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A comprehensive systematic and bibliometric review of the IoT-based healthcare systems

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Abstract
In the healthcare sector, the growth in technology has had a huge effect. Besides, when introduced to the world of healthcare, the Internet of Things (IoT) will simplify the transition by helping physicians closely track their patients, allowing rapid recovery. Aged patients/people should be intensively checked, and their loved ones must be aware of their wellbeing periodically. Therefore, using IoT in healthcare will simplify the lives of physicians and patients alike. Hence, this study explored a comprehensive review of intelligent IoT-based embedded healthcare systems. The papers around intelligent IoT-based healthcare systems printed until Dec-2022 are studied, and some research lines are suggested for the upcoming researchers. Thus, this study's innovation will apply healthcare systems based on IoT to include certain strategies for the future deployment of new generations of IoT-based health technology. The findings revealed that IoT is beneficial for governments to strengthen society's health and economic relations. Besides, owing to novel functional principles, IoT needs modern safety infrastructure. This study is helpful for prevalent and useful electronic healthcare services, health experts, and clinicians.

Keywords Intelligent IoT · Healthcare systems · Neural networks · Traditional algorithms · Metahistoric algorithms

1 Introduction

In the latest days, "staying healthy" has become a routine for many individuals, supported by smart healthcare devices, IT, clouds, and the Internet of Things (IoT) [1–4]. The IoT reflects the upcoming sensing, computation, and networking trend [5, 6]. In the healthcare sector, the IoT has made a fundamental shift. The IoT is a technology innovation that extends the current "anytime" and "any place" definitions to "anything" communication [7, 8]. IoT is a developing concept that allows sensors and smart devices to gather real-time data from the environment and relay it through the Internet [9]. The devices connected using IoT can even communicate, thus making their usage endless [10]. An exponential rise in the utilization of IoT has been seen in the past twenty years [11]. In recent years, IoT has been utilized in diverse areas, such as finance, agriculture, healthcare, learning, and manufacturing [12, 13]. The IoT explosion presents a huge range of chances [14]. Recently, there have been big developments in the IoT field. Around the same time, the need for ubiquitous healthcare services to boost human well-being and health is increasing [15]. According to the significant acceptance of smart and connected devices in healthcare, it has been founded on a remarkable scale in the healthcare field [16–18].

IoT applications can significantly affect the healthcare domain [19, 20]. This technology is undergoing a paradigm change in the healthcare industry, shifting from conventional ways of accessing hospitals. As stated by [21], three separate layers depend on IoT-based healthcare systems: network delivery, information perception, and application support. The information perception layer includes sensors tracking people's health statistics [22]. The network transmission layer is utilized for data transmission through the network [23]. Data is transferred through various wireless technologies, such as Zigbee and Wi-Fi. The IoT systems' app service layer supports remote patient control

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[24, 25]. IoT has been utilized primarily in multiple illness detection and health monitoring schemes [24]. New remote surgical methods are being studied, where a doctor can operate on patients on the other side of the world. The accuracy and precision with which the surgeries are carried out will be light years ahead of what is humanly conceivable as robotic arms. [26, 27]. The utilization of IoT in healthcare would also simplify physicians' and patients' lives [28, 29]. Several reasons enable the work to be carried out: (1) making it more available to the people not having access to healthcare services or public transport to get to hospitals; (2) giving more time to medical personnel to respond to patients who require more notice; (3) prohibiting delays in the reception of medical information from patients to healthcare providers, especially in incidents or emergency circumstances; and (4) decreasing the manual entry of patient data to enable medical personnel to track their patients better [30]. So, IoT links nurses, patients, and physicians to high bandwidth networks at low cost via smart, intelligent sensor systems [31].

People also attend poor general health under the rising pressure of society today [32]. The more deadly it is that individuals neglect the technological means required for the associated data to be in our physical state. The architecture of hospital information is planned to respond to the age of information and new medical modes. The eventual result of implementing information technology in hospitals is the health economy's requisite actions and the hospital information system [33]. It is necessary to provide an excellent patient information system for standardized hospital administration and ensure that clinical operations are carried out seamlessly to carry out appropriate science research activities [34]. Besides, IoT-based healthcare aims to give doctors greater visibility into patients' data, helping them formulate personalized and appropriate treatments. Intelligent devices drastically improve the healthcare system's productivity since such devices can conveniently interpret machine-generated reports with minimal human interference [35, 36]. The implementation of intelligent medical information collection, storage, conversion, transmission, and processing, along with numerous medical business processes of digital operation, requires the use of the modern network, computers, communication, and digital technology. As a result, it becomes apparent that there is contact between patients and medical personnel, medical equipment, and medical institutions, and medical information is gradually acquired [34]. However, no comprehensive platform supports the use of healthcare systems in conjunction with intelligent IoT [10]. Therefore, the purpose of this article is to review IoT-based healthcare systems. It is necessary to answer several basic questions in this study to achieve this goal. So, this part explains the list of study questions required in the intelligent IoT-based embedded healthcare systems to prepare the survey.

Q1: What are the primary features of this field of study?
Q2: What is the trend of scientific publications on IoT-based healthcare systems?
Q3: Which nations and writers are the most productive?
Q4: What are the key networks of writers, institutions, and nations cooperating globally?
Q5: What are the primary IoT-based healthcare systems research topics for the present and the future?

At the end of this section, the structure and framework of the article are presented. Section 2 presents the related work and motivation of the research. In Sect. 3, the methodology is explored. In Sect. 4, the literature review is analyzed. In Sect. 5, the discussion section is presented. In Sect. 6, the open issue is explored. Eventually, in Sect. 7, the conclusion is addressed.

2 Related works and motivation

Numerous healthcare applications of the IoT are available, including support for independent living, well-being, and disease management. IoT healthcare also aims to connect and engage patients with medical experts while assisting people in managing their conditions. By facilitating ordinary tasks, IoT is easing daily living. There are many real-world uses for the IoT, including the fields of mining, medicine, energy, intelligent cities, agriculture, and transportation [37]. Review articles by researchers on IoT and health systems in the literature are discussed in this section, and their weaknesses will be highlighted to highlight this study's motivation further. The present section concentrates on a literature review of these fields.

Islam, Kwak [38] examined the most recent network applications, architectures/platforms, commercial trends in IoT-based healthcare solutions, and developments in IoT-based healthcare technology. They also examined several IoT security and privacy elements, such as security standards, threat models, and attack taxonomies, from the standpoint of the healthcare industry. To reduce security risk, they also suggested an intelligent collaborative security paradigm. They talked about how various technological advancements, like wearables, ambient intelligence, and big data, may be used in the healthcare industry. To decide how they may aid economies and communities in terms of sustainable development, they examined numerous IoT and eHealth legislation and regulations from across the world. Based on some unresolved problems and difficulties, they offered several directions for future study on IoT-based healthcare.

Nuscheler, Engelen [39] discussed the utilization of IoT in the healthcare system, the problems of IoT in the healthcare system, and the analysis of different work conducted in this field of study with which a suggested technique was examined. They indicated that the main objective would be to dramatically increase healthcare quality and react to systemic public health emergencies via acquiring, managing, and utilizing IoT information in health data. Also, the IoT applications in the healthcare industry were summarized.

Alshehri and Muhammad [40] thoroughly analyzed IoT and IoMT-based edge-intelligent smart healthcare, especially concentrating on journal publications released between 2014 and 2020. They reviewed the literature by addressing numerous study fields on IoT and IoMT, edge and cloud computing, AI, security, and medical signals fusion. Along with addressing such issues, they provided several recommendations for future study areas.

Tuli, Tuli [41] systematically studied intelligent healthcare systems utilizing IoT. In their article, diverse new technologies were discussed along with their implementations. Their research represented the intelligent healthcare network's basic architecture, platform, and topology. The IoT needs to be utilized for the implementation of health care. Their article addresses the diverse applications in which intelligent healthcare can be applied.

Also, Rananga and Venter [42] explored the latest IoT architectures for better living environments and healthcare systems, concentrating on technology, implementations, threats, prospects, open-source networks, and operating systems. The current knowledge body was synthesized in this report, and common links and holes were established that opened up novel relevant, and daunting future study directions.

Dadhich [43] conducted a thorough overview of the latest literature on cloud computing and IoT convergence to address different healthcare application challenges, like patient control, smart hospitals, and remote medical services. A short introduction to cloud computing and IoT with a healthcare application was also provided. Their article also intended to show the modern and gap identification of multiple shades of integration elements, discussing various new cloud-IoT-health system proposals. Ultimately, challenges needed to be tackled, possible research directions were established, and a comprehensive bibliography was given.

Hayyolalam, Aloqaily [44] looked at edge-assisted IoT-based linked healthcare systems solutions. They analyzed a sizable number of publications in this field and categorized their findings into two primary taxonomies: patient-centric approaches and process-centric approaches. Additionally, crucial elements were defined and looked at, including data sets that were accessible and metrics like mobility, accuracy, and data rates.

Yang, Wang [45] reviewed the research describing intelligent health monitoring technologies and the many kinds of sensor components used in the Internet of Things. The use of device-based and device-free methodologies, along with signal processing and categorization methods, were taken into account while categorizing and analyzing the works. They specifically covered how various combinations of these methods might be imaginatively used to assist commercial and professional IoT networks for health monitoring. They also noted restrictions and possible paths for further study.

Al-Rawashdeh, Keikhosrokiani [46] investigated IoT Adoption and Application for Smart Healthcare. They gathered knowledge already in existence regarding what motivates medical practitioners to use IoT technologies in the healthcare industry. Their research thoroughly examined, gathered, dissected and synthesized pertinent facts. For their review, related studies from 2015 to 2021 were collected using both manual and automatic search techniques. Nine major scientific databases were used to thoroughly search the papers: Science Direct, Google Scholar, Wiley, Emerald, Springer, PubMed, IEEE, MDPI, and Scopus. The inclusion criteria led to the selection of a total of 22 papers. The results indicated that social influence, attitude, and personal inattentiveness are the three key perceived adoption determinants of IoT applications in healthcare at the individual level. At the technological level, perceived ease of use, perceived usefulness, effort expectations, and performance expectations were the IoT adoption determinants. Perceived privacy risk was another key element at the security level.

