Visualizing wearable medical device research trends: a co-occurrence network based bibliometric analysis

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Visualizing Wearable Medical Device Research Trends: A Co-occurrence Network-Based Bibliometric Analysis

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Abstract

Background. One of the most crucial aspects of someone's life is health. Therefore, individuals should be conscious about keeping themselves healthy by regular monitoring their health, which can be done with the help of modern medical technologies. Wearable medical devices using wearable sensors are the popular names of emerging technologies in the modern healthcare domain.

Aim. This work presents the results of a systematic investigation of extensive research that has occurred for the last two decades in these research streams to provide a comprehensive mapping and temporal distribution of wireless medical device research.

Methods. This study presents a relationship between the bibliographic items, their quality, and the quantity representing the most effective research topics on wearable medical devices. The analysis is performed using two useful parameters, namely a bibliometric network and a co-occurrence matrix. Data collection, data standardization, data mapping, and result analysis are the steps involved in the bibliometric analysis technique. In this study, VOSviewer software for bibliometric analysis is applied to the Scopus database.

Results. By analysing bibliometric indicators from the Scopus database and using VOSviewer, we represent their distribution in countries, institutions, top researchers, and top journals. Furthermore, we analyse the co-citation of cited authors and the co-occurrence of keywords. The outcomes of the clustering and keyword analysis indicate that the research domain primarily focuses on the Internet of Things, machine learning, wearable sensors, mobile health, electrocardiogram, etc.

Conclusions. Statistical investigation in association with the visual exploration presented in this article provides more substantial information than either of them used separately. In the future, this article can illuminate researchers and practitioners to develop a different theory to look at the factors that influence predictability in the research domain of wearable medical devices.

Keywords
Wearable Medical Devices; Bibliometric Analysis; VOSviewer; Scopus; Co-occurrence Matrix

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Introduction

On account of an aging worldwide population and the rising adoption of the Internet of Things (IoT), the wearable technology industry is expected to play a significant role in the medical and health industry. This growth has been accelerated by the pandemic, which has also led to an escalated trend in home fitness and the aim of generating a more interrelated healthcare system that can anticipate continuous monitoring. Wearable healthcare devices connect people with health providers and impart the opportunity for tracking, continuous monitoring, and diagnosis. Some devices are even able to store medical data and statistical health information [1]. Continuous health monitoring can noninvasively detect medical parameters, namely thermal, electrical, and optical signals produced by individuals' bodies. Wearable medical devices are generally IoT-based, and they can be put on as external accessories, attached on the skin or inserted into the body [2–4].

A recent scoping review by Cheong *et al.* [2] summarizes 40 articles, which all together demonstrate 22 kinds of wearable technologies for the primary detection of a virus based on the deviation of physiological characteristics. Early detection facilitates self-isolation. The worldwide pandemic that has impacted the world since 2019 has put the healthcare industry at the forefront. Again, different factors related to the practical implication of wearable medical devices need to be addressed to promote their effective application. Data protection and affordability are some of the prime concerns that need to be addressed [3]. This will enable a huge number of applications in the healthcare system, from physiological diseases to neurological disorders [4]. Various strategies have been incorporated to decrease the barrier between the patient and healthcare practitioners to ensure maximum clinical value. In this context, a new framework was presented by Khedraki *et al.* [5]. Bifunctionality in wearable medical devices has attracted widespread interest in this research field. These smart functions include biodegradability, self-healing, and biocompatibility [6]. To achieve active health monitoring, embedded control on medical devices has proven to be an emerging application domain. Embedded strategies in medical applications offer hardware miniaturization, portability, lower maintenance, and reduced power consumption [7]. Medical Internet of Things (MIoT) devices utilize deep learning methodologies to analyse previously captured data and effectively reduce the time complexity in the prognosis of physiological diseases [8–11]. Di Pasquale *et al.* [12] presented a detailed discussion on the specific application of wearable devices to monitor the health and safety of users. This technology still faces many challenges regarding security, data collection, and data processing [13].

The motivation behind this article is the fact that the emerging field of wearable medical devices has the potential to unfold new applications and research possibilities that can facilitate further studies. This study intends to provide significant insight into the potential of wearable medical devices in the modern healthcare system by exploring the research hotspots and systematically mapping the prime topics in this domain. To do so, bibliometric mapping [14–19] is performed on worldwide research on wireless medical devices (WMDs) by applying a comprehensive sample of articles published in the last two decades. Additionally, this study aims to recognize the research gaps and identify possible future research trends.

The rest of the paper proceeds as follows: The Materials and Methods section highlights the technical aspects of this domain along with our approach to bibliometric analysis. In the next section, a detailed bibliometric and co-occurrence analysis is presented, followed by a discussion on the findings and suggestions for this research stream. At the end, the conclusions of this analytical study are presented, followed by the future scope.

Materials and Methods

The proposed applied study uses a bibliometric network [14–19] and a co-occurrence matrix to study the potential relationship of two bibliographic items, their quality and quantity representing a certain research topic. The steps of the bibliometric analysis technique applied in this study are as follows: data collection, data standardization, data mapping, and result analysis.

