3	55	Zone 1
INTERNATIONAL JOURNAL OF MEDICAL INFORMATICS	11	3	58	Zone 1
MULTIMEDIA TOOLS AND APPLICATIONS	12	3	61	Zone 1
PEER-TO-PEER NETWORKING AND APPLICATIONS	13	3	64	Zone 1
SENSORS	14	3	67	Zone 1
TELEMEDICINE AND E-HEALTH	15	3	70	Zone 1

(Continued)

Table 3. List of most reliable sources by Bradford's Law *(Continued)*

Source	Rank	Freq	CumFreq	Zone
TRANSACTIONS ON EMERGING TELECOMMUNICATIONS TECHNOLOGIES	16	3	73	Zone 2
WIRELESS NETWORKS	17	3	76	Zone 2
COMPUTERS IN HUMAN BEHAVIOR	18	2	78	Zone 2

Source local impact. Source local impact refers the impact of sources (journals) due to the weightage of their h-index, g-index and m-index. According to h-index, every source will be given equal weightage upon its productivity whereas g-index represents that high cited articles will be given more weightage than others and m-index represents the weightage as per the time span of the source that means the older the source is the higher the weightage will be. Results reveal that most of the impact has come from IEEE Access, Sensors (Switzerland) and Journal of Medical System when compared their h-index (Figure 5), g-index (Figure 6) and m-index (Figure 7). All of these three sources along with Computers and Electrical Engineering journal have highest number of total citations (TC) as well (Table 4).