Abdulmalek, Nasir [47] used IoT to investigate the most recent developments in healthcare monitoring systems. Their research included the advantages of IoT-based healthcare systems, including their importance and advantages for IoT healthcare. Through a literature analysis, they comprehensively evaluated current research on IoT-based healthcare monitoring systems. The research also examined IoT monitoring systems based on wireless and wearable sensors and offered a taxonomy of healthcare monitoring sensors. Additionally, they went into great length on the difficulties and unresolved problems relating to healthcare security, privacy, and Quality of Service (QoS). After the study, suggestions and recommendations for IoT healthcare applications were given out, along with future directions relating to several current technological advances.

Finally, Yu, Wang [48] examined the illness prediction applications of deep learning techniques. The algorithms were separated into two categories: for structured data and for unstructured data. Their work detailed these algorithms' fundamentals, evolution, and use in illness prediction. They evaluated the flaws in the field of illness prediction as it exists today and offered potential contemporary fixes. Additionally, their study discussed the two main trends—integrating digital twins and supporting precision medicine—in future illness prediction and the medical profession. The main points covered in the relevant literature are included in Table 1.

In this section, 11 articles were reviewed and their most important points are summarized in Table 1. The findings demonstrated the importance of the IoT for cutting-edge applications such as smart cities, smart homes, and defense operations. IoT applications are extremely helpful for the provision of healthcare since they provide secure, real-time remote patient monitoring to improve people's lives. In the healthcare sector, IoT application adoption is frequently extremely low. Healthcare professionals present significant barriers to the effective implementation of IoT for the provision of healthcare services. Numerous research has provided crucial insights into the use of IoT in healthcare. However, a complete bibliometric examination of the driving forces behind IoT adoption is still required. Table 1 shows that a lot of research has been done on IoT technology and healthcare systems and has been published in literature reviews. Two crucial aspects of the current investigations are the subject of individual research. Furthermore, no history of bibliometric studies considers the importance of embedded healthcare IoT systems. By using the IoT, this bibliometric article investigates the most recent developments in healthcare systems. The article addresses the advantages of IoT-based healthcare systems, including their importance and their advantages. Through a literature analysis, we present a bibliometric evaluation of current research on IoT-based healthcare monitoring systems. The report concludes with ideas and suggestions for IoT healthcare applications and future directions connected to different technological advancements.

3 Materials and methods

In this section, the methodology of the article is described in detail.

3.1 Bibliometric analysis

Scient metric analysis, also known as bibliometric analysis, is a research approach whose major goal is to locate, compile, and analyze metadata to look at how a field of knowledge has changed over time [49]. In order to identify the dominant themes or patterns around a subject, bibliometrics quantitatively analyzes the published research findings on that subject, taking into account the sample, the nation, and the methodology.

3.2 Methodology applied to the data analysis

This investigation produced a graphical mapping of the bibliometric data using the VOS viewer software. Scopus data were utilized in this study since it has the majority of the literature on IoT healthcare systems. Nevertheless, following the advice of Harzing and Alakangas [50] and Mongeon and Paul-Hus [51], the major scientific repositories, including Scopus, Web Of Science, Google Scholar, and PubMed, have been consulted. Scopus was chosen for some reasons: (1) it is the repository with the greatest amount of data on authors, nations, and institutions [52]; (2) It has the largest number of publications that adhere to

Table 1 Comparison of discussed review articles about IoT-based healthcare systems

Paper	Type of review	The most important factors discussed in the literature				
		1	2	3	4	5
[38]	Survey	√	√	√	√	×
[39]	Review	√	×	√	×	×
[40]	Review	√	√	√	×	×
[41]	Review	√	√	×	×	×
[42]	Review	√	×	√	×	×
[43]	Review	√	×	√	×	×
[44]	Systematic	√	×	√	×	√
[45]	Review	√	√	√	√	×
[46]	Systematic	√	×	√	√	×
[47]	Review	√	×	√	×	√
[48]	Review	√	√	√	√	√
Our	Bibliometric	√	√	√	√	√

1: IoT; 2: Intelligent healthcare network; 3: Healthcare 4: Smart devices and systems; 5: Personalized healthcare system peer review's standards for scientific excellence [53, 54]; (3) Web of Science has less coverage than it does although their metrics are closely correlated [55, 56]; (4) A well-known citation database, Scopus, is commonly used as a reference source for numerous bibliometric investigations [57]; (5) It displays specific characteristics and factors of publications [58]. As a result, Scopus has been chosen as the best archive for bibliometric reviews [59].

3.3 The procedure of the bibliometric analysis

As stated in Table 2, the approach was implemented in three steps.

The methodology utilized is described in more depth below.

3.3.1 First stage: identification

This bibliographic database was built on Dec 2022, using Academic Publications on IoT-based healthcare systems from the Scopus database. An extensive bibliographic search was performed using the following terms: ((IoT OR "Internet of Thing*") AND (Healthcare OR Healthy OR Health)). The search has been carried out on "Titles". Nine types of documents were found and it was found that the most frequently used document type being the peer is as follows: the article (681; 39.63%), conference paper (679; 39.52%), book Chap. (258; 15.01%), review (63; 3.66%), editorial (11; 0.64%), book (10; 0.58%), conference review (8; 0.46%), erratum (5; 0.29%), note (1; 0.05%). The diagram in Fig. 1 also refers to the same issue. Therefore, 1716 research documents that matched the search criteria were discovered. The kind of scientific document was the first filter used; only research papers were selected since they are evaluated based on originality and go through rigorous peer review, which is a sign of higher scientific quality [60]. Additionally, in this analysis, we only looked at journal papers that were published online between 2010 and 2022. As a result, 1035 documents were disregarded since they did not match the search parameters. Following Donthu, Kumar [59]'s advice that creating translations was not possible for examining huge datasets, only papers published in English were ultimately picked. The actual number that satisfied the criteria for the search was 642.

3.3.2 Second stage: analysis and visualization

In December 2022, the data were downloaded and examined. In order to cluster and parse words, we also created network maps using Voswiever v.1.6.18 [61]. In light of this, the co-citation approach was used to assess the collaboration networks between writers and nations based on the papers that satisfied the search criteria. These transnational networks support the creation of new research by creating synergies that promote the interchange of ideas while offering insight into the interactions between researchers and the dissemination of information [62, 63]. Besides, the co-occurrence approach is the foundation of keyword analysis and was created to detect a conceptual and thematic framework such that the findings provide a broad overview of the topics that have been the subject of the greatest study in the interaction between IoT-based healthcare systems.

3.3.3 Third stage: results and discussion phase

To uncover research trends on IoT-based healthcare systems, the third step involved assessing authors, nations, and international cooperation networks as well as keywords. This helped to answer the research questions provided and offer the discussion and findings of this research activity in addition to the systematic literature review (SLR) [64]. SLR examines data and conclusions of other authors relative to a specified research question or questions [18, 65–67].

Using a standardized form created in Microsoft Excel, the primary descriptive characteristics of the selected papers were gathered. The research questions were linked with a list of keywords taken from studies on IoT-based embedded healthcare systems in order to define the search

Table 2 Applied bibliometric analysis methodology

Identification	Search String	((IoT OR "Internet of Things*") AND (Healthcare OR Healthy OR Health))
	Sources	Scopus. Document:1718
	Document type	Article. Document:681
	Time horizon	Time horizon: 2010–2022. Documents: 679
	Language	English. Documents: 642
	Publishers	All
Analysis and visualization	The data were exported for analysis using VOSviewer v. 1.6.18 software	
Results and discussion	Presentation and discussion of the bibliometric indicators	

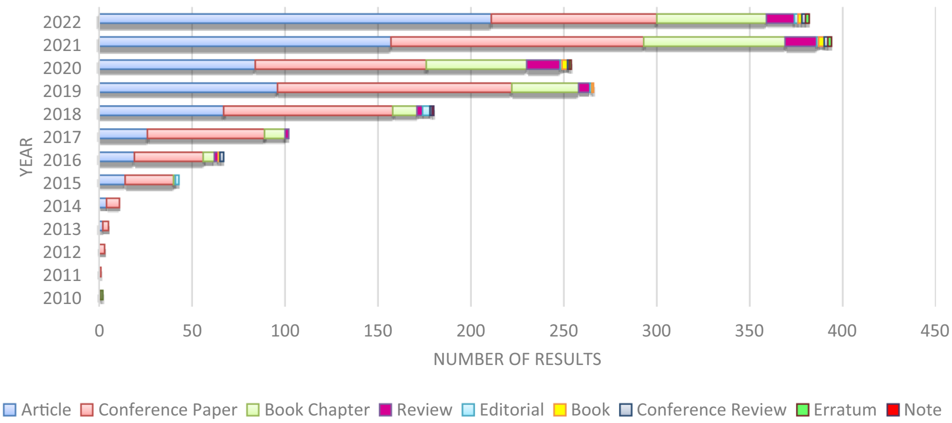

Fig. 1 The distribution of results in terms of years and type of them

string. Additionally, keywords were iteratively refined along with synonyms and other spellings. The keyword set was examined in several databases and improved.

3.4 Eligibility criteria for systematic review

A total of 1718 publications were identified in the Scopus database for the period 2010–2022 based on this search strategy. This search resulted in 642 articles, which became the basis for further analysis.

3.4.1 Conducting the review

Based on the above review protocol, the review process was conducted using the following steps illustrated in Fig. 2. The following steps were included in the search strategy:

- Using the search string and the studies published between 2010 and 2022;
- Removing the repetitive papers;
- Employing exclusion and inclusion criteria to filter publications;
- Using the title and abstract to search publications;
- Studying the content of chosen articles; and.
- Data extraction and result synthesis.

3.4.2 Data analysis and visualization maps

This work shows and adds to the body of bibliometrics literature. It is an effective approach for analyzing huge data sets. With bibliometrics, analysis can be done at various levels, including meso level (in this study, examining the contributions of countries and authors), macro level (in our case, over a thousand documents published over 13 years), and micro level (when counting the occurrences of each word).