Research Question

Many studies contribute to the field of WMDs from different perspectives; however, systematic mapping is highly essential to identify the research gap and investigate the extant articles in the entire research domain of WMDs. This leads to seeking a solution to the following research questions:

- RQ1: What are the publication dynamics in this research domain?
- RQ2: What are the visible trends of countries and organizations that participate in WMD research?
- RQ3: What are the prime research topics in WMDs?
- RQ4: What are the future trends of this research domain?

Answering these questions will build an overview of the scope of this research domain.

Research Process

Bibliometric analysis is a systematic mapping technique that is one of the most powerful literature review tools. In this method, major concentration is given to the research trend and its quantitative analysis rather than quality assessment. In this study, we performed a search and screening in the Scopus database for the search string “Wearable Medical Device” from 2002 to 2022, and 457 articles were found in the English language. The Scopus database was considered to perform this study, as it is one of the most authentic databases, consisting of worldwide peer-reviewed research publications with a huge number of citations. Extracting data from a single database eliminates the chance of duplication of any article in the considered data set. Figure 1 represents the step-by-step research process followed in this analytical study. While extracting bibliographic data from the Scopus database, some inclusion criteria (IC) are maintained, such as the type of document being limited to review and journal articles only and in the English language. In the exclusion criterion (EC), we excluded articles with incomplete bibliographic details and conference and book chapters, as they often do not concentrate on detailed novel technical outcomes.

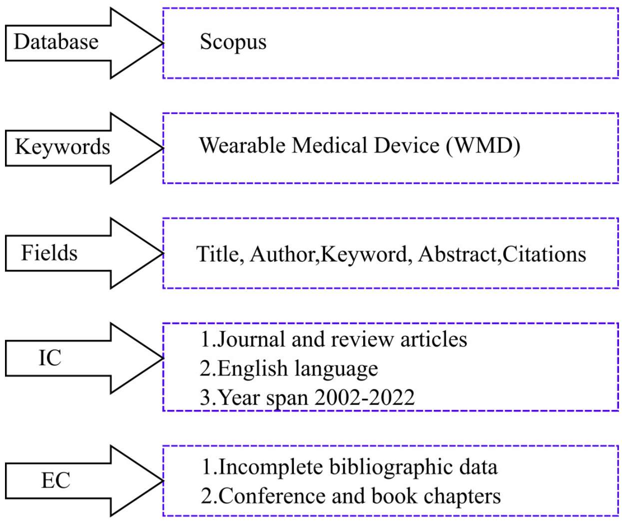

Figure 1. Research flow diagram.

The curve presented in Figure 2 exhibits the evolution trace in the WMD research field, which signifies the evolution and status quo in this field. The data in Figure 2 demonstrate a trend toward an increased number of publications between 2017 and 2022. The database contains primary important information, the author's name, author ID, title of the paper, publication year, journal name, volume and page number, citations, abstract, author keywords and index keywords.

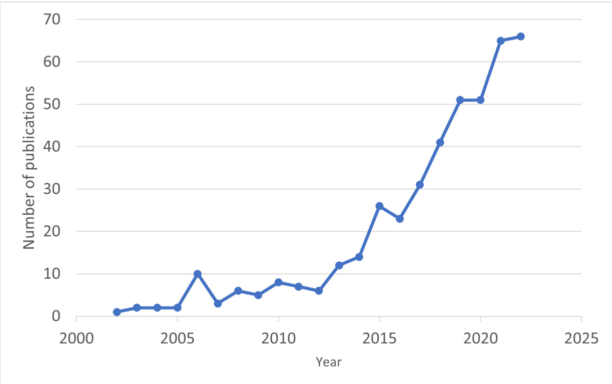

Figure 2. Distribution of publications for wearable medical devices.

Used Tools

VOSviewer is extensively applied in web-based bibliometric analysis, particularly in thematic analysis, cartography, and cluster analysis [18]. This mapping technique is applied to investigate the development and expansion of a particular research domain. This quantitative analysis tool focuses on discovering the latest state of the literature and research gaps using different measures. There are several other mapping and analysis tools, such as Citespace, sci2, and Gephi. In this analytical study, we used VOSviewer software because of its ease of access, high intuition, and versatility.

By analysing bibliometric indicators from the Scopus database and using VOSviewer, we represent their distribution in countries, institutions, top researchers, and top journals. Furthermore, we analyse the co-citation of cited authors and the co-occurrence of keywords.