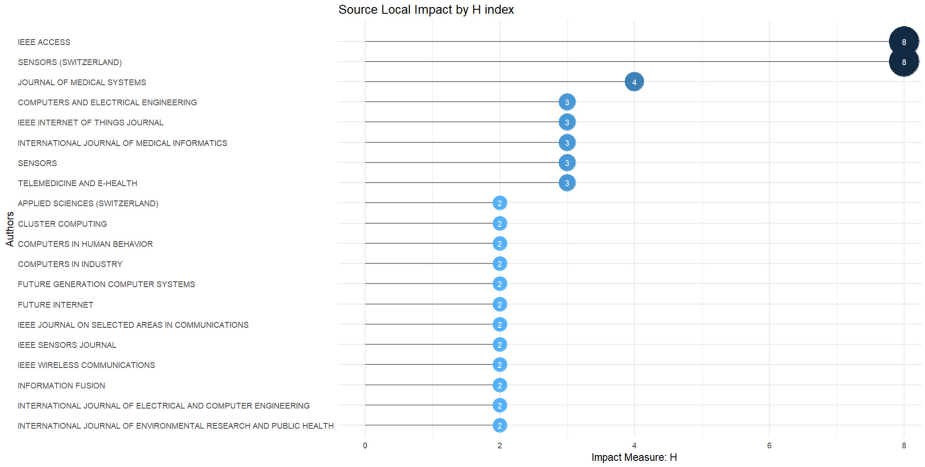

Fig. 5. Source local impact by H-index

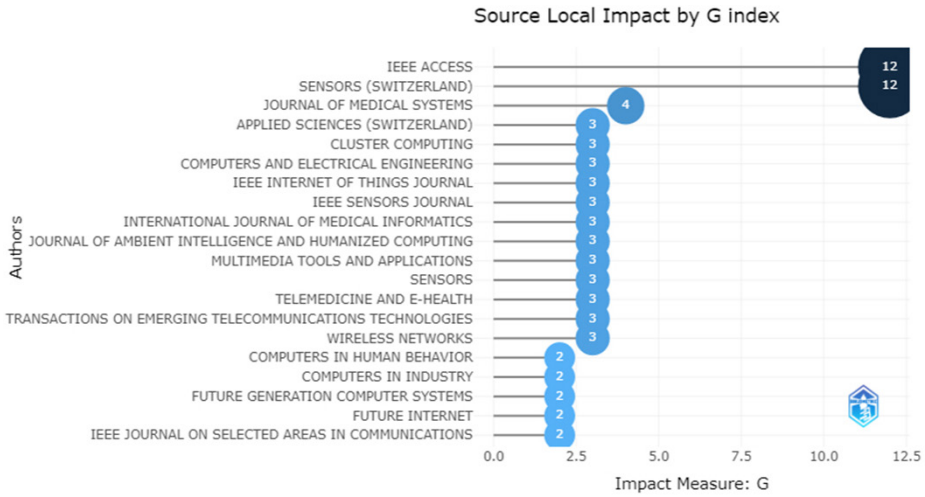

Fig. 6. Source local impact by G-index

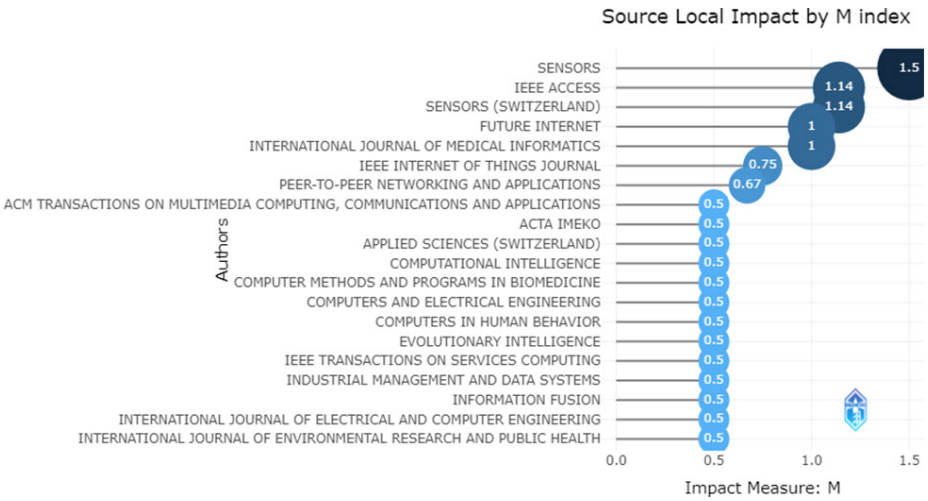

Fig. 7. Source local impact by M-index

Table 4. List of sources' local impact with H, G, and M-index

Element	H-Index	G-Index	M-Index	TC	NP	PY_ Start
IEEE ACCESS	8	12	1.14	436	12	2016
SENSORS (SWITZERLAND)	8	12	1.14	316	12	2016
JOURNAL OF MEDICAL SYSTEMS	4	4	0.44	188	4	2014
COMPUTERS AND ELECTRICAL ENGINEERING	3	3	0.5	215	3	2017
IEEE INTERNET OF THINGS JOURNAL	3	3	0.75	47	3	2019
INTERNATIONAL JOURNAL OF MEDICAL INFORMATICS	3	3	1	61	3	2020
SENSORS	3	3	1.5	12	3	2021
TELEMEDICINE AND E-HEALTH	3	3	0.2	30	3	2008
APPLIED SCIENCES (SWITZERLAND)	2	3	0.5	13	3	2019
CLUSTER COMPUTING	2	3	0.33	66	3	2017
COMPUTERS IN HUMAN BEHAVIOR	2	2	0.5	46	2	2019
COMPUTERS IN INDUSTRY	2	2	0.25	131	2	2015
FUTURE GENERATION COMPUTER SYSTEMS	2	2	0.4	429	2	2018
FUTURE INTERNET	2	2	1	9	2	2021
IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS	2	2	0.14	97	2	2009
IEEE SENSORS JOURNAL	2	3	0.4	29	3	2018

Prolific authors. Similar to that of sources analysis, the most prolific and relevant authors have been highlighted. Analysis of authors comprises of identification of most relevant authors, their productivity, and impact.

Most Relevant and Local Cited Authors. Results shown top 20 relevant authors in 'wearable devices and healthcare service' search. According to authors' number of documents as the frequency measure, Lee S. and Shen J. are leading other authors by producing 04 articles respectively. All other relevant authors are given in Figure 8.

Most local cited authors reflect the list of authors mentioned specifically in the data file extracted for analysis. Among the most local cited authors, Castro L., Favela J., Hernandez N., Medina-Quero J., Michan L., and Mortenson W.B. are at the top with 08 local citations. They are followed by others mentioned in Figure 9.

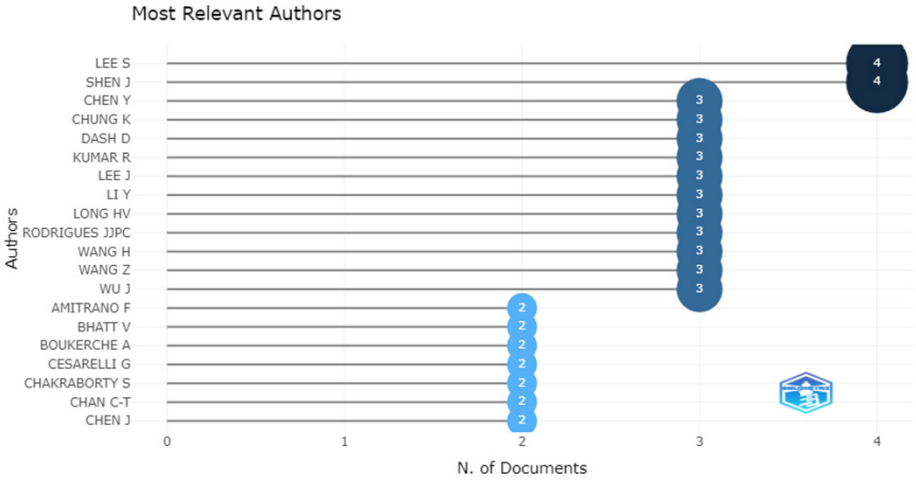

Fig. 8. Most relevant authors

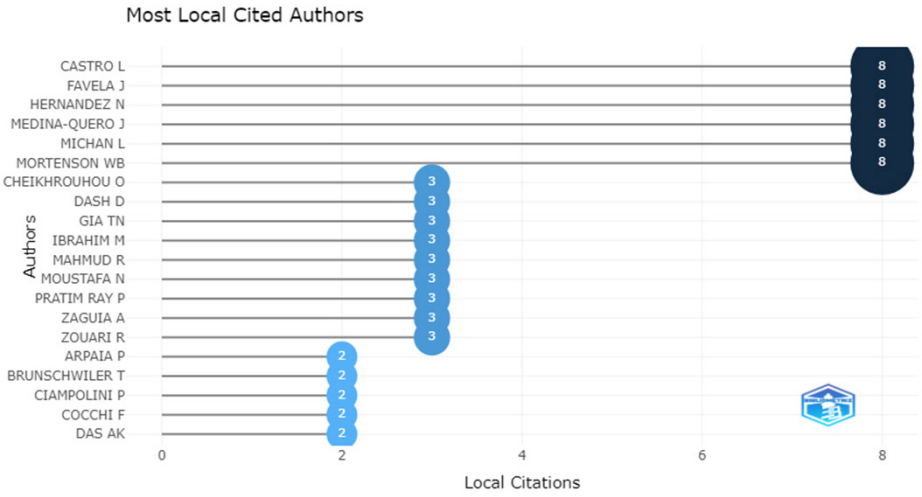

Fig. 9. Most local cited authors

Authors' productivity. We analyzed the productivity of top 20 authors by highlighting their production over time, their top documents, and Lotka's law. Results reveal that most of the productions hasswve occurred in recent years e.g., 2021, 2020, 2019, 2018 and 2017 by top productive authors (Figure 10). Top authors' documents have also been identified with their publication year, title, source, citation and DOI. These documents are listed in (Table 6). Productivity of authors is also found with the help of Lotka's Law. This law suggests that as number of documents increases, the productivity of authors decreases. It is reflected in Figure 11 & Table 5 that 706 authors have produced 01 document, then 02 documents have been produced by 55 authors and this productivity decreases when number of documents increase. Thus, only 02 authors have produced 04 documents.