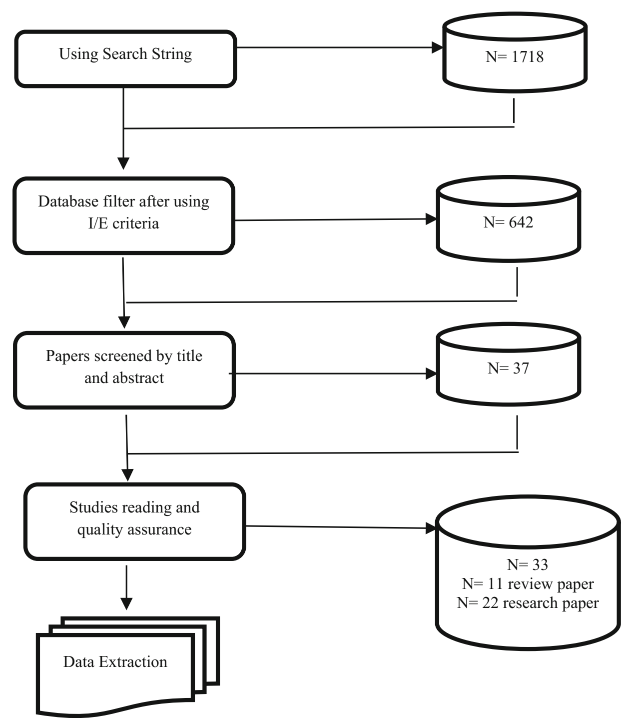

Fig. 2 Strategy for search and filtering in the systematic literature review

4 The results of the bibliometric analyses

In this section, the results of the bibliometric are presented, and then the selected articles are discussed in the systematic section.

4.1 Bibliographic coupling of the Countries

The number of articles published in each nation was counted, and the collaboration patterns across nations and regions were examined using the VOS viewer. The citations covered 92 nations and regions in all. The size of each label shows the number of citations in Fig. 3. China, India, and Saudi Arabia were the top three nations with a lot of yellow nodes, with 242, 94, and 83 articles, respectively. The linkages between the nodes symbolized cooperative ties between the nations. More connections equate to more influence on a nation. Figure 3 demonstrates how a country's impact is represented via linkages. Notably, the area of the yellow circle that corresponds to the label "India" is the largest, suggesting that research done in India has the most overall impact on the development of IoT-based healthcare systems. The information in Table 3 supports this assertion. A nation's centrality increases with the number of its connections. India generally has the most publications and is thought to be the most influential nation. The analysis reveals those East Asian countries indeed author the majority of articles.

The blue cluster, which consists of seven nations and is headed by India, is the biggest. Seven nations make up the green cluster as well, led by China and Saudi Arabia, which are also in the middle of the diagram and show that they collaborate with many other nations; this is followed by the red cluster, which consists of ten nations and is headed by South Korea, the yellow cluster, which has seven countries and is headed by the United Arab Emirates, and the purple cluster, which has four countries and is headed by the United Kingdom. The group of four nations in light blue, led by the United States, is composed. Ultimately, Taiwan is in charge of the orange group, which consists of just one nation.

4.2 Co-authorship of authors

A bibliographic-coupling analysis was carried out on the author's level using the full counting approach. Based on the number of publications and citations they received, 22

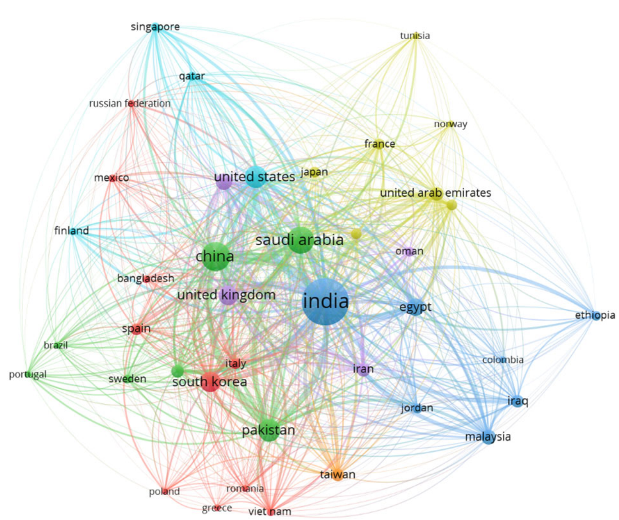

Fig. 3 Cooperation network between countries

writers were chosen as the most prolific and influential out of the 2089 authors that made the largest contributions. The results for the top 10 authors are shown in Table 4; writers who appeared in both rankings are italicized, and their associated nation (determined by their university) is shown in parenthesis (Table 5).

Gunasekaran Manogaran stands out as the most productive author, but more significantly, he also receives the most citations, making him the author with the most influence. He obtained up to 12.63% of all citations, according to a rapid estimate (507 citations out of a total of 4014 citations). Additionally, this research supports our earlier findings from the country-level analysis: when we look at these writers, we observe that they represent China and India, the two most prominent and productive nations in this sector.

4.3 Co-occurrence of keywords

The term-level analysis will create a collection of distinct clusters by demonstrating the relationships between various terms. It is a result of terms appearing both in the publication's abstracts and title. The words' separation from the other terms determines how closely linked they are. 201 keywords with a high degree of relatedness were found in the abstract and title field of the literature on IoT-based healthcare systems. Words that are often used in the context of IoT-based healthcare systems are grouped and evaluated more effectively.

A total of 642 articles contained the subject field of IoT-based healthcare systems in the abstract, keywords, or title. The keywords were retrieved based on word repetition. With regard to bibliographic descriptions, the repeatability score was 7. Out of the 4475 words retrieved, 201 terms from the aforementioned criteria appeared at least seven times in this instance. It was determined using the scores for each of the 201 terms and the binary technique of counting in the VOS viewer. 201 relevant words are gathered, and the map is displayed below (Fig. 4). Five clusters were developed from the 27 words that appeared seven or more times in the research article, as illustrated in Fig. 5. The words that co-occur several times include these 27 keywords. The outcome of 201 terms has the following sub-areas: (1) algorithms and patient monitoring (marked in red), (2) Healthcare big data and their security and storage (marked in green), (3) Algorithms in healthcare systems (marked in blue), (4) energy and cost optimization of healthcare systems (marked in yellow), (5) privacy and authentication of health care systems (marked in purple).

The created clusters show that the topics in this field overlap a lot. Also, the use of algorithms is a common theme among all clusters. Also, since the use of meta-heuristic algorithms has been growing in recent years to

Table 3 Top 20 countries publishing work on IoT-based healthcare systems

Rank	Region/Country	Number of Articles	Total Number of Citations	Average Number of Citations	Cooperation Index
1	India	241	5317	22.06	16.18
2	China	93	2741	29.47	41.93
3	Saudi Arabia	82	1093	13.32	47.56
4	United States	54	3029	56.09	72.22
5	Pakistan	53	1133	25.17	73.58
6	South Korea	45	1334	29.64	86.66
7	United Kingdom	43	1154	26.83	90.69
8	Egypt	35	1024	29.25	100
9	Australia	30	1036	34.53	100
10	Malaysia	24	797	33.20	100
11	Iran	22	990	45	100
12	United Arab Emirates	21	556	26.47	100
13	Iraq	18	757	42.05	100
14	Canada	18	769	42.72	100
15	Taiwan	17	509	29.94	100
16	Spain	15	244	16.26	100
17	France	14	196	14	100
18	Italy	14	295	21.07	100
19	Turkey	14	467	33.35	100
20	Japan	13	155	11.92	100

Table 4 Most productive and influential authors

Rank	Productive authors	H-index	Articles	Country
1	Debasis Dash	31	10	India
2	Partha Pratim Ray	31	10	India
3	Mohsen Guizani	100	9	Qatar
4	Neeraj Kumar	109	9	India
5	Deepak Gupta	14	8	India
6	Debashis De	38	7	India
7	Salman Khan	49	7	India
8	Ravinder Kumar	36	6	India
9	Shashank Kumar	9	6	India
10	Jian Ping Li	12	6	China

solve optimization problems, it shows the importance of this issue. Therefore, it seems interesting to systematically check the realizations in this field of the algorithms used in healthcare systems based on IoT. The next section will address this issue.

4.4 The analysis of selected articles

IoT has emerged as a novel trend in the healthcare industry, offering a wide range of effective services for medical practitioners and patient therapies for various disorders [68]. Through its countless uses, IoT has been steadily bringing significant technical improvements into our daily lives, simplifying and improving it in the process. By lowering the cost of services and providing care to patients who need critical care or remote support, IoT has several advantages in the field of healthcare. It opens up a lot of possibilities for lowering healthcare costs and raising healthcare quality. IoT-based innovations must be tailored to solve the challenges in medical services due to a shortage of medical service assets and growing clinical expenditures. IoT brings about unprecedented growth in the healthcare domain. This article explores the different ways that IoT is altering the healthcare industry and benefiting humanity as a whole by offering accessible, practical treatment. This study discusses IoT in healthcare, literature analysis of related research, different difficulties encountered, and potential future applications. The chosen articles from the previous section will be examined in this section. Based on their algorithms, three parts are created from the selected articles (see Fig. 6).

