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SYSTEMATIC REVIEW

Bibliometric Analysis of IoT-Based Technologies for Health Monitoring: Trends, Impact, and Key Findings (2014-2024)

Análisis bibliométrico de tecnologías basadas en IoT para el monitoreo de la salud: Tendencias, impacto y hallazgos clave (2014-2024)

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ABSTRACT

Introduction: the integration of IoT technologies into health monitoring has revolutionized healthcare delivery, enabling real-time data collection, remote patient monitoring, and improved management of chronic diseases.
Objective: this study conducts a comprehensive bibliometric analysis of IoT-based health monitoring research, aiming to identify influential contributors and emerging research themes.
Method: the analysis was based on data retrieved from the Scopus database using a search query designed to capture studies focused on IoT in health monitoring. Only peer-reviewed journal articles published between 2014 and 2024 in English or Spanish were included. The study adhered to PRISMA guidelines for literature selection and employed the *biblioshiny* package in R for data processing and visualization.
Results: the analysis revealed an increase in research activity, particularly after 2017, with notable peaks in publication volume during the COVID-19 pandemic. Journals such as *Sensors* and *IEEE Access* were identified as key publication outlets, while authors like Pasi Liljeberg and Amir M. Rahmani were the most influential contributors. Geographically, the United States, China, and India dominated scientific output. Thematic analysis indicated an evolution from early studies focused on IoT architecture to recent concerns over data privacy, cybersecurity, and interoperability.
Conclusions: the growing body of research on IoT-based health monitoring highlights its transformative potential for healthcare, especially in managing chronic conditions and remote care. However, challenges such as data security and device interoperability must be addressed. Future research should focus on developing standardized protocols and ensuring the ethical use of IoT in healthcare to enhance its adoption and effectiveness.

Keywords: Telemedicine; Patient Safety; Delivery of Health Care; Data Management; Chronic Disease Indicators.

RESUMEN

Introducción: la integración de tecnologías IoT en el monitoreo de salud ha transformado la atención médica, permitiendo la recolección de datos en tiempo real, el monitoreo remoto de pacientes y una gestión mejorada de las enfermedades crónicas.
Objetivo: este estudio realiza un análisis bibliométrico exhaustivo de la investigación sobre el monitoreo de

salud basado en IoT, con el objetivo de identificar los contribuyentes más influyentes y los temas emergentes de investigación.
Método: el análisis se realizó utilizando datos recuperados de la base de datos Scopus, con una ecuación de búsqueda diseñada para capturar estudios relacionados con IoT en el monitoreo de la salud. Solo se incluyeron artículos revisados por pares, publicados entre 2014 y 2024, en inglés o español. El estudio siguió las directrices PRISMA para la selección de la literatura y utilizó el paquete *biblioshiny* en R para procesar y visualizar los datos.
Resultados: el análisis mostró un aumento significativo en la actividad investigadora, especialmente a partir de 2017, con picos notables en las publicaciones durante la pandemia de COVID-19. Revistas como *Sensors* y *IEEE Access* fueron identificadas como fuentes clave, mientras que autores como Pasi Liljeberg y Amir M. Rahmani fueron los más influyentes. Geográficamente, Estados Unidos, China e India encabezaron la producción científica. El análisis temático mostró una evolución desde la arquitectura de IoT hacia preocupaciones recientes sobre privacidad de datos, ciberseguridad e interoperabilidad.
Conclusiones: la creciente investigación sobre IoT en salud destaca su potencial transformador para la gestión de enfermedades crónicas y la atención remota. Sin embargo, se deben abordar desafíos como la seguridad de los datos y la interoperabilidad. Las investigaciones futuras deben centrarse en protocolos estandarizados y el uso ético de IoT para mejorar su adopción.

Palabras clave: Telemedicina; Seguridad del Paciente; Atención a la Salud; Manejo de Datos; Indicadores de Enfermedades Crónicas.