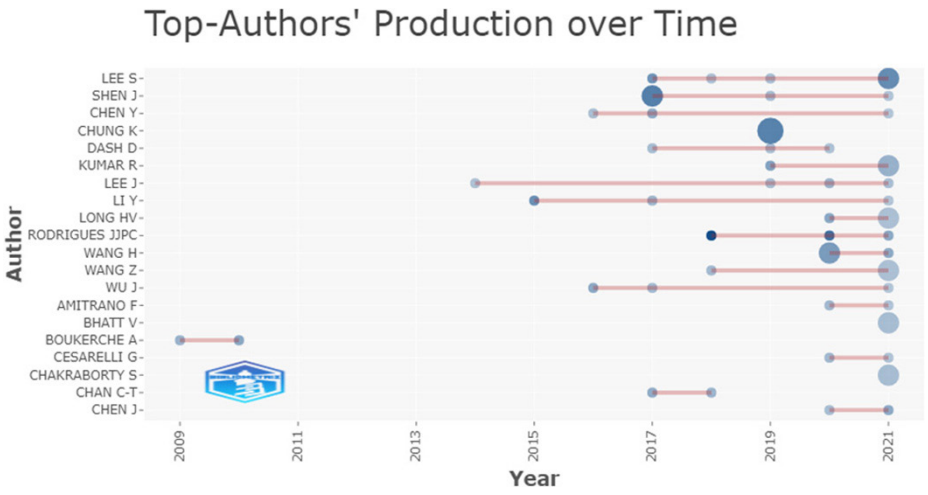

Fig. 10. Authors' production over time

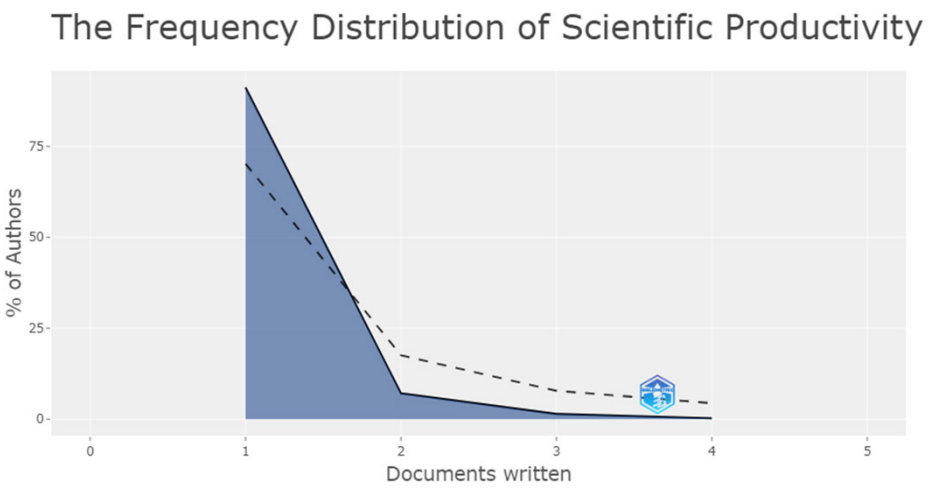

Fig. 11. Authors' scientific productivity through Lotka's Law

Table 5. Authors' scientific productivity through Lotka's Law

Documents Written	No: of Authors	Proportion of Authors
1	706	0.912
2	55	0.071
3	11	0.014
4	2	0.003

Authors' local impact. Authors' local impact refers the impact of authors' productivity due to the weightage of their h-index, g-index and m-index. According to h-index, every author will be given equal weightage upon his or her productivity whereas g-index represents that high cited authors will be given more weightage than others and m-index represents the weightage as per the time span of the author that means the time spent by an author. Findings reveals that these authors have leading impact in all top authors; Lee S. (h & g-index, Figure 12 & Figure 13) and Bhatt V. (m-index, Figure 14). It represents that Lee S. is more productive in terms of producing more articles and having higher cited articles whereas Bhatt V. has spent more time in his works.

Table 6. List of top authors' documents

Author	Year	Title	Source	DOI	TC	TCpY
LEE S	2021	OPPORTUNITIES AND CHALLENGES FOR CONTACTLESS HEALTHCARE SERVICES IN THE POST-COVID-19 ERA	TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	10.1016/j.techfore.2021.120712	31	15.5
LEE S	2021	HAND GESTURE RECOGNITION USING SINGLE PATCHABLE SIX-AXIS INERTIAL MEASUREMENT UNIT VIA RECURRENT NEURAL NETWORKS	SENSORS (SWITZERLAND)	10.3390/s21041404	4	2
LEE S	2019	CUFFLESS AND CONTINUOUS BLOOD PRESSURE MONITORING USING A SINGLE CHEST-WORN DEVICE	IEEE ACCESS	10.1109/ACCESS.2019.2942184	8	2
LEE S	2018	A STUDY OF PRESCRIPTIVE ANALYSIS FRAMEWORK FOR HUMAN CARE SERVICES BASED ON CKAN CLOUD	JOURNAL OF SENSORS	10.1155/2018/6167385	6	1.2
LEE S	2017	WHAT DRIVES CONSTRUCTION WORKERS' ACCEPTANCE OF WEARABLE TECHNOLOGIES IN THE WORKPLACE: INDOOR LOCALIZATION AND WEARABLE HEALTH DEVICES FOR OCCUPATIONAL SAFETY AND HEALTH	AUTOMATION IN CONSTRUCTION	10.1016/j.autcon.2017.08.005	91	15.167
SHEN J	2021	EFFICIENT AND ANONYMOUS AUTHENTICATION FOR HEALTHCARE SERVICE WITH CLOUD BASED WBANS	IEEE TRANSACTIONS ON SERVICES COMPUTING	10.1109/TSC.2021.3059856	1	0.5
SHEN J	2019	A COMBINATION OF INDOOR LOCALIZATION AND WEARABLE SENSOR–BASED PHYSICAL ACTIVITY RECOGNITION TO ASSESS OLDER PATIENTS UNDERGOING SUBACUTE REHABILITATION: BASELINE STUDY RESULTS	JMIR MHEALTH AND UHEALTH	10.2196/14090	12	3
SHEN J	2017	A LIGHTWEIGHT AND PRIVACY-PRESERVING MUTUAL AUTHENTICATION SCHEME FOR WEARABLE DEVICES ASSISTED BY CLOUD SERVER	COMPUTERS AND ELECTRICAL ENGINEERING	10.1016/j.compeleceng.2017.04.012	37	6.167
SHEN J	2017	EFFICIENT END-TO-END AUTHENTICATION PROTOCOL FOR WEARABLE HEALTH MONITORING SYSTEMS	COMPUTERS AND ELECTRICAL ENGINEERING	10.1016/j.compeleceng.2017.03.016	91	15.167