Result Analysis Techniques

To build a worldwide overview of ongoing research on WMDs, we used VOSviewer, which can efficiently construct intelligible large bibliometric networks and co-occurrence matrices. It incorporates the following parts:

- most influential author in the research domain (RQ1)
- most active organizations and countries in the WMD research domain (RQ2)
- topmost journals in the WMD research field (RQ1)
- co-occurrence analysis of keywords (RQ3, RQ4)

Results

Top 10 Researchers in the Domain of Wearable Medical Devices

Table 1 shows the list of active researchers in the field. The above tabular format represents the top 10 author's names and their respective publication number as well as total global citation score (TGCS) (RQ1). In addition, we have found that 1, 502 authors have published a total of 457 research papers. We have set a threshold value of three publications and found that out of the 1,502 authors, only 82 meet the threshold. It has also been found that 81 authors have published a total of 316 articles in our selected time span. A threshold value ensures higher rigor of analysis. The aim is to obtain the most influential parameters in a particular domain for a more classified visualization map. During our search period, Y.T. Zhang was the most influential author, having the authorship of 12 articles. We have sorted the most productive authors depending on the number of articles they have published. From the above table, it can be noted that Y.T. Zhang has the highest TGCS of 475, followed by N.K. Jha with the TGCS of 420 and A. Raghunathan with the TGCS of 405. The TGCS represents the citation count of an article by another article globally. However, A.C. Arias and Y. Khan each published three articles, each having 944 citations. The visual analysis is presented in Figure 3.

Table 1. Top 10 researchers in the wearable medical device research field.

Serial No.	Author's Name	Publications	Citations	Total link strength
1	Y.T. Zhang	12	475	11
2	N.K. Jha	9	420	13
3	C.C.Y. Poon	9	378	12
4	L. Wang	9	163	10
5	A. Raghunathan	8	405	13
6	Y.T. Zhang	7	249	6
7	R. Azarderakhsh	7	38	5
8	M. Kermanim	6	52	8
9	S. Li	6	30	21
10	M. Zhang	5	244	10

A link in a co-occurrence network indicates the relation between two items in the network. Each of these links has a positive numerical value that indicates the strength of the link. A higher value represents a stronger link. The link strength of an item denotes the total strength of links of that item with the other items in the network. In the network visualization, one can observe nodes of different sizes and colours associated with specific labels. The size of the circle is determined by the weight of that item or label, and the colour indicates the cluster to which they belong. In the visualization, the colours demonstrate the distribution of the nodes through the two-dimensional space of underlying networks. Cluster colours enable immediate density visualization that allows viewers to detect the dense areas where multiple nodes are presented closely. Therefore, it simply presents the relatively strong areas in each domain.

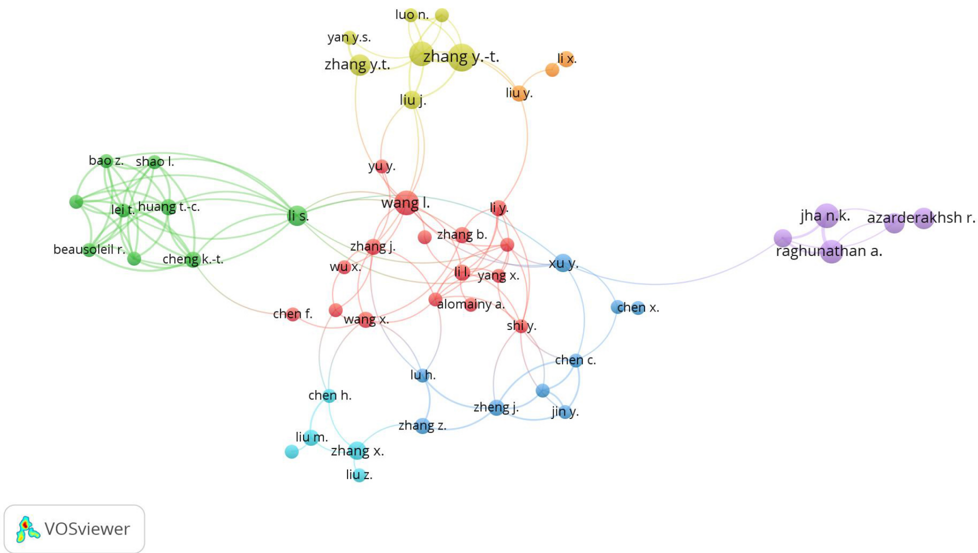

Figure 3. Top researchers in the wearable medical device research field.

Top 10 Organizations in the Domain of Wearable Medical Devices

In this study, we found that a total of 953 organizations were engaged in this field during the specified period (RQ2), the link of which is presented in Figure 4. We have set a threshold value of two, which indicates that we consider only the organizations that have published more than or equal to two articles. Out of 953 institutions, we found 35 that met this criterion. The topmost influential institutions are presented in Table 2. Princeton University and Purdue

Table 2. Top 10 organizations in the wearable medical device research field.