4.4.1 Data acquisition optimization

The monarch of the digital era is data. The method through which businesses extract examine, and store data to

Table 5 Most influential authors

Rank	Influential authors	H-index	Citations	Country
1	Gunasekaran Manogaran	57	507	India
2	Sandeep K. Sood	37	417	India
3	Ximeng Liu	48	324	China
4	Mohsen Guizani	100	301	Qatar
5	Yang Yang	11	292	China
6	Partha Pratim Ray	31	249	India
7	Neeraj Kumar	109	243	India
8	Debasis Dash	31	234	India
9	Ravinder Kumar	36	183	India
10	Ghulam Muhammad	68	171	Saudi Arabia

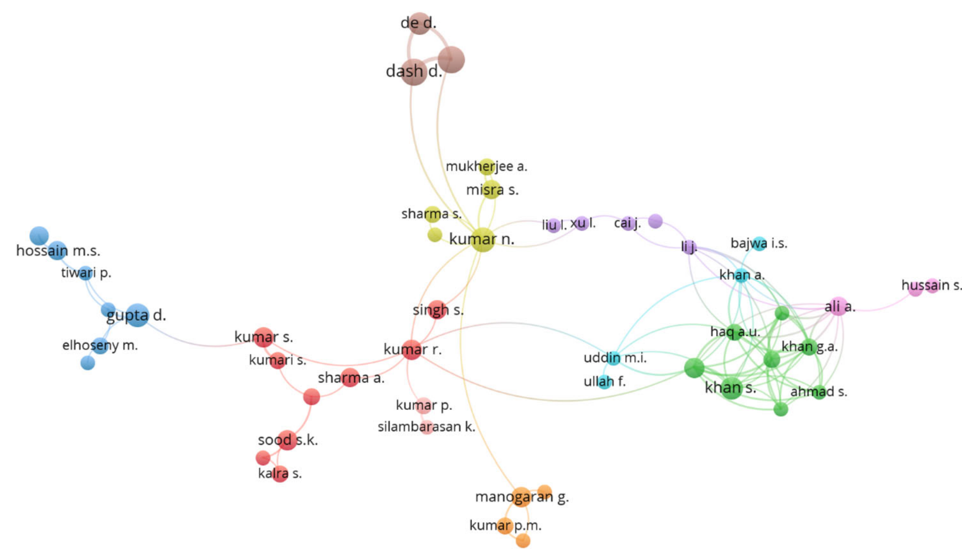

Fig. 4 Authors' cooperation network based on co-authorship

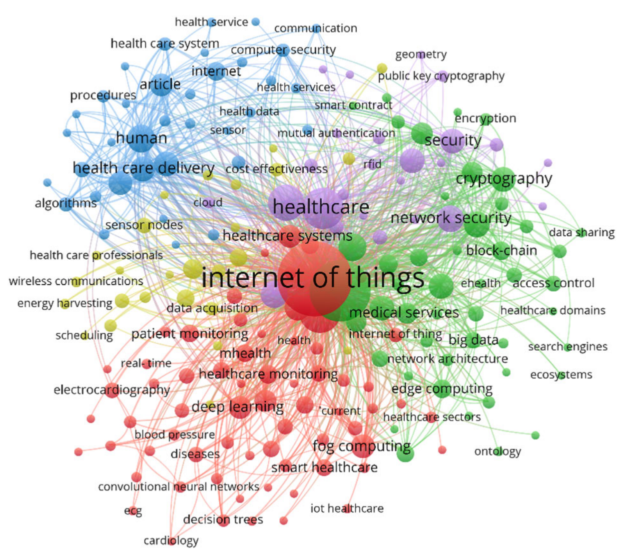

Fig. 5 Term Map with colors indicating three clusters (Color figure online)

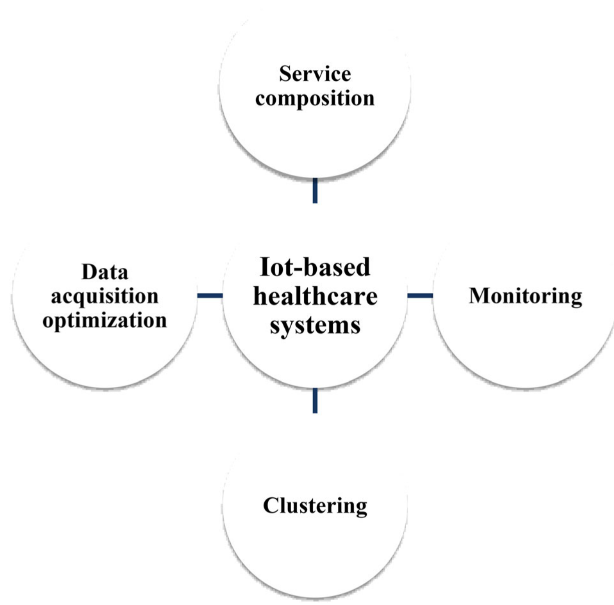

Fig. 6 Classification of the articles reviewed in Sect. 3

maximize efficiency is known as data optimization. Making ensuring the information is current, meaningful, and relevant is the aim. You may utilize a wide range of data optimization techniques, such as automation solutions, to improve your data. Gaining more efficiency with data requires finding the appropriate data optimization solutions for certain company objectives. Therefore [69], according to the necessity of data acquisition optimization, articles related to data optimization in the healthcare sector will be reviewed in this section.

Rahmani, Gia [70] demonstrated cutting-edge IoT for healthcare smart e-health gateways. They suggested building a geo-distributed intermediate layer of data across the cloud and sensor nodes to implement the fog computing idea in healthcare IoT systems. Their fog-assisted system design could address some issues in ubiquitous healthcare networks, including mobility, energy consumption, dependability, and scalability, by taking on some of the duties of the sensor network and a far-off healthcare facility. Along with addressing a medical case study, they also put their system through an IoT-based early warning score health monitoring to demonstrate its usefulness and success. Their proof-of-concept design demonstrated an IoT-based health monitoring system with improved overall mobility, system intelligence, interoperability, energy consumption, dependability, performance, and security.

Munirathinam, Ganapathy [71] suggested a novel e-healthcare system for tracking the death illness level with the aid of DL methodology, fuzzy rules with temporal characteristics, and cloud technologies. The medical information used in this system was obtained from several patients who were located and were using e-healthcare helping devices. The first step was to apply a recently developed secured cloud storage technique to the recovered and encrypted data before storing it in the cloud. Next, the stored data could be recovered as original data using the decryption procedure. Furthermore, utilizing the medical data generated through the UCI Repository dataset, a novel cloud framework was built to forecast heart beat rates and diabetes levels. A novel DL method that used a convolutional neural network to forecast the severity of an illness was also available. The dataset and hospital patient records were used to run some analyses for the suggested model in order to achieve the experimental findings. In terms of prediction accuracy, the suggested model surpassed the current illness prediction systems.

Rastogi, Singh [72] proposed a Secure eHealth Framework based on a progressive temporal blockchain technique to address the problems. Therefore, as the smart contract rules required, the context-based smart contract aided in recording medical data in a text format with temporal aspects and disseminating the data among all other peers. The framework could also provide tamper-proof, secure transactions for the healthcare sector and handle data issues. They tested the compatibility of RBAC and other system components with the Delegated Byzantine Fault Tolerance (DBFT) consensus mechanism. The findings showed that the system could handle and distribute EHRs securely and efficiently.

In IoT-based healthcare, secure data routing was done to enhance medical data security by Devi and Muthuselvi [73]. In the proposed model Wi-Fi technology was used as the communication medium for data transmission since it consumed less energy compared to Bluetooth. Encryption algorithms were used to provide data confidentiality. Hashing techniques guaranteed data integrity. Their simulation results showed that the algorithm provided security to healthcare data.

Magsi, Sodhro [74] put forth a novel battery-aware algorithm (ABA) for data transmission in IoT-based healthcare applications that recover any charges that are not utilized and makes the most of the remaining charges. The suggested ABA used this recovery impact to improve throughput, battery longevity, and energy efficiency. They also put up a brand-new paradigm for IoMT-based widespread healthcare. Thirdly, for IoMT energy efficiency and longer battery life, they evaluated and executed the recommended ABA and framework on a hardware platform. Additionally, the deterministic mealy finite state machine described the change of states. The suggested ABA was contrasted with other traditional approaches like improving battery recovery lifespan using MATLAB's Convex optimization tool (BRLE). The suggested ABA also improved intelligent ubiquitous healthcare's battery life, dependability, and energy efficiency.

Kushan, Anuar [75] used a data optimization method to assess the IoT device's human health state. The objective of their research was to create a tool that can be utilized to determine a person's present health state utilizing a sensor and a data optimization algorithm. The project also employed a web system to handle the data obtained, along with the LM-35 Body Temperature sensor, the Pulse Sensor for measuring heart rate, and the CT-UNO (Arduino Uno) microcontroller as its basis. A patient health survey is carried out using the online system, which also serves as an interface for patients and medical professionals. A data optimization algorithm will be used for the acquired data, including heart rate, body temperature, and the health survey, to create a more precise result. The system then created the patient's current health status using the data optimization algorithm, which compared the patient's data with the most recent information given by the health department. The project's findings demonstrated that using smart devices in conjunction with a data optimization algorithm leads to accurate outputs that can then be used to reduce the amount of work that has to be done by the medical officer.

This section analyzes the papers on data acquisition optimization, and Table 6 summarizes the important elements. Six important papers were analyzed in the data acquisition optimization section. Table 6 summarizes the advantages and disadvantages of the articles. The most critical benefits in this group are high security, accuracy, and efficiency.

4.4.2 Service composition

IoT service composition creates new value-added services by integrating single current services [76]. Finding necessary services and building a service composition with certain quality assurances becomes a substantial technological challenge and raises a lot of worry due to the IoT services' brisk expansion and variable QoS [77]. As a result, articles that combine several services to enhance various aspects are discussed and reviewed in this part.