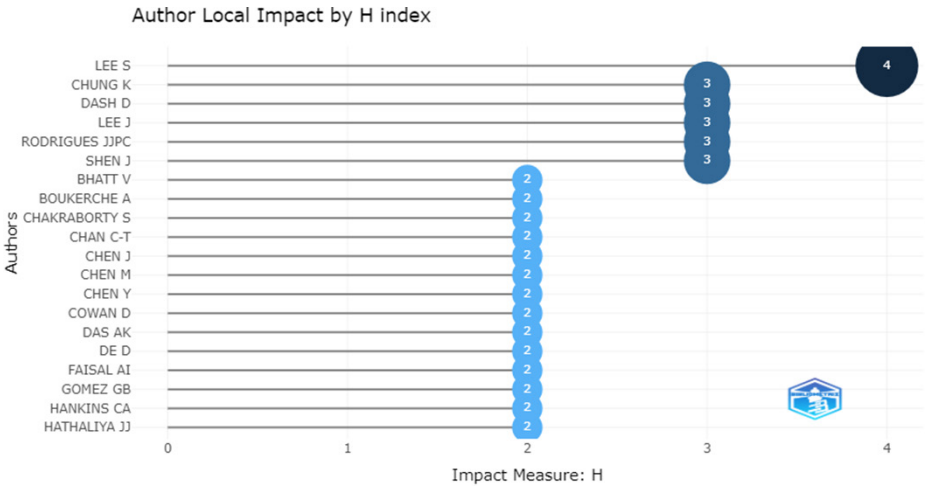

Fig. 12. Author local impact by H-index

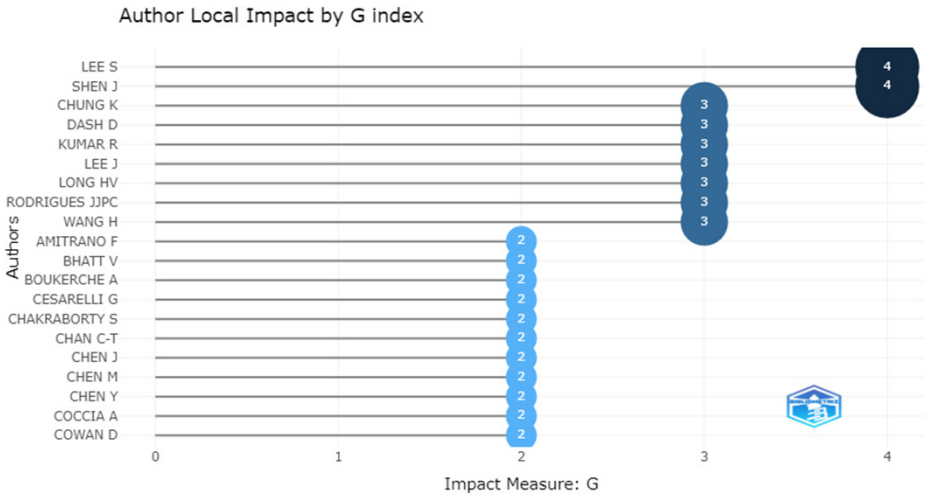

Fig. 13. Author local impact by G-index

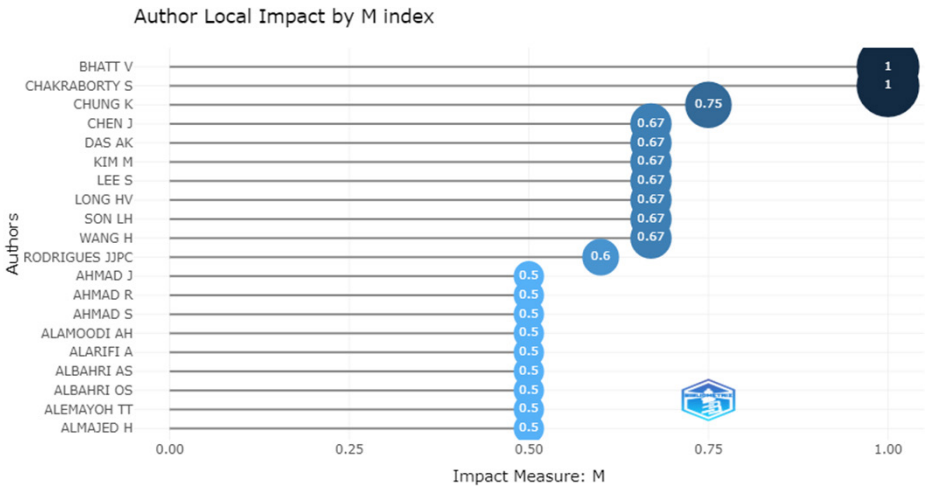

Fig. 14. Author local impact by M-index

3.3 Affiliation & country analysis

This section contains the identification of most relevant affiliations, corresponding authors' country and country's scientific production in the searched area of 'wearable devices in healthcare service'.

Most relevant affiliations. We identified the top 20 most relevant affiliations, and it represents the contributions of renowned institutions in producing articles in the selected area of research. King Saud University is leading with 14 articles, it is followed by Mcmaster University (10), National University of Ireland Galway (Nuig) (9), Sastra Deemed University (9) and others mentioned in Figure 15.

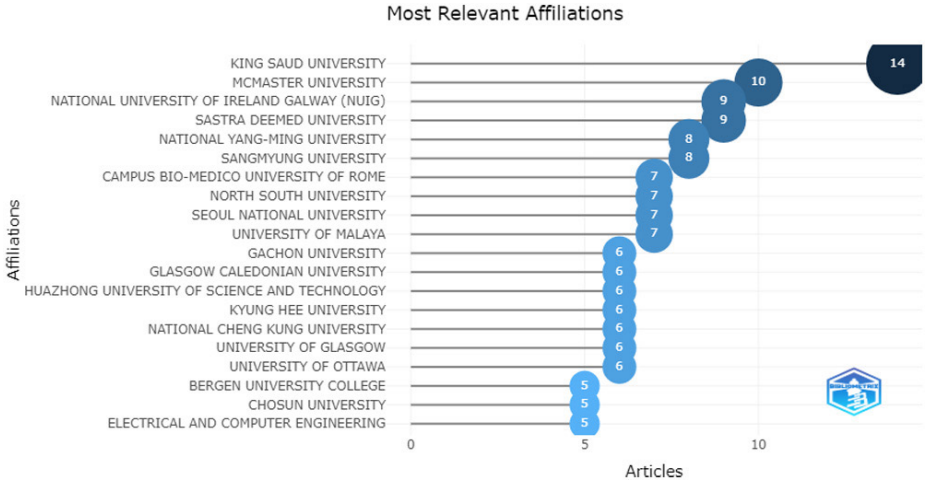

Fig. 15. Most relevant affiliations

Most relevant countries by corresponding author & country's scientific production. Top 20 most relevant corresponding author's countries have been identified with their simple publications (SCP) and multiple publications with other countries (MCP). China is leading with 34 articles, 25 SCP and 09 MCP. It is followed by Korea (31 articles, 24 SCP, 07 MCP), India (30 articles, 25 SCP, 05 MCP) and others mentioned in Table 7.