Serial No.	Organization	Publications	Citations	Total link strength	Country
1	Department of Electrical Engineering, Princeton University, Princeton	7	399	10	United States
2	School of Electrical and Computer Engineering, Purdue University, West Lafayette	7	399	10	United States
3	Department of Electrical and Microelectronic Engineering, Rochester Institute of Technology, Rochester, New York	3	93	5	United States
4	Department of Electrical Engineering and Computer Sciences, University of California, Berkeley	3	944	0	United States
5	Department of Materials Science and Engineering, Peking University, Beijing	3	2	8	China
6	Key Laboratory for Biomedical Informatics and Health Engineering, Chinese Academy of Sciences, Shenzhen	3	68	3	China
7	Advanced Computing and Microelectronics Unit, Indian Statistical Institute, Kolkata	2	115	5	India
8	Art of Technology AG, Zurich	2	35	0	Switzerland
9	Department of BME, Chinese PLA General Hospital, Haidian District, No. 28 Fuxing Road, Beijing	2	36	0	China
10	Department of Chemical Engineering, Hanyang University, Seoul	2	113	0	South Korea

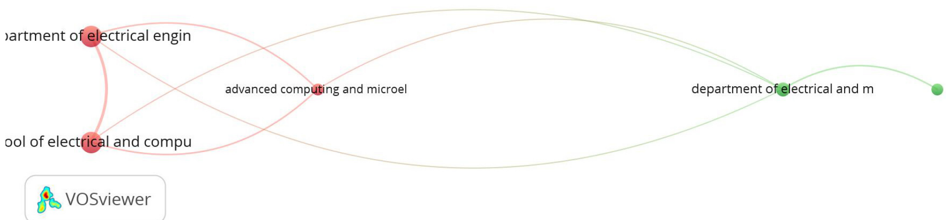

Figure 4. Top 10 organizations in the wearable medical device research field.

University in the United States each have seven publications and 399 citations with the highest link strength of 10. However, three articles from the University of California have 944 citations. The aggregate level analysis using VOSviewer shows that most of the influential organizations actively involved in this research domain are in the United States and China.

Top 10 Countries

Table 3 indicates the best countries in the field of wearable medical devices (RQ2). We have set a threshold for a minimum of five articles per country, and out of the 86 countries involved in this research domain, 24 meet the criterion. By analysing Table 4, the United States has the highest effect in the field, with 104 publications and the highest citation of 3,220, followed by China with 98 articles and 1,185 citations. India has 41 publications with a total of 857 citations. A visual representation using VOSviewer is shown in Figure 5, which shows the link among the countries involved in this research domain.

Top Journals in the Wearable Medical Devices Research Field

This study analyses the number of citations and publications of all journals (RQ1). Table 4 shows the list of journals with more than three articles in the research area of

Table 3. Top 10 countries in the wearable medical device research field.

Serial No.	Country	Publications	Citations	Total link strength
1	United States	104	3,220	35
2	China	98	1,185	33
3	India	41	857	13
4	Hong Kong	25	903	15
5	United Kingdom	25	773	13
6	Italy	22	242	8
7	Japan	15	174	6
8	Canada	14	258	9
9	South Korea	14	596	6
10	Taiwan	14	44	7

Table 4. Popular journals in the wearable medical devices research field.

Serial No.	Source	Publications	Citations	Total link strength
1	Advanced Materials	4	1,294	4
2	Scientific Reports	3	285	0
3	IEEE Access	8	277	1
4	Annual International Conference of the IEEE Engineering in Medicine and Biology - proceedings	4	214	1
5	IEEE Transactions on Biomedical Circuits and Systems	4	125	1
6	Biosensors	3	86	2
7	Journal of Materials Chemistry	3	74	0
8	Electronics Letters	3	65	1
9	ACS Applied Materials and Interfaces	3	61	2
10	Physiological Measurement	3	46	1

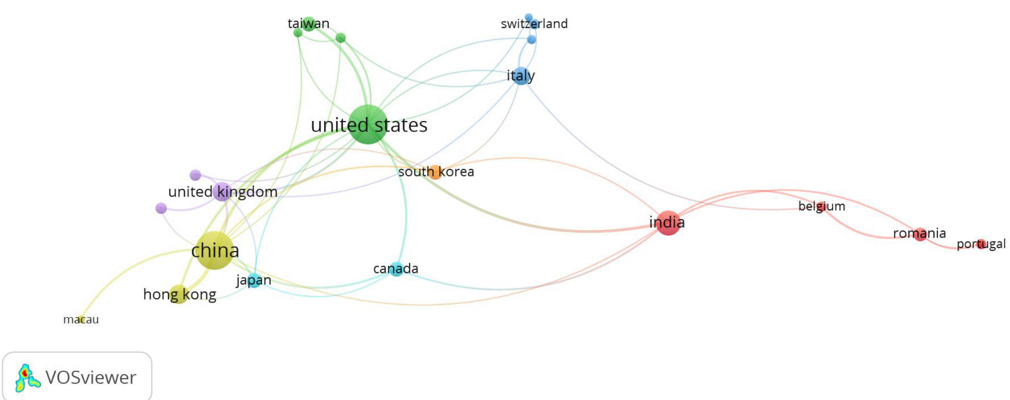

Figure 5. Top 10 countries in the wearable medical device research field.

wearable medical devices. Figure 6 represents link mapping. The most impactful journals are selected depending on the number of citations. However, in our concerned research field, IEEE Access has published the highest number of articles, a total of eight. Table 4 shows that Advanced Materials, Scientific Reports, IEEE Transactions on Biomedical Circuits and Systems, ACS Applied Materials and Interfaces have the highest impact in this area.