INTRODUCTION

The integration of the Internet of Things (IoT) into health monitoring systems represents a transformative shift in healthcare delivery, enabling real-time data collection, remote monitoring, and enhanced patient engagement. IoT connects medical devices and sensors to the internet, allowing continuous monitoring of patients' health conditions outside traditional clinical settings, particularly benefiting chronic disease management by improving outcomes and reducing hospital admissions.[1,2,3]

Wearable IoT devices track vital signs such as heart rate and oxygen saturation, transmitting data to healthcare providers, which supports timely, informed decision-making.[4,5,6]

The proliferation of cloud computing with IoT has further advanced health monitoring by enhancing data storage and processing, enabling large-scale data analysis and predictive analytics.[7,8,9] Additionally, smart hospitals utilize IoT to streamline operations, monitor patient flow, and manage resources efficiently.[10,11,12] IoT has also facilitated patient engagement through mobile health applications and telemedicine platforms, empowering patients to take control of their health.[13,14]

Despite these benefits, challenges such as data security, privacy, and device interoperability remain significant barriers to widespread IoT adoption in healthcare. Protecting sensitive health data from unauthorized access is critical to maintaining patient trust.[15,16,17] The need for standardized protocols to ensure seamless communication between devices is also a key factor.[1,18,19] As IoT continues to evolve, addressing these challenges will be essential to improving global health outcomes, especially in aging populations and chronic disease management.[20,21,22,23,24]

The importance of bibliometric analysis in understanding research trends

Bibliometric analysis serves as a vital tool for understanding research trends, particularly in rapidly evolving fields such as IoT-based technologies for health monitoring. By systematically analyzing published literature, bibliometric studies can reveal patterns in research output, citation frequencies, and the interrelationships between various research themes. This quantitative approach allows researchers to identify key contributors, influential publications, and emerging trends within a specific domain, thereby providing a comprehensive overview of the state of research.[25]

In the context of IoT-based health monitoring technologies, bibliometric analysis can illuminate the trajectory of research efforts from 2014 to 2024. By evaluating the volume of publications, citation counts, and the geographical distribution of research activities, scholars can discern how interest in IoT applications in healthcare has evolved over time. This analysis not only highlights the most impactful studies but also identifies gaps in the literature that warrant further investigation.[26,27,28] For instance, understanding which aspects of IoT in health monitoring have garnered the most attention can guide future research directions and funding priorities.

Moreover, bibliometric analysis can facilitate collaboration among researchers by mapping co-authorship

networks and institutional affiliations. This aspect is particularly relevant in interdisciplinary fields like IoT and healthcare, where collaboration between technologists, healthcare professionals, and policy makers is essential for developing effective solutions.[29,30,31] By identifying key players and their contributions, bibliometric studies can foster partnerships that enhance the quality and applicability of research outcomes.

The primary objective of this study is to conduct a comprehensive bibliometric analysis of research on IoT-based technologies for health monitoring between 2014 and 2024. Through this analysis, we aim to achieve the following specific goals:

1. Identify key trends in scientific production related to IoT health monitoring technologies, including the volume of publications and citation patterns over time.
2. Evaluate the most influential journals, authors, and institutions contributing to the field, highlighting their impact on advancing IoT applications in healthcare.
3. Map the geographical distribution of research activities to understand the global reach and collaboration networks involved in this field.
4. Analyze emerging research themes and topics within IoT health monitoring, identifying gaps in the literature and potential areas for future investigation.
5. Discuss key findings and their implications for the future of IoT technologies in healthcare, focusing on the challenges and opportunities in expanding IoT's role in health monitoring.

By achieving these objectives, this study will provide valuable insights into the current state of research in IoT-based health monitoring and offer recommendations for future research directions.