Aoudia, Benharzallah [78] demonstrated an adaptive QoS-Aware Service Composition Approach (P-MPGA) based on a multi-population genetic algorithm in a healthcare-related fog-IoT context. They developed a 5-layer Fog-IoT design to improve Cloud-IoT architecture. They also used a QoS-Aware Multi-Population Genetic Algorithm (P-MPGA), taking into account 12 QoS dimensions. They could choose the appropriate service thanks to a sophisticated selection procedure that their P-MPGA algorithm employed. A monitoring system that

Table 6 Summarization of the most significant attributes of the papers in the present section

Papers	Year	Cited until 1 Dec	Journal or conference name	Proposed system	Finding
[73]	2016	2	• International Journal of Engineering Research	• Exploring the secret sharing of IoT healthcare data using a cryptographic algorithm	• High security
[70]	2018	1042	• Future Generation Computer Systems	• Exploiting smart e-health gateways at the edge of healthcare IoT	• High energy efficiency • High mobility • High interoperability • High security • High reliability
[71]	2020	3	• Journal of Intelligent & Fuzzy Systems	• Proposing cloud and IoT based privacy preserved e-healthcare system using secured storage algorithm and deep learning	• High accuracy
[74]	2021	29	• Electronics	• Proposing an ABA algorithm for data transmission in IoT-based healthcare applications	• High lifespan • High effectivity
[75]	2021	–	• International Jasin Multimedia and Computer Science Invention and Innovation Exhibition	• Examining human health status IoT device using a data optimization algorithm.	• Reducing the work doctors do
[72]	2022	–	• 2022 2nd International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE)	• Designing a blockchain-based security algorithm for IoT in healthcare	• High safety • High effectivity

keeps track of services is also implemented by P-MPGA to handle the dynamic changes in IoT settings. Despite the population growth, experimental findings demonstrated the P-great MPGA's performance in terms of average fitness values, execution time, and execution time/best fitness value ratio.

Nasser, Hasan [79] put out a novel strategy based on cutting-edge software and hardware technologies. A DL model for AI was specifically suggested to forecast glucose levels in the next 30 min. In order to execute the prediction model and link it with the current wearable CGM model to give patients the forecast of future glucose levels, cloud computing and IoT technologies were also considered. A cascaded RNN-RBM DL model based on both Restricted Boltzmann Machines (RBM) and Recurrent Neural Networks (RNNs) was regarded among the various DL approaches in the state-of-the-art (SoTA) owing to its superior qualities regarding enhanced prediction accuracy. The outcomes demonstrated that the suggested Cloud&DL-based wearable methodology outperformed comparable existing blood glucose prediction algorithms in the SoTA, with an average accuracy value of 15.589 in terms of RMSE.

Rajan Jeyaraj and Nadar [80] concentrated on developing an innovative IoT application-based physiological signal monitoring system to enhance the e-healthcare system. The recommended system was implemented using a precise signal prediction and estimation method based on DNN. The recommended system's sophisticated electronics component was prototyped using a National Instruments myRIO for intelligent data collection and an intelligent sensor for signal measurement. The intelligent sensor was utilized in the creation of the Smart-Monitor as a consumer good. Four physiological signal prediction accuracies for two users were computed to validate the proposed Smart-Monitor system. An average accuracy of 97.2% was reached in the prototype experimental setup. It demonstrated the dependability of the suggested automated system and the feasibility of accurate monitoring.

In order to maximize the usage of medical services and enhance the efficacy of the medical diagnosis procedure for complicated business situations in the medical IoT environment, Ahmadian, Abedinia [81] introduced a smart medical service system architecture. The principle of the multi-terminal aggregation algorithm, the resource representation model, and the latent factor model-based resource discovery algorithm were also examined. Afterward, a smart medical service framework inside the IoT ecosystem was established based on the open-source project. Empirical studies utilizing real-world datasets revealed that the smart medical service system's suggested design would, to some degree, facilitate the smart and effective management of medical services and help improve digitalization, precision, and intelligence in the medical sector.

Greidanus and Liao [82] examined embedded gateway services for IoT applications in the ubiquitous healthcare system, enabling intelligent and automated monitoring. The device employed the identification of position (IP) connectivity and the Internet for end-to-end communication, from each 6LoWPAN (IPv6 over low-power wireless area networks) sensor node to the Internet web user interface. Gateway's suggested algorithm conducts multi-threaded processing on the collected medical signals for conversion to real data, attribute extraction, and wireless view. Results showed that users could connect and display medical data from smartphones and handheld devices via the server's user interface. The ubiquitous method discussed the possibility of linking the Internet with objects and healthcare for people.

Secundo, Gioconda [83] suggested a healthcare intelligent service model that provides a person with efficient feedback. They implemented the protocol of cooperation that transferred risk factors between personal health devices of the IoT. Besides, they suggested an algorithm for implementing intellectualized service that would run in the personal health device. Ultimately, based on the trial results, the efficacy of the suggested model was verified.

In this section, papers on service composition were evaluated. Table 7 summarizes the major aspects. The final count of reviewed papers in the service composition category was six papers. These papers were analyzed in terms of the aspects described in Table 7. The most critical benefits of the studied metaheuristic algorithms are their high accuracy and effectiveness.

4.4.3 Clustering

The goal of clustering, a form of unsupervised learning, is to identify the organic groups among a collection of points, patterns, or objects. The problems with clustering may be resolved by using clustering ensemble as knowledge reusing. Without having access to the features, it aims to investigate outcomes with high stability and resilience by assembling calculated solutions from basic clustering methods. When base clustering is combined with low-quality ensemble members, the quality of the resulting solution is reduced [84]. The articles of various clusters will be examined in this section.

Bharathi, Abirami [85] provided a method for choosing cluster heads among various IoT devices called Energy Efficient Particle Swarm Optimization based Clustering (EEPSOC). The IoT devices that are utilized to collect healthcare data are organized into clusters, and a cluster head was chosen using EEPSOC. The data was sent to the cloud server by the elected cluster chiefs. Subsequently, the

Table 7 Summarization of the most significant attributes of the papers in the present section

Papers	Year	Cited until 1 Dec	Journal or conference name	Proposed system	Finding
[81]	2014	83	• Frontiers in Energy	• A smart medical service system architecture	• High efficiency • High precision • Lack of heterogeneous network virtualization • Lack of network management strategy
[78]	2021	3	• The International Arab Journal of Information Technology	• Presenting a multi-population genetic algorithm for adaptive QoS-aware service composition in FogIoT healthcare environment	• Low execution time • Improving average fitness values
[79]	2021	14	• Electronics	• Proposing a new wearable device and cloud-based deep learning algorithm for monitoring diabetes	• High accuracy
[82]	2021	8	• Journal of Business Venturing	• IoT-based health monitoring system	• Improving monitor and providing services to patients • Improving access control • Appropriate for real-time systems • Low scalability
[83]	2021	102	• Technological forecasting and social change	• Intelligent healthcare service • Personal health devices	• Improving manage metabolic syndrome autonomously • High effectiveness
[80]	2022	32	• IETE Journal of Research,	• Proposing a patient monitoring system for IoT-based healthcare system using deep learning	• High accuracy • High reliability

cluster chiefs used fog devices to send data from IoT devices to the cloud server. Following that, a classification model based on artificial neural networks was used to analyze the healthcare data stored on a cloud server and determine the severity of the disorders. A systematic student perspective healthcare dataset was created for testing using a collection of unique client identifiers and medical devices to predict the various student levels of disease severity. A thorough comparison study was conducted, and the simulation results confirmed the EEPSOC artificial neural network model's superiority to the comparable approaches in some areas.

Goyal, Kaushik [86] developed an enhanced PSO technique for enhancing physiological sensor-data fusion computation accuracy in the IoT context. Their method assisted in automatically detecting brain deaths and natural epilepsy from observed EEG signals that the medical facility received. A discrete wavelet transform application for featuring abolition was also used. Particle swarm optimization aided in the optimization of neural networks and EEG propagation for the identification of neurological disabilities. Complex signals like EEG were needed as input for a gadget that was more precise in its results. The core ANN model did not optimize the parameters, but it diagnosed signals from the patient. It suggested that the PSO-ANNs had the ideal number of cells in their hidden layer to outperform the fundamental EEG-Signal ANN-Model. In terms of execution times, the suggested model significantly outperformed the GA optimal selection model by 4.6%. Additionally, the outcome of the test indicated the patient's sensitivity and accuracy metrics for various neurological illnesses.

Chandran, Gayathri [87] created a medical resource allocation technique for distributing a certain amount of workload among those numerous, time-consuming computer layers in a healthcare Industrial IoT (IIoT) system. IOT involved integrating controllers and microprocessors. Workload partitioning could help designers make crucial choices about how many computing resources were required to build a local private cloud in conjunction with IoT. Ant Lion Optimization (ALO) and TABU Looked for the appropriate path. The easiest way to calculate the distance to a location was to select an OLSR routing protocol based on the required definition or unit of measurement. The suggested strategy for allocating and storing medical resource data was quite effective.

The existing investigators concentrated on cloud computing, IoT, and healthcare monitoring applications. It had some issues with computing cost, complexity, time, and incorrect storage of healthcare data, among other things. Jacob, Pravin [88] introduced the unique IoT-enabled secure healthcare monitoring paradigm as a solution to these problems. In the beginning, many sensors were implanted in patients' bodies to collect data on crucial variables such as body temperature deviance. Ten attributes made up the patient's health record dataset: marital status, phone numbers, ages, body temperatures, addresses, heart rates, names, smoking, oxygen levels, and blood pressure. The IoT medical sensor dataset, which contained redundant or unnecessary features that were removed during preprocessing, was reduced in size and normalized. The Artificial Hummingbird (AHB) algorithm-based convolutional neural network (AHB-CNN) model carried out the feature extraction and classification of cancer illness. Based on the sensor data gathered, the AHB-CNN model determined whether or not the patient was cancer-prone. The hospital management then handed the results for analysis. Due to its significant advantages in terms of asymmetric encryption, usability, deployment simplicity, and high security associated with factoring big prime numbers, the Rivest-Shamir-Adleman (RSA) encryption technique was mostly employed in this work. In order to increase the security of the standard RSA method, a modified RSA algorithm was utilized in this paper. This modified RSA algorithm made use of the double encryption-decryption process and "n" prime integers. Before being saved in the cloud or used for additional processing, the data was always encrypted throughout transit. According to the results of the experiments, the suggested strategy demonstrated superior performances in comparison to other cutting-edge approaches.

Li and Jiang [89] investigated the use of the Whale Optimization Algorithm in Energy-Aware Healthcare Systems for Wireless Body Region Networks in an IoT environment. They suggested a solution based on sensor node clustering techniques. The suggested technique separated the body region into three sections: the upper, lower, and middle regions. In each region, the LEACH clustering technique was enhanced. The cluster heads were selected using the evolutionary whale optimization algorithm (WOA) technique. The algorithms were put into practice in the MATLAB environment and contrasted with the SEP and LEACH-H solutions previously provided for the equivalent problems to assess the suggested technique. The suggested approach performed better than the alternatives, giving sensors in a wireless body area network a longer lifespan.