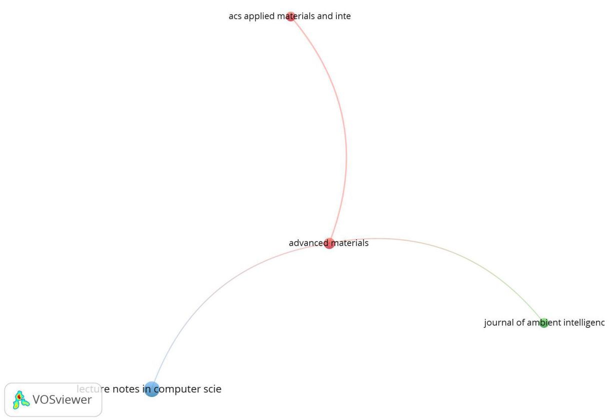

Figure 6. Top journals in the wearable medical devices research field.

Co-occurrence of the Keywords

We have set the minimum keyword occurrence as five (258 keywords meet the threshold), and the list of the most frequently used keywords for the wearable medical device research domain and their occurrences are presented in Table 5. To further investigate the key topics and potential research trends, a co-occurrence matrix was generated using VOSViewer (RQ3, RQ4). Figure 7 shows that "wearable medical devices", "healthcare", "electronic devices", "electrocardiography", "the Internet of Things", "biomedical engineering", and "signal processing" are some of the keywords with high link strength that can be used as a hotspot in this domain. The keywords presented in Figure 7 can be divided into five clusters. The most frequent keywords in cluster 1 are "biomedical equipment", "internet of things", "artificial intelligence", "learning system", "machine learning digital storage"; cluster 2 – "wearable medical device", "flexible electronics", "biocompatibility", "energy harvesting", "energy transfer", "power supply", "electrode", "electric rectifiers"; cluster 3 – "article", "male", "female", "adult", "blood", "blood pressure", "human experiment"; cluster 4 – "humans", "equipment", "telemetry", "electronic devices", "physiological monitoring"; cluster 5 – "patient monitoring", "biomedical engineering", "physiological parameters", "m-health". An initial observation can conclude that clusters one and two represent multiple techniques applied in developing and improving WMDs. Cluster three keywords primarily concentrate on different experimental parameters.

To further enrich the previous keyword analysis, author keywords with a high frequency of occurrence are exhibited in a tree map in Figure 8. In this figure, the rectangle size is equivalent to the keyword frequency. Keywords with

Table 5. Keyword co-occurrence in the wearable medical device research field.

Serial No.	Keywords	Occurrence	Total link strength
1	Wearable Medical Devices	283	2,080
2	Wearable Technology	138	1,090
3	Biomedical Equipment	102	813
4	Human	87	994
5	Humans	68	806
6	Wearable Sensors	65	482
7	Article	56	635
8	Health Care	55	477
9	Diagnosis	38	325
10	Internet of Things	38	319

a high frequency of occurrence are represented by a larger rectangle. Each rectangle consists of the keyword and its frequency of occurrence. The author's keyword contributes highly to obtaining the research interest and research trend in the domain. By analysing Figure 8, the most frequent keywords can be identified as "wearable medical device", "internet of things", "healthcare", "machine learning", "security", "flexible electronics", "electrocardiogram", "sensor", and "deep learning". This validates the consistency of the previous analysis with more details. A primary conclusion can be developed, as the recent WMD research trend is mainly based on recent cutting-edge technologies, namely the IoT, sensors, machine learning (ML), artificial intelligence (AI), and deep learning. Additionally, the prime application domain of WMDs includes healthcare, electrocardiogram (ECG), telemedicine, diabetes, and heart rate monitoring. Furthermore, more emphasis should be given to security and reliability. Overall, an author keyword analysis provides insight into the application and challenges of WMDs by incorporating the abovementioned technologies.

Co-citation Analysis on Cited Authors

To further enhance the understanding of the cited references in the domain of WMDs, a co-citation matrix of the cited authors is generated. Co-citation of cited authors seeks to recognize the most influential authors by surveying their citation count. Thereafter, co-citation indicates that more than one author is cited by some other researcher, i.e., it involves pairs of articles cited simultaneously by another paper. To discover the most eminent authors in this research field, a sample of 32,369 first authors is obtained. Henceforth, with a minimum of 50 citations, the sample size is minimized to a new sample that contains 41 authors and has a total citation count of 3,169. The systematic mapping technique distributes 41 authors into four clusters, which are presented in Figure 9. There are four clusters indicated by red, green, blue, and yellow. VOSviewer utilizes colours to identify a cluster to which a node belongs. The green cluster has the lowest weighted links, which indicates that the cited authors of this cluster have minimal co-citation values. On the other hand, other clusters hold huge numbers of weighted links and hence, have a large number of mutual co-citations.