Scientific contribution of top 20 countries has been identified globally. China is leading with 155 frequency of scientific production followed by South Korea (106), India (102), USA (66) and others mentioned in Table 8.

Table 7. List of corresponding authors' countries

Country	Articles	Freq	SCP	MCP	MCP_Ratio
CHINA	34	0.18579	25	9	0.265
KOREA	31	0.1694	24	7	0.226
INDIA	30	0.16393	25	5	0.167
USA	9	0.04918	7	2	0.222
SAUDI ARABIA	8	0.04372	5	3	0.375
UNITED KINGDOM	7	0.03825	3	4	0.571
MALAYSIA	6	0.03279	1	5	0.833
ITALY	5	0.02732	5	0	0
SPAIN	5	0.02732	3	2	0.4
CANADA	4	0.02186	4	0	0
EGYPT	4	0.02186	1	3	0.75
GERMANY	4	0.02186	3	1	0.25
JAPAN	4	0.02186	4	0	0

Table 8. List of top producing countries across the globe

Region	CHINA	SOUTH KOREA	INDIA	USA	ITALY	UK	SPAIN	SAUDI ARABIA	MALAYSIA	CANADA	GERMANY	PAKISTAN	JAPAN	IRELAND	EGYPT	MEXICO	BRAZIL	IRAQ	AUSTRALIA	TURKEY
Freq	155	106	102	66	43	39	34	29	25	22	19	18	16	15	13	13	11	10	9	9

3.4 Documents & words analysis

This section contains the analysis of documents that includes most global cited documents and most local cited documents, and words that includes most frequent words, wordcloud, tree map and trend topics.

Most global & local cited documents. Most global cited documents reflect all documents related to the central theme of search whereas local cited documents

represent the specific documents provided in the software for analysis. Top 20 global and local cited documents are shown and listed in Figure 16 & Table 9 and Figure 17 & Table 10 with their local and total citations, total citations per year and DOI.

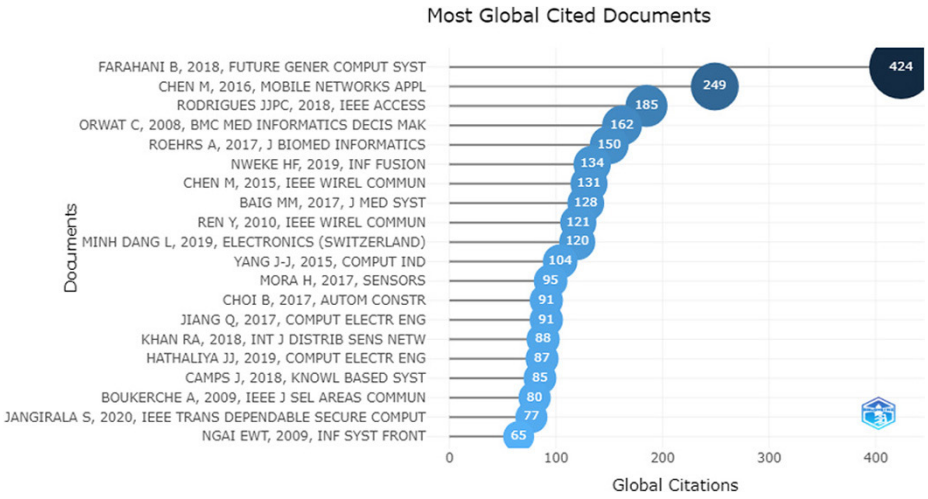

Fig. 16. Most global cited documents

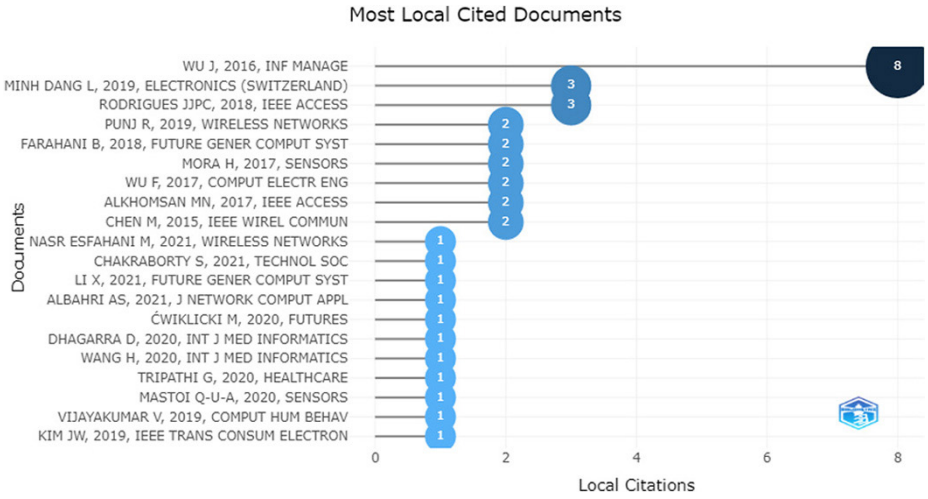

Fig. 17. Most local cited documents

Table 9. List of most global cited documents with DOI and TC

Paper	DOI	TC	TC/Year	Normalized TC
FARAHANI B, 2018, FUTURE GENER COMPUT SYST	10.1016/j.future.2017.04.036	424	84.8	7.9762
CHEN M, 2016, MOBILE NETWORKS APPL	10.1007/s11036-016-0745-1	249	35.571	3.9316
RODRIGUES JJPC, 2018, IEEE ACCESS	10.1109/ACCESS.2017.2789329	185	37	3.4802
ORWAT C, 2008, BMC MED INFORMATICS DECIS MAK	10.1186/1472-6947-8-26	162	10.8	1.9286
ROEHRS A, 2017, J BIOMED INFORMATICS	10.1016/j.jbi.2017.05.012	150	25	3.3369
NWEKE HF, 2019, INF FUSION	10.1016/j.inffus.2018.06.002	134	33.5	5.1048
CHEN M, 2015, IEEE WIREL COMMUN	10.1109/MWC.2015.7054715	131	16.375	1.9699
BAIG MM, 2017, J MED SYST	10.1007/s10916-017-0760-1	128	21.333	2.8475
REN Y, 2010, IEEE WIREL COMMUN	10.1109/MWC.2010.5416351	121	9.308	1.7664
MINH DANG L, 2019, ELECTRONICS (SWITZERLAND)	10.3390/electronics8070768	120	30	4.5714
YANG J-J, 2015, COMPUT IND	10.1016/j.compind.2015.01.012	104	13	1.5639