This section analyzes the papers that discuss clustering, and Table 8 summarizes the important elements. Table 8 summarizes the articles' most essential features, such as advantages and disadvantages. The advantages of the analyzed mechanism in this group are high accuracy, low cost, and low latency.

4.4.4 Monitoring

Monitoring is keeping a watch on someone or something, frequently with recording equipment. Therefore, monitoring is the practice of keeping an eye on others. For instance, monitoring (medicine) is the process of keeping track of a condition, illness, or one or more medical parameters throughout time. One of the technologies with the fastest global growth is the Internet of Things. A thorough grasp of various frameworks is necessary to implement IoT for remote healthcare monitoring systems. These frameworks can be found in the form of underlying technologies, apparatuses, systems, models, layouts, use cases, and programs [90]. In this area, articles on monitoring will be examined.

Manogaran, Varatharajan [91] suggested a brand-new IoT architecture to store and handle massive amounts of data from scalable sensors for medical applications. Meta Fog-Redirection (MF-R) and Grouping and Choosing (GC) architectures were the two primary sub-architectures that made up the recommended architecture. For the gathering and storage of the huge data generated by various sensor devices, the MF-R architecture uses big data technologies like Apache Pig and Apache HBase. Fog computing and cloud computing were securely integrated using the suggested GC architecture. To provide security services, this design additionally included a key management service and a data classification mechanism. To forecast cardiac illnesses, the system also employed a MapReduce-based prediction model. The results demonstrated improvement in performance assessment metrics, including sensitivity, throughput, accuracy, and f-measure.

Ray, Thapa [92] created and is now developing a widespread and intelligent IoT-based sensor system to track the intravenous fluid bag level in real-time. They looked into this problem and carried out various tests to create a non-invasive, semi-automatic device to track the intravenous fluid level in real-time using the Internet of Things. An integrated Web server powered by the ESP8266 was added to the prototype hardware created as a result of this investigation to inform connected users of the fluid exhaust status flag. Nurses can receive immediate notification when the IV fluid bag is close to running out. Therefore, a new, non-invasive, IoT-based approach was

Table 8 Summary of the key characteristics of the publications in this area

Papers	Year	Cited until 1 Dec	Journal or conference name	Proposed system	Finding
[85]	2020	66	• Sustainable Computing: Informatics and Systems	• Proposing energy-efficient clustering with disease diagnosis model for IoT-based sustainable healthcare systems.	• Reducing energy drain • High efficiency
[86]	2021	2	• Informatics in Medicine Unlocked	• Proposing IoT-based cloud network for smart healthcare using an optimization algorithm	• High accuracy • Low latency • Improving sensitivity
[87]	2021	–	• Journal of Medical Imaging and Health Informatics	• Proposing reliability-aware medical resource allocation for healthcare IIoT using tabu search and Alo algorithm	• Improving distribution and data storage
[88]	2022	–	• Transactions on Emerging Telecommunications Technologies	• Proposing a secure IoT-based healthcare framework using a modified RSA algorithm using an artificial hummingbird-based CNN	• Low cost • Low latency • Proper health care data storage
[89]	2022	1	• Wireless Personal Communications	• Exploring energy-aware healthcare system for wireless body region networks	• Longer lifespan

created using pervasive sensors that were both power- and money-efficient.

Hussain, Muhammad [93] established a new paradigm in vision sensor Internet of Things technologies through an intelligent multimodal system to analyze infant behavior. To assess the infant's behavior, their vision-based baby monitoring system used control charts, one of the process improvement tools. They created a control chart for real-time frames produced by a Raspberry Pi with an attached vision sensor, and they did it at regular intervals. Points on a control chart indicate a baby's motion; if they go beyond the top control limit or fall below the lower control limits, the baby is acting abnormally. When such conduct is seen, a signal is sent to the IoT's network of linked gadgets as a warning to babysitters at advanced medical facilities. Their suggested architecture was flexible; one Raspberry Pi can be used to monitor a baby at home, or a network of RPis can be utilized to create an IoT in a nursery to monitor numerous kids. An examination of the suggested framework's performance using the dataset they produced showed that it was more accurate and effective.

Samuel, Omojo [94] suggested a blockchain-based anonymous system called GarliMediChain to offer privacy and anonymity throughout the transfer of COVID-19 information. GarliMediChain combines blockchain technology and garlic routing to offer low-latency communication along with anonymity, privacy, security, and trust. Additionally, before being sent to a number of network nodes, COVID-19 data was encrypted many times. A coalition system based on blockchain was suggested to guarantee that COVID-19 data was successfully shared. The coalition structure allowed healthcare organizations to exchange knowledge while maximizing their gains. Each institution also utilized the suggested imaginary play to research other people's tactics in order to choose the finest ones to support their updated beliefs. According to simulation results, the suggested system is resilient to security-related threats and efficient, robust, and adaptable. According to the findings, the proof-of-epidemiology-of-interest consensus protocol was 15.93% less computationally expensive than the proof-of-work consensus protocol (26.30%) and the proof-of-authority consensus protocol (57.77%, respectively). However, by fusing already-existing anonymity and trust solutions with the backing of blockchain technology, the proposed GarliMediChain system encouraged international partnerships.

Khan, Khan [95] focused on attentively observing, deftly retrieved the keyframe, and then processed the light cosine functions utilizing a hybrid method of chaotic map keyframe picture encryption. At first, a standard idea of extracted keyframe was used to recover significantly identified frames by sending an alert to the administration on its own. Afterward, a simple cosine function was used for encryption. This encryption uses incredibly safe keyframes from the outside world and other adversaries. The efficacy of the suggested technique was confirmed across the IIoT ecosystem. The result was far superior to any other (keyframes) image encryption techniques in terms of production quality, execution speed, resilience, and properly selected, cost-effective, secure parameters. Additionally, in order to maintain security and confidence regarding the actual patient-based data in the cleverly developed

Table 9 Summary of the key characteristics of the publications in this area

Papers	Year	Cited until 1 Dec	Journal or conference name	Proposed system	Finding
[91]	2018	466	• Future Generation Computer Systems	• Proposing a new architecture of IoT and big data ecosystem for secured smart healthcare monitoring and alerting system.	• High throughput • Improving sensitivity • High accuracy
[92]	2019	24	• Circuit World	• Proposing novel implementation of IoT-based non-invasive sensor system for real-time monitoring of intravenous fluid level for assistive e-healthcare	• High power-efficient • Low cost
[93]	2019	60	• Journal of Artificial Intelligence and Systems	• Introducing intelligent baby behavior monitoring using embedded vision in IoT for smart healthcare centers.	• High accuracy • High efficiency
[94]	2022	7	• IEEE Systems Journal	• Proposing an anonymous IoT-based e-health monitoring system using blockchain technology	• Maximizing the payoffs • Less computational cost • Supporting blockchain technology • High robust • High efficiency • High adaptive
[95]	2022	8	• Scientific Programming	• Examining secure smart healthcare monitoring in IIoT ecosystem with cosine function hybrid chaotic map encryption	• Low execution time • High robustness • Low cost • High security • Low bandwidth

environment, this methodology has optimally decreased essential communicating price, bandwidth, storage, transmission cost, and immediately judicious analysis of each happened activity from the outside world or any adversary.

In the monitoring portion, five significant publications were examined in terms of certain factors. The pros and drawbacks of the articles are presented in Table 9. Its most important advantages are the examined monitoring's precision, efficacy, and affordability.

5 Discussion

In recent times, there have been huge advancements in technology. Like the agricultural and industrial revolutions, each transition is followed by improved technology and human life expectancy as a consequence [28]. IoT is an Internet evolution that has attracted growing interest from academics in both scientific and industrial settings. Successive technical advances make constructing intelligent systems with high communication and data collection capability feasible, creating several opportunities for various IoT applications, specifically healthcare systems [96]. The increasing usage of IoT, particularly smart wearables, will play a major role in enhancing medical care quality, providing patient comfort, and improving hospital management levels [97]. IoT supplies healthcare systems with essential capabilities like affordability, mobility, and scalability. The continuous technological advancements make it feasible to construct IoT devices via countless sensing, data fusion, and logging services, leading to many developments for ELEs [42]. In the rest of this section, the findings of the study will be presented.

5.1 Finding

The hospital's limited resources may now be used more efficiently thanks to the medical data integrating system. Additionally, through streamlining resource management and allocation, the hospital's operations may become more structured, and healthcare delivery may become more efficient without violating medical contracts. Important medical resources are typically in short supply following major disasters; thus, resource distribution must be streamlined to improve the effectiveness of rescue activities. Reliability and timeliness are the two primary objectives for healthcare industry applications. Hence, these two factors should be carefully considered while designing a smart healthcare sector. Using hybrid IoT and cloud technology is a well-known strategy for security and timeliness in the intelligent healthcare sector. However, it is insufficient to safeguard their strict deadlines for time-sensitive applications using the cloud. The use of IoT's intermediate processing layer, which may be connected between healthcare facilities, industrial equipment, and the cloud, may be a means to meet the efficiency and latency requirements for stringent time-sensitive applications [87].

Data about healthcare are essential for monitoring patients. These data should be of the highest caliber to provide patients with the greatest care. Several security concerns impact the originality of medical data. With the use of IoT, an amazing technology, medical data can now be accessed whenever and wherever the user wants. Although IoT-based healthcare offers many benefits, it makes data breaches and healthcare fraud easier. Due to data misuse, sensitive, protected data is stolen by an unauthorized individual, lowering the standard of medical care [73].

IoT is receiving increased attention to lower illness severity by allowing users to monitor their disease's current state based on dynamic inputs from their bodies through IoT devices. Additionally, integrating IoT and cloud computing technologies significantly impacts e-health services. In this case, security is a significant problem for the transmission and storage of data [71].