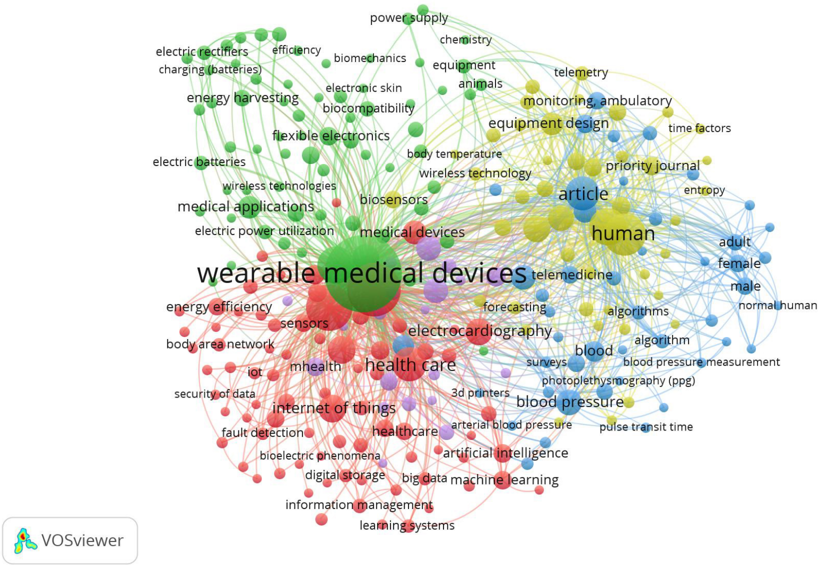

Figure 7. Co-occurrence of the keywords in the wearable medical device field.

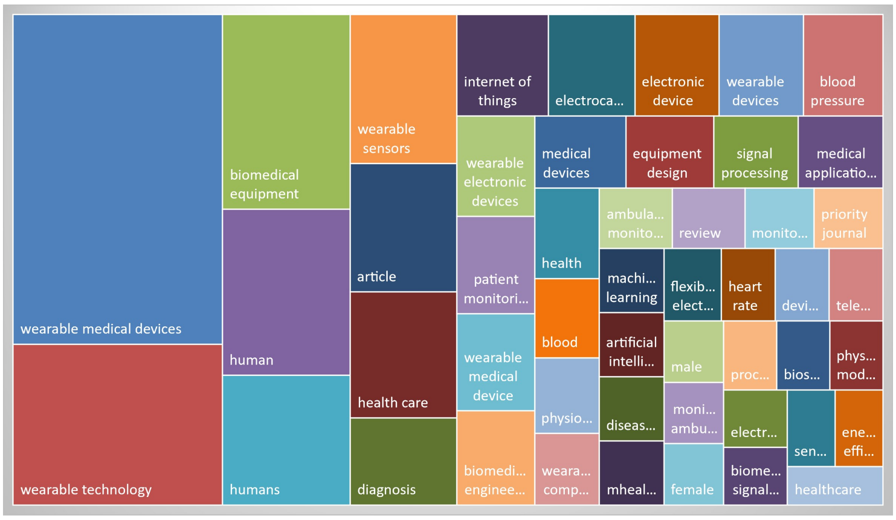

Figure 8. Tree map of author keyword frequency.

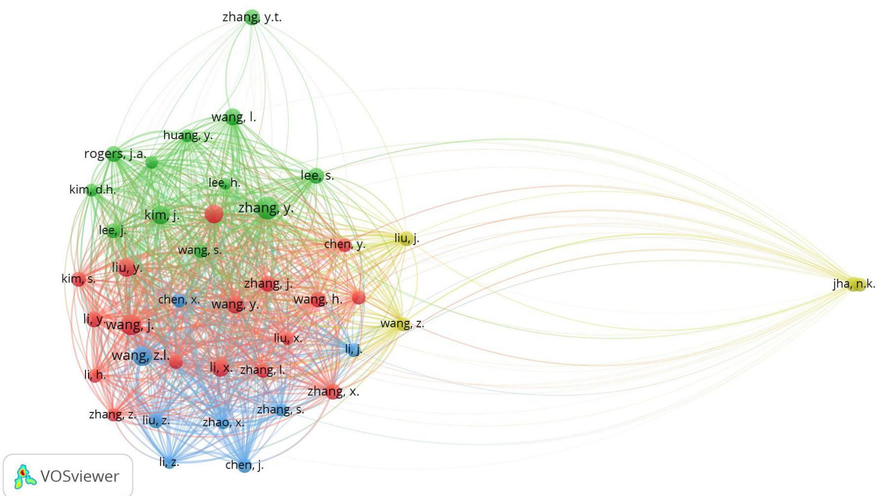

Figure 9. Co-citation analysis on cited authors.