Table 10. List of most local cited documents with DOI and TC

Document	DOI	Year	Local Citations	Normalized Local Citations
WU J, 2016, INF MANAGE	10.1016/j.im.2016.07.003	2016	8	5.33
MINH DANG L, 2019, ELECTRONICS (SWITZERLAND)	10.3390/electronics8070768	2019	3	8.00
RODRIGUES JJPC, 2018, IEEE ACCESS	10.1109/ACCESS.2017.2789329	2018	3	6.33
PUNJ R, 2019, WIRELESS NETWORKS	10.1007/s11276-018-1694-3	2019	2	5.33
FARAHANI B, 2018, FUTURE GENER COMPUT SYST	10.1016/j.future.2017.04.036	2018	2	4.22
MORA H, 2017, SENSORS	10.3390/s17102302	2017	2	2.47
WU F, 2017, COMPUT ELECTR ENG	10.1016/j.compeleceng.2017.04.012	2017	2	2.47
ALKHOMSAN MN, 2017, IEEE ACCESS	10.1109/ACCESS.2017.2731363	2017	2	2.47
CHEN M, 2015, IEEE WIREL COMMUN	10.1109/MWC.2015.7054715	2015	2	2.00

Most frequent words. We have identified the occurrence of different words in terms of Keyword Plus (Overall keywords in the library of R package), Author Keywords (specific to data file provided in the software), and titles. Occurrence of Keywords Plus reveal that 'health care' has occurred most of the times with 98 occurrences followed by internet of things (56), human (44), healthcare services (43), wearable technology 43 and others mentioned in Figure 18. Author keywords reflect the keywords provided by authors in a searched data file and its limited to specific keywords only. The most frequent author keyword is healthcare with 38 occurrences. It is followed by internet of things (34), wearable devices (19) and others mentioned in Figure 19.

Biblioshiny software enables researchers to organize the frequency of words in unigrams, bigrams or trigrams means it can customize the results of occurrence in identifying the words in single, double or triple themes. We have identified the frequency bigrams and trigrams used in titles only. The most frequent bigram is 'health monitoring' with 13 occurrences in titles. It is followed by healthcare system (10), health care (09), cloud computing (06) and others mentioned in Figure 20. 'Ambient assisted living', 'health care systems', 'health monitoring systems', 'healthcare monitoring system', 'healthcare system based', 'human activity recognition', 'inertial measurement unit', 'mobile healthcare system', 'monitoring systems current', 'recurrent neural networks', 'roadside wellness centres', 'smart health care', 'smart healthcare system' are the most frequent trigrams with 02 occurrences respectively (Figure 21).

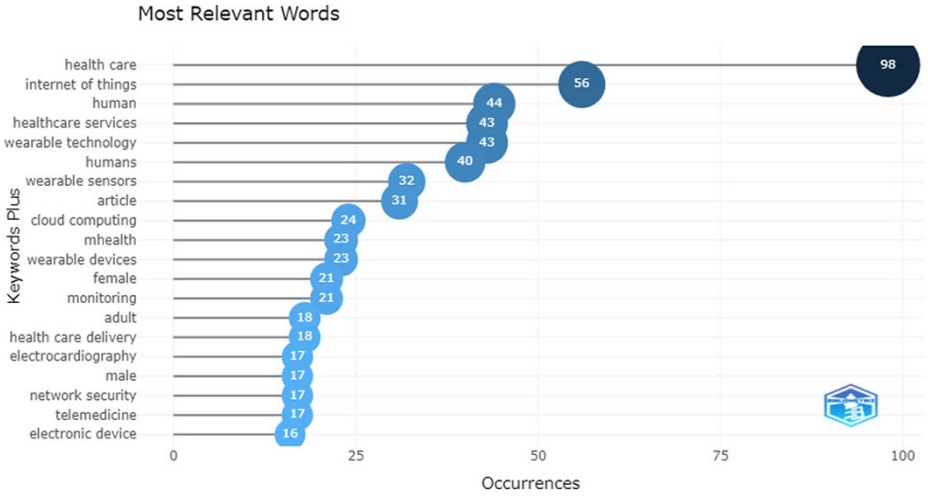

Fig. 18. Most relevant words (keyword plus)

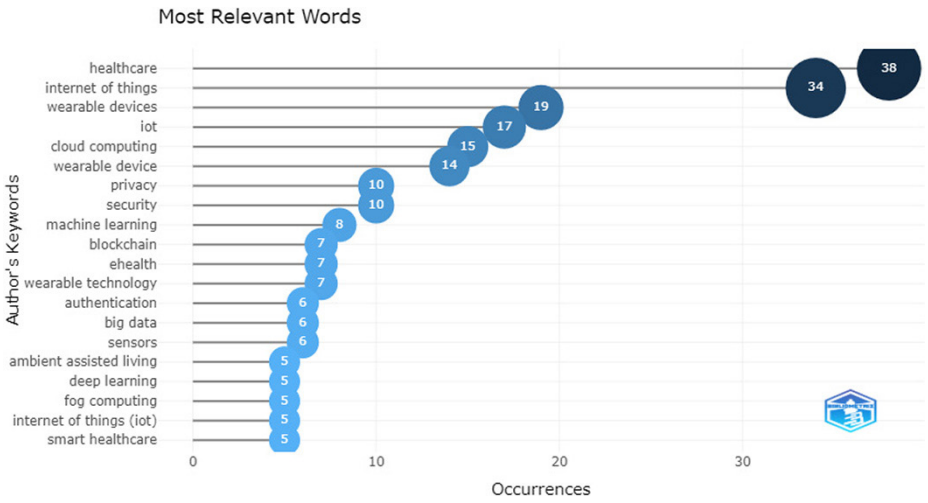

Fig. 19. Most relevant words (author keyword)