The utilization of IoT-enabled medical support and resources would encourage physicians to have patient records readily accessible if they are in the hospital, at home, or living somewhere else. For tracking personal health and safety, handheld devices and wearable body sensors are increasingly being introduced [98]. One of the key IoT advancements in healthcare tracking systems is wearable sensor processing [99]. Incorporating IoT in healthcare has also aided in the development of smart apps like smart healthcare and mobile healthcare management systems.

Chronic disease control is essential for well-being and self-management. In self-management for fitness, the IoT principle plays an important part. Personal health devices require two features, including application network protocol and intelligent service, to achieve it. However, plenty only has basic features, like indicating measured data and briefly storing it [83]. Intelligent medical care can increase the hospital and medical personnel's work performance, minimize job errors, and address the uneven allocation of community health services through remote consultation and medical treatment, among others [34]. In this way, IoT is the basis for linking all services in order to increase the quality of human life and medicine [41].

Besides, studies to accomplish remote control of elderly patients receiving healthcare treatments would undoubtedly encounter the requirement to build business models to support the general population [100]. It means that wearable sensors and systems meet their pledge to increase the level of care given to older people and can be expanded to vulnerable populations impacted by chronic diseases. Wearable sensors and mobile devices can be flawlessly incorporated with patient health tracking. Also, in the healthcare sector, the cloud-IoT model's introduction will provide medical information technology with many opportunities. Experts say it will greatly enhance healthcare services and lead to continuing systemic innovation [101].

Table 10 shows a comparison of the key factors of the previous literature analyzed in Sect. 3. The results show that several articles have attempted to enhance real-time efficiency, reliability, security, and feasibility. In addition, some articles suffer from scalability, reliability, and latency.

5.2 Response the questions

The answers to the questions presented in the introduction section are given in this part.

Q1: What are the primary features of this field of study?

This study's main characteristic will apply to healthcare systems based on IoT to include certain strategies for the future deployment of new generations of IoT-based health technology.

Q2: What is the trend of scientific publications on IoT-based healthcare systems?

The trend of scientific publications shows that the frequency of published articles related to the IoT based on health systems has increased significantly since 2018.

Q3: Who are the most productive authors and countries?

Table 4 shows the top 10 authors in this field, the most productive of which are Debasis Dash and Partha Pratim Ray. Additionally, Gunasekaran Manogaran stands out as the most productive but also the most referenced author, making him the most significant author. Furthermore, the

Table 10 Comparison of the key factors discovered in Sect. 3

Key factors	Efficiency	Security	Reliability	Feasibility	Quality	Accuracy	Cost	Dynamically	Precision	Scalability	Latency	Lifespan
Clustering												
[85]	Yes	No	No	No	No	No	No	No	No	No	Yes	No
[86]	No	No	No	No	No	Yes	No	No	No	No	Yes	No
[87]	Yes	No	Yes	No	No	No	No	No	No	No	No	No
[88]	Yes	No	No	No	No	No	Yes	No	No	No	Yes	No
[89]	Yes	No	No	No	No	No	No	No	No	No	No	Yes
Service composition												
[81]	Yes	No	No	No	No	No	No	No	Yes	No	No	No
[78]	Yes	No	No	No	Yes	No	No	No	No	No	Yes	No
[79]	No	No	No	No	No	Yes	No	No	No	No	No	No
[82]	No	No	No	No	No	No	No	No	No	Yes	Yes	No
[83]	No	No	No	No	No	No	No	No	No	No	Yes	No
[80]	No	No	Yes	No	No	Yes	No	No	No	No	No	No
Data acquisition optimization												
[73]	No	Yes	No	No	No	No	No	No	No	No	No	No
[70]	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No
[71]	No	No	No	No	No	Yes	No	No	No	No	No	No
[74]	Yes	No	Yes	No	No	No	No	No	No	No	No	Yes
[75]	Yes	No	No	No	No	No	No	No	No	No	Yes	No
[72]	Yes	No	No	No	No	No	No	No	No	Yes	No	No
Monitoring												
[91]	Yes	No	No	No	No	Yes	No	No	No	No	No	No
[92]	Yes	No	No	No	No	No	Yes	No	No	No	No	No
[93]	Yes	No	No	No	No	Yes	No	No	No	No	No	No
[94]	Yes	Yes	No	No	No	No	Yes	No	No	No	No	No
[95]	Yes	Yes	No	No	No	No	Yes	No	No	No	Yes	No

two most significant and producing nations in this subject are China and India.

Q4: What are the key international networks connecting writers, institutions, and nations?

201 keywords with a high degree of relatedness were found in the abstract and title field of the literature on IoT-based healthcare systems. The outcome of 201 terms has the following sub-areas: (1) algorithms and patient monitoring, (2) Healthcare big data and their security and storage, (3) Algorithms in healthcare systems, (4) energy and cost optimization of healthcare systems, (5) privacy and authentication of health care systems.

Q5: What are the primary IoT-based healthcare systems research topics for the present and the future?

The most important main issues related to ethical issues in the field of IoT are based on health systems, including security, privacy, and trust, which are among the most important issues investigated in research in this field.

6 Open issue and future lines of research

Since human intelligence may evolve more quickly than artificial intelligence, it is seen as superior [102, 103]. AI systems are in demand in today's world since it is difficult for humans to analyze a large amount of data owing to the growing data deluge. However, these AI systems do not have self-awareness, social abilities, multitasking, or quicker adaptation. By acting as a key motivator for knowledge-rich automation tasks, cognitive computing, a subset of AI effectively responds to these problems. One of the first steps needed for academics to advance on this front is understanding the most recent research and state-of-the-art in cognitive computing [104].

The remote health management system facilitated by IoT has tremendous advantages over the normal health monitoring system [105]. Despite all the benefits, a range of open problems still faces key IoT obstacles, such as usability, portability, interoperability, protection of information, and privacy [42]. Energy is one of the most important issues related to the IoT [106, 107]. Energy efficiency is one of the main problems in the utilization of IoT. The potential growth in power demand is a previously ignored IoT feature [108, 109]. IoT has a major effect on energy efficiency, verifying the drift of mammoth to related objects [110]. Adopting hierarchical and collaborative systems to have a high degree of consistency in core aspects like latency, availability, and real-time analytics is the key to effectively unlocking and facilitating this horizon transition [111].

Healthy individuals are vital for the growth of every country. In order to conduct real-time actions in the event of crises, the utilization of IoT-based body area networks is growing for constant surveillance and medical healthcare. Nevertheless, several sensors attached to human bodies produce vast amounts of heterogeneous data, called "big data,“ to track the well-being of all people or individuals in the world [112]. The analysis of big data and real-time behavior in crucial conditions is a complex task [113]. So, reliable and precise data collection is a big challenge in developing smart hospitals. New sensor strategies cannot meet health standards. Intelligent systems do not rule out interference that significantly affects the calculation of the devices. Besides, The wearable device has significant wearable location and measurement accuracy drawbacks while providing individuals with ease and convenience [114]. AI acts as an effective computational method in studying big data and offers a scalable and effective analysis of data in real-time. Nevertheless, there are some problems with designing and creating a beneficial big data analysis method using AI, like security and privacy, unified infrastructure, lack of appropriate training data, and resource limitations [115].

Besides, when the quantity of IoT data and data is crucial, cloud computing and fog computing play a key role. Therefore, it would not be possible to withstand standalone power forced by IoT. The cloud of things is an IoT integration of cloud computing or fog computing that will help meet the emerging IoT's and upcoming Internet's aims [116]. Fog computing is an extension of the principle of cloud computing to the brim of the network, making it appropriate for IoT and other systems involving real-time and fundamental interactions. Despite several nearly infinite tools and facilities provided by cloud-like intelligent building surveillance and others, while interfering with many smart things in human life, it also faces different problems. The most influential concerns are mobility, response time, and location awareness. In order to get out of these cloud computing issues, fog and mobile edge computing have been developed [117].

A common issue confronting the globe in the latest days is the growing number of older adults. Providing in-home health care services for older adults is also very necessary. When using a specific health application or product, health conditions can cause added safety risks for patients [118]. For example, by embedding flashing animations, hackers would like to promote them through the subsequent online forums to direct them improperly and gather data from them. In most cases, older adults will not be aware of the possible dangers and safety effects of accessing health-related facilities. The executives should inform these individuals of the possible difficulties of exchanging their data and utilizing adversary resources or instruments [100].

The issue of prescription non-compliance has also created a significant danger to public health [119]. Some of the potential future applications are customized and context-sensitive prescribing of medication through the consideration of instruments that quickly scale to several different locations [100].

The Internet of medical things is comparatively novel territory for IoT networks. In terms of smart future network computing and intelligent healthcare systems, many possible benefits will reap [120]. The crucial factor in reaching such capacity is the successful use of healthcare data, which can be a major obstacle since the data is highly heterogeneous and distributed through multiple devices of varying degrees of value and authority to access it [121]. However, new interventions are being outperformed in several ways due to the present IoT-cloud scenario's delay, power, and concentrated problems. In order to reduce the packet transmission delay between the end-user computer and the remote cloud, edge computing has come up with a novel dimension. A new method of mitigating delays was then possible [122].

In the successful introduction of pervasive healthcare, security, and privacy pose another major obstacle. This study hopes that all the restrictions and challenges can be handled by understanding the possible advantages of linked healthcare relative to the downsides and dangers. In the future, thanks to continued technological advancements in these sectors, it is certain that we will see several innovations in the healthcare industry [123].

Remarkably, the IoT technologies created by the rapid growth of wearable devices and smartphones are transforming healthcare from a traditional hub-based structure to a more customized healthcare system [49, 124]. Empowering the effectiveness of advanced IoT technologies, however, is still dramatically challenging given several problems in the field: unstandardized architectures of the IoT system, lack of cost-effective and precise smart medical sensors, multi-dimensionality of the generated data, heterogeneity of connected wearable devices, and high requirement for interoperability [125]. When considering the duty of managing part of the responsibilities of the sensor network and a distant healthcare center, a smart e-health gateway may address several issues in ubiquitous healthcare systems, including scalability, energy consumption, and usability challenges [15].