Discussion

A bibliometric analysis and co-occurrence matrix are two powerful paradigms that present insight into the research foci that guide the development of WMDs in multiple healthcare domains. As a result of this detailed discussion, researchers can build a knowledge domain in the techniques applied in the development of WMD and its huge application domain. The bibliographic data are extracted from the Scopus database (for the last two decades) and are imported into VOSviewer. Systematic mapping is performed in such a way that it can provide answers to the research question presented earlier in this article. A tradeoff is maintained in deciding the threshold value of mapping any paradigm so that it does not result in a huge number of clusters, which may lead to complex, inaccurate, and unclear analysis. In the following sections, a qualitative discussion is presented that is subjected to the analysis and content identified from the keyword analysis. This section aims to address an in-depth discussion of the emerging technologies in WMD research, followed by a brief discussion of their application domain and challenges.

Prospect of IoT in WMD

The IoT is one of the key technologies applied in WMD. This fact is validated by Figure 8. An intelligent wearable device (IWD) aims to measure medical parameters automatically. To develop a smart medical device, multiple communication techniques such as Bluetooth, ZigBee, and 802.11 are employed that need to maintain an interconnection with IoT devices in the network to create realistic solutions [20]. Remote health monitoring is a key challenge in the healthcare industry, especially for patients with cardiovascular disease. IoT devices enable the analysis of ECG signals in an embedded platform. With the help of a support vector machine (SVM), IoT medical devices can implement highly accurate and efficient tools for remote diagnosis and monitoring of patients with chronic diseases [21]. Another IoT-based medical device, developed in 2019 [22], continuously monitors the heart details of a patient by employing a high-order Boltzmann model. This model claims to provide high accuracy with less computation time. A smart wearable medical device incorporates IoT along with AI, big data, and cloud computing for better health monitoring and managing health requirements. From this standpoint, WMD shows a path toward the digital healthcare industry [23]. In regard to the fact that there are various sociotechnical barriers and challenges in employing large-scale WMDs, a study on different groups of elderly people was performed in China [24]. The obtained outcomes were analysed, which brought out some serious and critical challenges, such as financial issues, technical reasons, and clinical and legal issues, that needed to be addressed before large-scale deployment of IoT-enabled WMDs. To further enhance the understanding of this domain, a study was conducted by applying exploratory factor analysis techniques [25], which resulted in five key enablers. The outcome improved the body of knowledge of IoT-based WMDs to support healthy living. In this context, a detailed investigation [26] was performed to analyse the performance of IoT and AI-based medical devices for real-time remote health monitoring of the vital signals of a patient. However, a data integration IoT model [27] is needed to create an interface that can connect multiple heterogeneous WMDs with different healthcare platforms through middleware.

Prospect of ML in WMD

ML techniques have recently gained huge attention for their application in the field of WMDs. Various ML models are able to act or make decisions by learning from past experience. A large quantity of ML research [28–30] is classification tasks or clustering or regression problems. ML models learn from body signals (ECG, electroencephalogram (EEG), electromyogram (EMG), oxygen saturation (SpO_2), blood pressure) and assist in remote monitoring, disease diagnosis, and elderly care [31]. An integrated data-driven framework in addition to ML can perform decision-making tasks [32] that depend on the interpretation developed from the signal features collected from elderly patients. Advanced deep learning techniques such as the recurrent neural network (RNN), long short-term memory (LSTM), and convolution neural network (CNN) can be applied to develop a predictive model that can investigate sleep quality as well as physical activity patterns during awake time [33]. ML can be further utilized to extract important and useful features from the collected data and to analyse them to monitor patients' health conditions and diagnose diseases [34]. Some advanced ML models are even capable of detecting epileptic seizures by processing data from EEG devices [35]. Real-time data handling is one prime issue faced by WMDs due to a large amount of data needing to be handled and timely diagnosis needing to be achieved. Deep learning technology can solve this issue and improve accuracy in the real-time prediction of cardiovascular diseases [36]. However, these advanced functionalities bring concern about securities related to data tampering in any medical emergency. This issue can be resolved using a security framework [37] that can be developed using ML techniques.