METHOD

Data Collection Strategy

The data for this bibliometric analysis was collected using the Scopus database, a comprehensive source of peer-reviewed literature, known for its extensive coverage of research publications across disciplines. Scopus was selected due to its relevance in indexing high-quality scientific journals and its robust bibliometric tools, which allow for detailed citation analysis and trend identification. The search was designed to capture studies published between 2014 and 2024 that focus on the integration of IoT (Internet of Things) technologies in health monitoring.

The search strategy was developed using Boolean operators to ensure that relevant terms related to IoT and health monitoring were included. The following search equation was used:

TITLE-ABS-KEY ("Internet of Things" OR "IoT" OR "smart devices" OR "Internet de las cosas" OR "dispositivos inteligentes") AND TITLE-ABS-KEY ("health monitoring" OR "remote health monitoring" OR "health surveillance" OR "monitoreo de la salud" OR "vigilancia de la salud" OR "monitoreo remoto de la salud") AND PUBYEAR > 2013 AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "Spanish")) AND (LIMIT-TO (SRCTYPE , "j"))

This search equation was carefully constructed to include articles published in both English and Spanish, ensuring comprehensive coverage of the relevant literature. The decision to include articles published after 2013 was driven by the need to focus on recent developments in IoT technologies and their application in health monitoring, which have evolved significantly in the last decade.

This study adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure a transparent and systematic approach to literature selection. The following inclusion criteria were applied:

1. Study Type: Only original research articles were considered, excluding review articles, conference papers, book chapters, and editorial materials. This criterion was set to focus on primary research and original findings.
2. Publication Date: Studies published between 2014 and 2024 were included to capture the most recent developments in IoT-based health monitoring technologies.
3. Language: Publications in both English and Spanish were included to broaden the scope of the analysis and encompass relevant research from different linguistic regions.
4. Document Type: Only articles published in peer-reviewed journals were considered. This criterion ensures the quality and reliability of the selected studies, focusing on validated research outcomes.
5. Relevance to the Topic: The studies had to specifically focus on the use of IoT technologies for health monitoring, including remote health monitoring systems, wearable devices, and smart health applications. Studies that only tangentially mentioned IoT without a clear focus on health monitoring were excluded.
6. Stage of Publication: Only studies in the final stage of publication were considered to avoid the inclusion of incomplete or pre-publication data.