Ultimately, individuals and businesses using this technology must be aware of the various ethical issues involved. In the IoT space, morals and ethics refer to social conduct norms. The most ethical arguments center on property rights, accessibility, and the private use of data. The difficulty of increasing user knowledge of attack dangers is one of those. There will be millions of IoT devices that require new security rules in connection with a variety of regulatory requirements and obstacles. For instance, IoT omnipresence would effectively blur the barriers between private and public life without established user information restrictions. Additionally, hackers or virus assaults on common computer systems might result in data loss or actual computer system damage. The loss in the IoT assaults will not end at this level; it will go beyond it and directly impact people's lives. IoT poses a threat from various viewpoints, including privacy, property rights, and life risk, in the event that improper management is applied, according to the aforementioned problems and ethical considerations relating to IoT generally and medical applications particularly. Efficient technological solutions must be implemented to attract consumers to sign up for the IoT network. Advanced encryption methods, electronic signatures, laws that restrict the use of the data obtained by other parties, and other measures might be used as solutions [126].

7 Conclusions

This paper examines a thorough review of intelligent IoT-based embedded healthcare systems. Besides, this paper incorporates the current body of expertise and discusses common threads and differences for healthcare services that open new relevant, and daunting future research directions. The report identifies the issues facing today's healthcare services and analyzes with the aid of IoT ways to solve them. In addition, centered on a series of open concerns and problems, it offers several avenues for potential studies on IoT-based healthcare. This study can enlighten interested scholars and aid them in comprehending the present state of illness prediction algorithms, their challenges, and potential future directions. They will be able to concentrate on hot-spot algorithms, integrate modern technological technologies and concepts, and conduct more efficient, sensible, and successful research to advance the medical field.

The findings revealed that by changing the hospital-centric to the patient-centric ecosystem, a large wave of AI-driven IoT-based innovation would expand the limits of healthcare beyond hospital environments. The IoT is proving to be a viable alternative to many health-related concerns. The IoT-based publishing pattern clearly shows the essential role of IoT-based systems in diverse areas, such as healthcare, architecture, entertainment, economics, communication, and learning. Also, machine learning and soft computing methods can assist in recognition and illness detection. Nevertheless, we are mindful that the targets set for IoT in healthcare are not readily achievable. There are still many obstacles to overcome; thus, this study area is gaining more and more traction. By solving fundamental concerns linked to human factors, intelligence architecture and execution, and defense, social, and ethical issues, investigators with distinct backgrounds improve the current IoT in healthcare. Consequently, the total vision of IoT and its full implementation in healthcare and human health will materialize with this synergistic approach. Huge and smart networking, tremendous bandwidth, lower latency with the ultra-high data rate, and improved quality of healthcare experience are needed for IoT healthcare. The new 6G connectivity infrastructure, unlike the 5G broadband network, is supposed to provide intelligent IoT healthcare facilities anywhere at any time to enhance the quality of human life. The key objective of intelligent IoT-based embedded healthcare systems, existing problems, open concerns, solutions, and processes in healthcare systems are summarized by describing the responses. However, some ideal work could be omitted due to applying certain filters to pick the primary posts. It is also unlikely to survey all the papers on the IoT-based embedded healthcare systems issue. However, we are attempting to provide a perfect investigation of IoT-based embedded healthcare systems.

Appendix

The PRISMA checklist is presented in Tables 11 and 12.

Table 11 PRISMA 2020 item checklist [127]

Section and topic	Item #	Checklist item
Title		
Title	1	Identify the report as a systematic review
Abstract		
Abstract	2	See the PRISMA 2020 for Abstracts checklist (Table y)
Introduction		
Rationale	3	Explain the reasoning behind the review in light of the knowledge that already exists
Objectives	4	Clearly describe the objective(s) or question(s) the review attempts to answer
Methods		
Eligibility criteria	5	Describe the review's inclusion and exclusion criteria as well as how the studies were categorized for the syntheses
Information sources	6	Include a list of any databases, registrations, websites, organizations, reference lists, and other sources used to find research. Give a date on which each source was last looked at or consulted
Search strategy	7	Include all search tactics for all databases, registries, and websites, including any filters and restrictions
Selection process	8	Describe the procedures used in determining if research fulfilled the review's inclusion criteria, including the number of reviewers who looked through each record and report that was obtained, whether they were independent, and, if appropriate, the specifics of any automated technologies that were utilized
Data collection process	9	Describe the procedures used to gather information from reports, including the number of reviewers who did so, whether they worked independently, any procedures for acquiring or verifying information from study investigators, and, if appropriate, specifics on the automated tools utilized in the procedure
Data items	10a	List and describe each result for which information was sought. Indicate if all findings consistent with each study's end domains were sought (for example, for all measurements, time points, and analyses), and if not, describe the processes used to select which results to gather
	10b	List and describe all additional factors (such as participant and intervention characteristics and funding sources) for which data were sought. Describe any inferences drawn based on any ambiguous or missing information
Study risk of bias assessment	11	Include information on the tool(s) used, the number of reviewers who evaluated each research, whether they were independent, and, if appropriate, information about automated tools. Describe the procedures used to determine the risk of bias in the included studies
Effect measures	12	Indicate the effect measure(s) used in compiling or presenting findings for each outcome, such as the risk ratio or mean difference

Table 11 (continued)

Section and topic	Item #	Checklist item
Synthesis methods	13a	Explain the procedures used to choose the studies included in each synthesis, such as tabulating the study intervention features and comparing them to the groups included in each synthesis (item #5)
	13b	Describe any procedures needed to get the data ready for display or synthesis, such as how you will handle missing summary statistics or convert the data
	13c	Describe any techniques used to tabulate or graphically present the findings of distinct research and syntheses
	13d	Describe any techniques utilized to combine the results and explain your decision(s). Describe the model(s), technique(s) utilized to determine the presence and degree of statistical heterogeneity, and software package(s) if a meta-analysis was conducted
	13e	Describe any techniques (such as subgroup analysis or meta-regression) that were utilized to investigate potential reasons why research outcomes were heterogeneous
	13f	Describe any sensitivity tests that were done to see how reliable the outcomes of the synthesized work were
Reporting bias assessment	14	Describe any techniques used to evaluate the possibility of bias in a synthesis caused by missing findings (resulting from reporting biases)
Certainty assessment	15	Describe any techniques applied to determine the level of confidence (or certainty) in the body of evidence supporting a conclusion
Results		
Study selection	16a	Use a flowchart, if possible, to describe the outcomes of the search and selection process, from the number of records found during the search to the number of studies included in the review
	16b	Mention research that could have appeared to match the inclusion requirements but was rejected, and explain why
Study characteristics	17	Cite each included study and describe its findings
Risk of bias in studies	18	Describe the bias risk for each study that was included
Results of individual studies	19	If possible, use structured tables or plots to provide all outcomes for each research, including (a) summary data for each group (where applicable) and (b) an effect estimation and its accuracy (e.g., confidence/credible interval)
Results of syntheses	20a	Briefly describe the characteristics and bias risk of the contributing studies for each synthesis
	20b	Display the findings of every completed statistical synthesis. If a meta-analysis was performed, including the summary estimate, its accuracy (such as confidence intervals and credible intervals), and statistical heterogeneity measures for each. Describe the direction of the effect when comparing groups
	20c	Report the findings of all inquiries into the sources of suspected research result heterogeneity
	20d	To evaluate the reliability of the synthesis results, present the findings of all sensitivity studies that were performed
Reporting biases	21	Give estimates of the likelihood of bias resulting from missing findings (caused by reporting biases) for each synthesis considered
Certainty of evidence	22	Describe your evaluations of the body of evidence's certainty (or confidence) for each outcome you have evaluated
Discussion		
Discussion	23a	Give a broad interpretation of the findings in light of the surrounding data
	23b	Talk about any restrictions on the reviewed evidence
	23c	Describe any restrictions placed on the review procedures employed
	23d	Discuss the conclusions' implications for future study, practice, and policy
Other information		
Registration and protocol	24a	Specify the review's registration details, such as the register name and registration number, or indicate that the review was not registered
	24b	Indicate how to access the review protocol or mention that no protocol was created
	24c	Describe and offer an explanation for any changes to the data entered during the registration or in the protocol
Support	25	Indicate the sources of any financial or in-kind assistance for the review as well as the function of any funders or sponsors

Table 11 (continued)

Section and topic	Item #	Checklist item
Competing interests	26	List any conflicting interests the review writers may have
Availability of data, code, and other materials	27	Indicate which of the following are accessible to the general public and where to find them: Data from included studies that were extracted, data utilized for all analyses, analytical code, and any additional materials used in the review

Table 12 PRISMA 2020 for abstracts checklist

Section and topic	Item #	Checklist item
Title		
Title	1	Identify the report as a systematic review
Background		
Objectives	2	Explain clearly the major goal(s) or question(s) the review aims to answer
Methods		
Eligibility criteria	3	Define the review's inclusion and exclusion criteria
Information sources	4	List the information sources (such as databases and registrations) that were utilized to locate the research and the most recent date that each was searched
Risk of bias	5	Describe the procedures used to evaluate the included studies' potential for bias
Synthesis of results	6	Indicate the techniques utilized to show and combine the results
Results		
Included studies	7	Mention the total number of studies and people covered and any pertinent study features
Synthesis of results	8	Results for key outcomes should be included, preferably together with information on the number of included studies and participants for each. If a meta-analysis was conducted, report the summary estimate and confidence/credible interval. When comparing groups, indicate the direction of the impact (i.e., which group is preferred)
Discussion		
Limitations of evidence	9	Give a succinct description of the evidence's constraints (such as bias, consistency, and precision risks, for example)
Interpretation	10	Give a broad analysis of the findings and their key ramifications
Other		
Funding	11	Name the main funding source for the review
Registration	12	Give the name and registration number from the registry

Author contributions PC wrote the main manuscript text and WB prepared method, tables and figures. All authors reviewed the manuscript.

Data availability All data are reported in the paper.

Declarations

Conflict of interest The authors declare no conflict of interest.

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