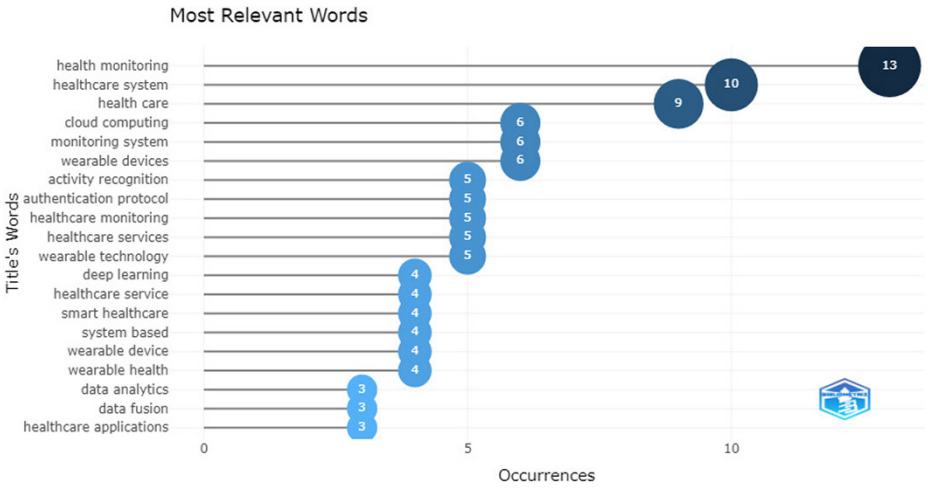

Fig. 20. Most relevant words (title's words bigrams)

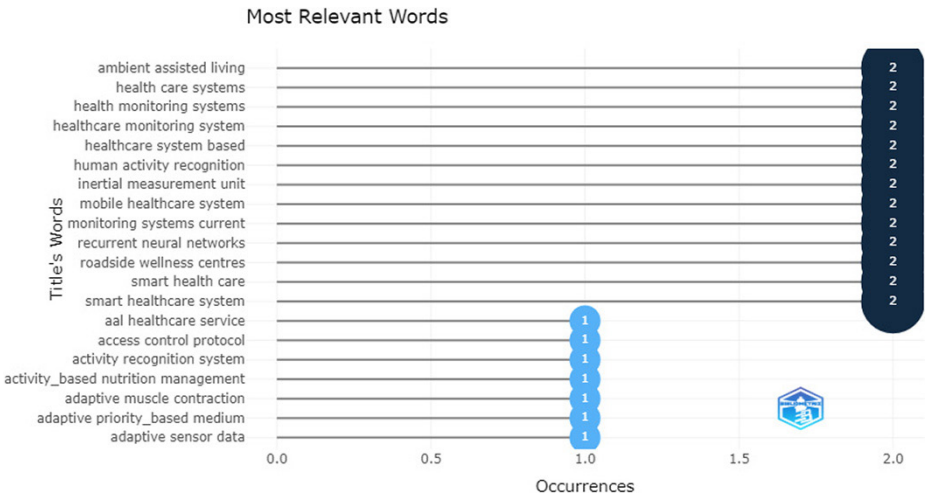

Fig. 21. Most relevant words (title's words trigrams)

Wordcloud & Tree map. Wordcloud and Tree map refer to the visualization and prominence of words due to their frequency or occurrence. We have created three wordclouds representing keyword plus (Figure 22), author keywords (Figure 23) and bigrams in titles (Figure 24) and two tree maps showing keyword plus (Figure 25) and author keywords (Figure 26). The most prominent words in wordclouds and tree maps are Healthcare, Internet of Things, Wearable Devices, Wearable Technology, Cloud Computing, Monitoring System, Deep Learning, Machine Learning, Privacy, and Activity Recognition. It shows the growing research interests in the area of healthcare services and wearable devices.