Prospect of Wearable Medical Device Sensors

Advanced WMD utilizes IoT, ML, and AI technologies for remote patient monitoring and disease diagnosis. To do so, these devices need to capture vital signals from the patient's body. These sensors need to have biomulti functionalities such as biodegradability, self-healing, and biocompatibility to improve human-machine interactions [38]. Sensing techniques, fabrication, and data handling [6] need to be addressed for efficient data processing and transmission in vital sensors. Healthcare wearable devices can be broadly classified into three categories, namely synthetic skin, biofluid-based devices, and physiological devices. Synthetic skin (also known as e-skin) can sense touch, automatic reflex, and temperature detection for individuals with nerve damage. The possible application areas for e-skin are huge and include robotics and prosthetics [5]. Despite having an extensive application domain, the challenges of skin-based wearable devices remain difficult in terms of maintenance, prohibitive cost, and limited availability. While designing the sensor to interface with human skin, the sensor material needs to be stretchable and flexible. Silicon-based vital sensors have the potential for viable medical monitoring [39]. A non-invasive biosensor can be applied in electrochemical sensing applications. Biomarker data can be recorded using a biofluid-based wearable device to provide real-time health monitoring and wound healing-related information. These biomarkers can be extracted from human body secretions such as sweat, urine, tears, saliva, etc. These devices are low-cost and provide real-time wound healing information. However, this method has some limitations, such as contamination, difficulty to wear, fluid leakage, and blockages [39–41]. Large-scale real-time monitoring remains a challenge. Health smart clothes are an advanced technology that offers a huge opportunity for continuous monitoring of elderly persons, militaries, athletics, people with disabilities and even working professionals [41]. Challenges remain in real-time monitoring, miniaturization, low power consumption, flexibility, and minimized cost.

Application of WMDs

To capitalize on this rising demand and work and to develop more precise sensors and more dependable data for medical use, industries will also increase their research and development (R&D) expenditures for wearable technology. As a result, most of the population will start to quickly adopt new wearable technologies, assisting in the sector continuous growth. More cutting-edge wearables than just activity trackers will be available in the future, and this research will lead a path to the advancement of these technologies [21–25, 28–37]. Due to advancements in material fabrication that allow for the creation of flexible electronics and instantaneous charging of smaller power sources, wearables are already becoming smaller in size [40, 41]. Additionally, integrating wearable technology with a faster IoT could put wearable devices at your wrists, fingertips, or other body parts for health data exchange, personal comfort, and safety [13]. Wearable technology could increase staff productivity because it enables medical staff to resolve problems more quickly. The data obtained from each individual are then utilized to predict potential health problems beforehand, enabling the use of low-cost and more effective preventive action in contrast with treating a disease once it has already taken hold.

Challenges

Wearable technology is being used by an increasing number of people to collect crucial data and improve their health management, but data collection alone is insufficient. If information is to be effectively integrated into the patient care management process, it must be transmitted to the clinician's electronic health record (EHR) system. For the popularity and acceptance of this technology, there are a few factors to be considered. First, one of the key challenges for wearable medical devices is security, as connected devices are soft targets of cyberattacks [19]. For successful implementation of these stringent rules, WMD and the healthcare industry require trustworthy IoT engineers. Second, most medical wearables are expensive for many individuals to afford. Moreover, people need to purchase new and improved devices, as the older versions sometimes do not fit with the compatibility of the wearables [19]. Third, WMD technology generally requires a large amount of power, which restricts its long-duration application. Fortunately, due to the rapid development in this industry, wearable device battery limitations [19] have improved over time. Additionally, the accuracy of consumer sensors and the lack of actionable data are two major challenges for the further expansion of this industry. Therefore, promoting research and development to advance these technologies can address these issues.

However, this investigation is only limited to the Scopus database, whereas other international databases, such as World of Science (WOS) or PubMed, can be taken into consideration. Additionally, this technique only considers the parameters included in the Scopus database to analyse the bibliometric network, whereas there are several other important parameters (discrimination between theoretical and experiential articles, etc.) that should be taken into account for a more detailed analysis of this domain. Based on these facts, a deeper investigation is suggested that will lead to a broader aspect in this research domain.

Conclusions

This bibliometric study presented the results of an extensive study of a potential relationship between the bibliographic items, their quality, and their quantity, representing a certain research topic on wearable medical devices. It is performed using two useful parameters, a bibliometric network and a co-occurrence matrix. VOSviewer software for bibliometric analysis was used on the Scopus database to accomplish the goal. This study findings have significance in opening new opportunities in the emerging field of wearable medical devices, which can facilitate further studies in this domain. Data collection, data standardization, data mapping, and result analysis are the process of the bibliometric analysis technique applied in this study. The analysis clearly indicates wide-ranging participation by the United States and China thus far in this domain. We have presented some major journals that concentrate on this field. As a result of our analysis, researchers and practitioners can build a body of knowledge on different prospects of wearable medical device research platforms and understand the growth of the subject by topic, context, and quantification. Wearable medical devices are emerging research streams and significant phenomena in the modern healthcare industry. The statistics presented here clearly show that more than fifty percent of the articles (274 out of 457) were published in the last five years. Therefore, it is necessary to repeat bibliometric studies at least once a decade to assist researchers in comparing the scope, impact, and development of emerging research fields.

Ethical Statement & Informed Consent

Not applicable due to the design of the study, which does not anticipate involving human or animal subjects. The presented article is based on results of bibliometric analysis and data from existing literature sources. Therefore, no ethical approval or consent procedures were required.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interest

Nilanjan Dey is an editorial board member of the journal; however, he was not involved in the editorial process or any decision-making regarding the acceptance or rejection of this manuscript, and his role was solely limited to co-authorship of this manuscript. The remaining authors of this article declare that there is no conflict of interest regarding the research and publication of this work, and have nothing to disclose.

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