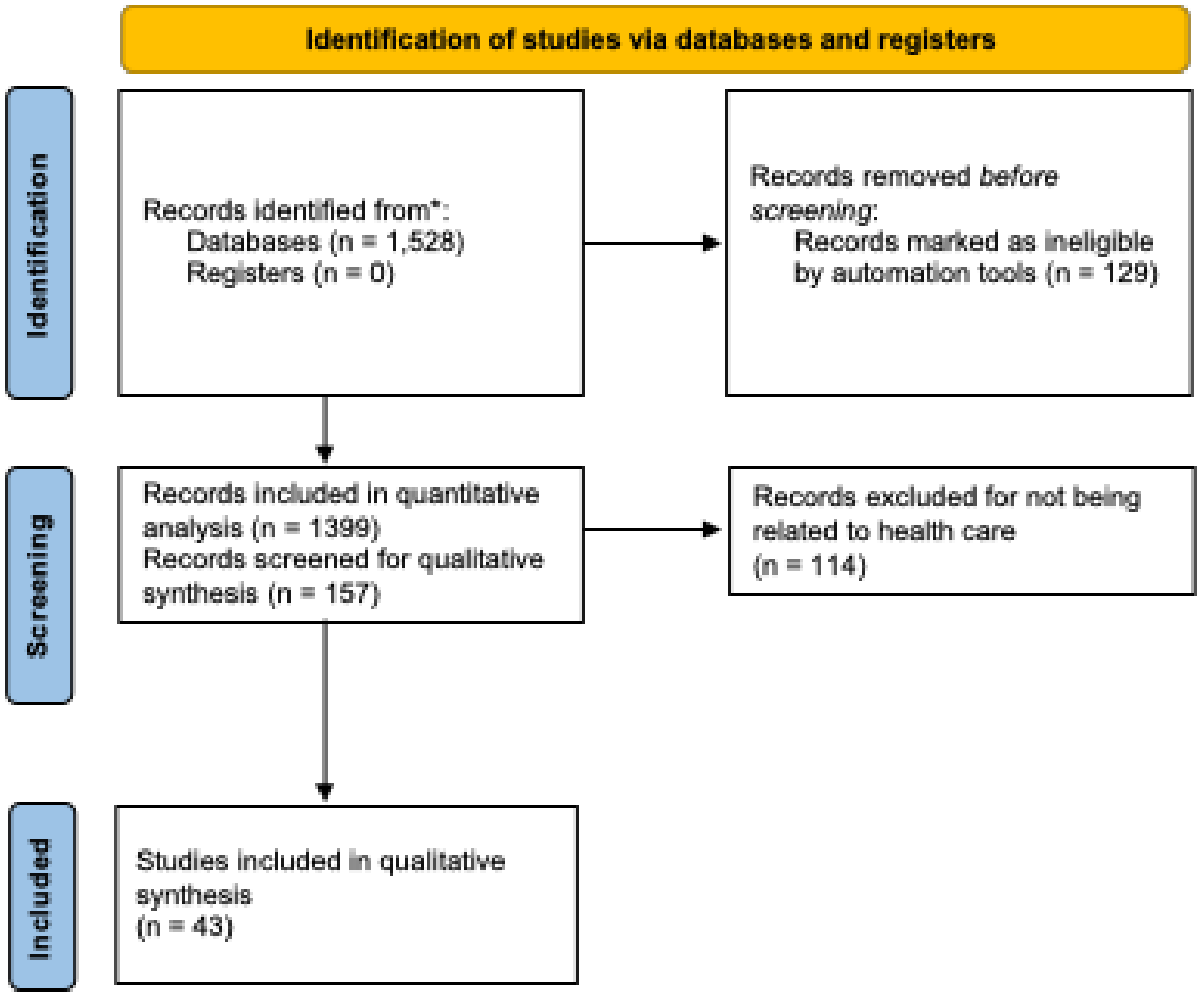


Figure 1. PRISMA 2020 flow diagram for new systematic reviews

The PRISMA guidelines (figure 1) were followed to ensure that the selection process was both systematic and replicable. Articles were first screened by title and abstract, followed by a full-text review to assess their relevance based on the inclusion criteria. Any discrepancies in the inclusion process were resolved through discussion among the reviewers.

Analytical Tools and Procedures

The bibliometric analysis was conducted using the biblioshiny package in R, enabling comprehensive data processing and visualization. The Scopus data, exported in BibTeX format, was directly imported into biblioshiny for seamless analysis.

Key bibliometric indicators and visualizations were employed to address the study's objectives. These include: annual scientific production and citation trends, identification of influential sources and authors, mapping of geographical research distribution and collaboration networks, and analysis of keyword co-occurrence and thematic evolution to uncover research themes and emerging topics.