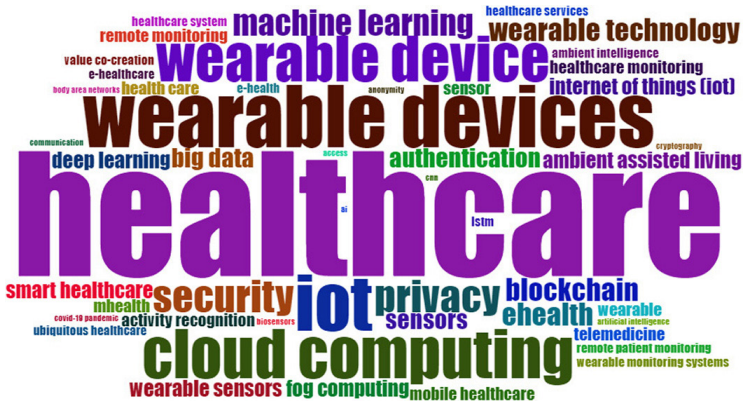

Fig. 22. Wordcloud showing author keyword

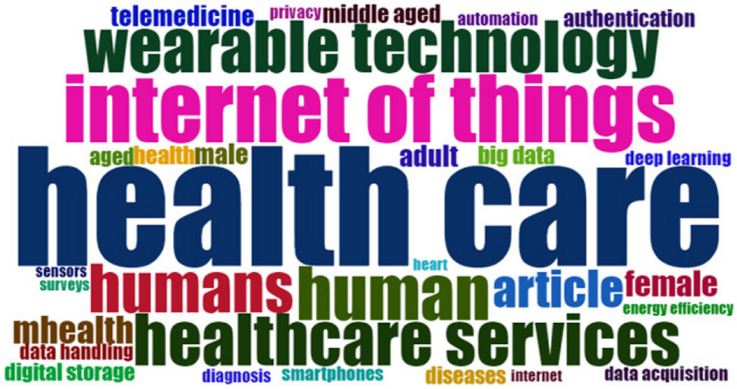

Fig. 23. Wordcloud showing keyword plus

Fig. 24. Wordcloud showing bigrams in titles

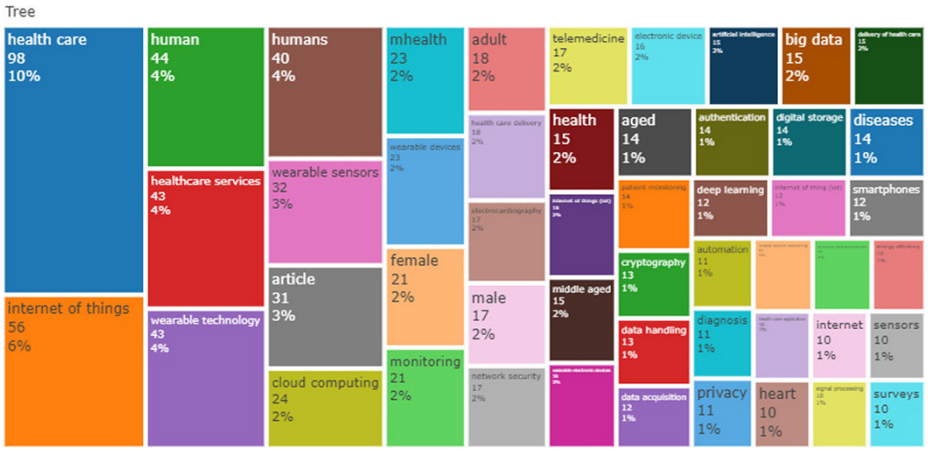

Fig. 25. Tree map showing keyword plus

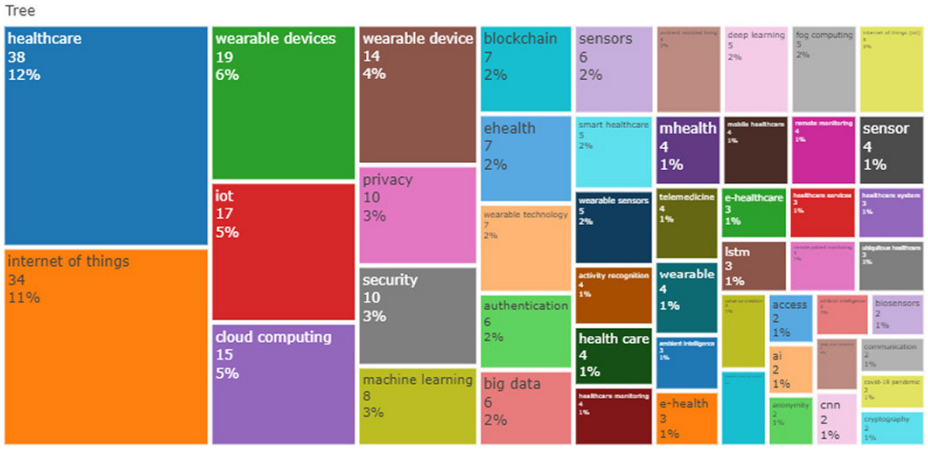

Fig. 26. Tree map showing author keywords

Trend topics. Trend topics analysis shows the pattern of different themes and words which are being studied in different timelines. In our analysis, different themes and words have emerged that are considered as recent trends in the searched area. Network Security, Cryptography, Deep Learning, Healthcare Application and Healthcare System are emerged as trending topics in year 2021 (Figure 27).

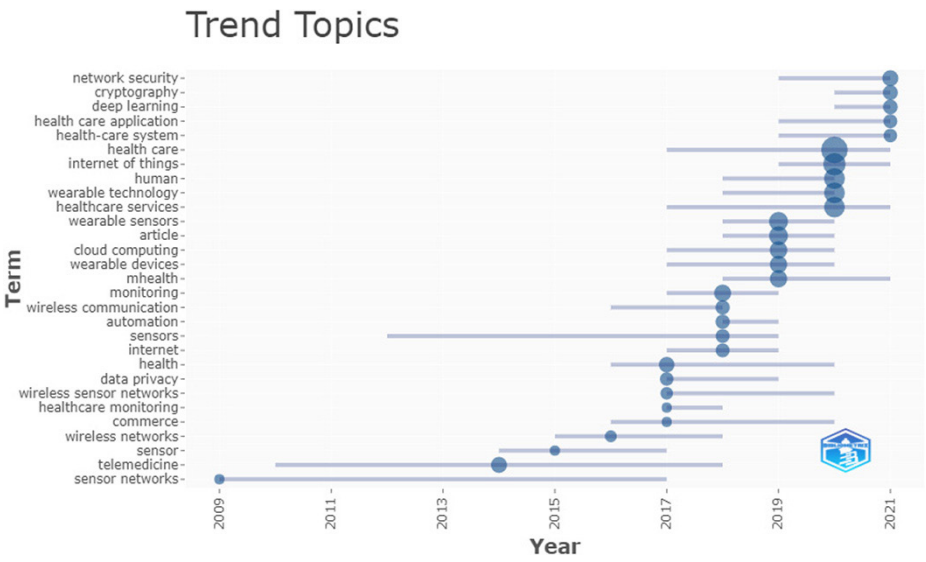

Fig. 27. Map showing the trending topics across years

4 Limitations and future research directions

The current study is restricted to only two themes or keywords used e.g., 'Wearable Devices and Healthcare Service'. Different other combinations can be used instead such as 'wearable technology and healthcare system' or others. One of the limitations of using 'R package biblioshiny' is that it does not give the option of editing the searched keywords by using thesaurus file as it can be done in VOSviewer. Due to this limitation, different similar keywords or themes are shown separately e.g., 'wearable devices and wearable device', 'internet of things and iot' and others.

Different avenues for future research are recommended. The central theme of this study shows increasing pattern of publication specifically in recent years that shows the interest of researchers, therefore more studies are suggested in usage wearable devices in healthcare. Researchers and practitioners are suggested to look into the sources of IEEE Access and Sensors (Switzerland) and works of Lee S. and Shen J. for their upcoming projects and studies. Most of the articles have been produced from China, South Korea, India and USA so more studies are suggested from low producing countries e.g., Mexico, Ireland, Hong Kong, Brazil, Iran and Bangladesh. Network Security, Cryptography, Deep Learning, Healthcare Application and Healthcare System are found to be trending topics where more studies are recommended. Different other databases such as Web of Science, and MedLine can be used to explore wearable technology in healthcare services to understand the differences in patterns and analytics.

5 Conclusion

The study is designed to present the analytics of 'wearable devices in healthcare services' from 2008 to 2021. Bibliometrix analysis by using biblioshiny of R-package is performed on 204 documents after screening them on inclusion and exclusion criteria. Different analyses have been executed in identifying research output, prominent sources and their impact, prolific authors their contribution and impact, prominent affiliations and countries, most relevant and frequent documents and words and visualizations of most frequent words and trending topics.

6 Conflict of interest

No any.

7 Acknowledgment

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9 Appendix-I

9.1 The search string

"*Wearable devices*" AND "*healthcare services*" AND (EXCLUDE (PUBYEAR, *2022*)) AND (LIMIT-TO (DOCTYPE, "*ar*")) AND (LIMIT-TO (SRCTYPE, "*j*")) AND (LIMIT-TO (LANGUAGE, "*English*")) AND (LIMIT-TO (EXACTKEYWORD, "*Health Care*") OR LIMIT-TO (EXACTKEYWORD, "*Wearable Technology*") OR LIMIT-TO (EXACTKEYWORD, "*Healthcare Services*") OR LIMIT-TO (EXACTKEYWORD, "*Healthcare*") OR LIMIT-TO (EXACTKEYWORD, "*Wearable Devices*") OR LIMIT-TO (EXACTKEYWORD, "*Wearable Sensors*") OR LIMIT-TO (EXACTKEYWORD, "*Wearable Electronic Devices*") OR LIMIT-TO (EXACTKEYWORD, "*Wearable Device*"))

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