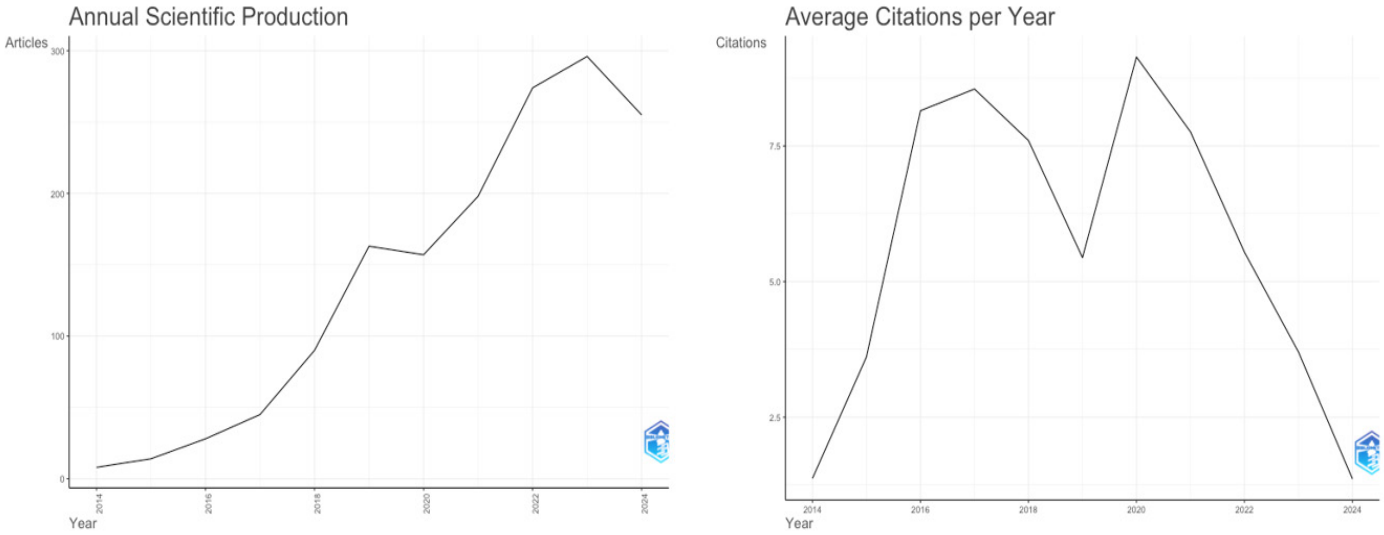
RESULTS

This section presents the key findings of the bibliometric analysis. These findings encompass various aspects of research on IoT-based health monitoring technologies, including the trends in scientific production, the identification of influential journals and authors, the geographical distribution of research activities, and the thematic evolution of research topics. By systematically analyzing these bibliometric indicators, this section aims to provide a comprehensive overview of the current state of research in IoT health monitoring and highlight the emerging trends shaping the future of this rapidly evolving field.

Scientific Production Over Time

The analysis of scientific production over time provides valuable insights into the evolution of research on

IoT-based technologies for health monitoring. By examining the volume of publications and citation patterns from 2014 to 2024, we can identify key trends that reflect the growing interest and development in this field.



Note: The left graph shows the annual scientific production in IoT-based health monitoring from 2014 to 2024, with a notable peak in publications during 2021, likely driven by the increased demand for remote health solutions during the COVID-19 pandemic. The right graph displays the average citations per year, indicating two peaks in 2016 and 2021, with a sharp decline in 2023, reflecting the lag in citation accumulation for more recent publications.

Figure 2. Trends in Annual Scientific Production and Average Citations in IoT Health Monitoring

The analysis of scientific production from 2014 to 2024 (figure 2) reveals a clear upward trend in research on IoT-based health monitoring technologies. In 2014, only 8 articles were published, reflecting the emerging nature of the field. However, from 2017 onwards, there was a sharp increase in publications, exceeding 45 articles by that year. This growth accelerated further after 2019, largely driven by advancements in wearable devices and the adoption of IoT technologies in healthcare, with more than 300 publications expected by 2024.

Citation patterns follow a similar trajectory, with relatively low citation counts between 2014 and 2016. However, citations surged from 2018 onwards, particularly during the COVID-19 pandemic, when IoT-based remote monitoring gained prominence. The highest citation peaks occurred in 2020 and 2021, driven by the need for telemedicine and remote health solutions during global healthcare crises.

Overall, the growing volume of publications and increasing citation rates underscore the expanding influence of IoT in health monitoring. This trend highlights the field's maturation and its significant role in advancing healthcare delivery, particularly in remote and chronic disease management.

Analysis of Key Sources and Authors

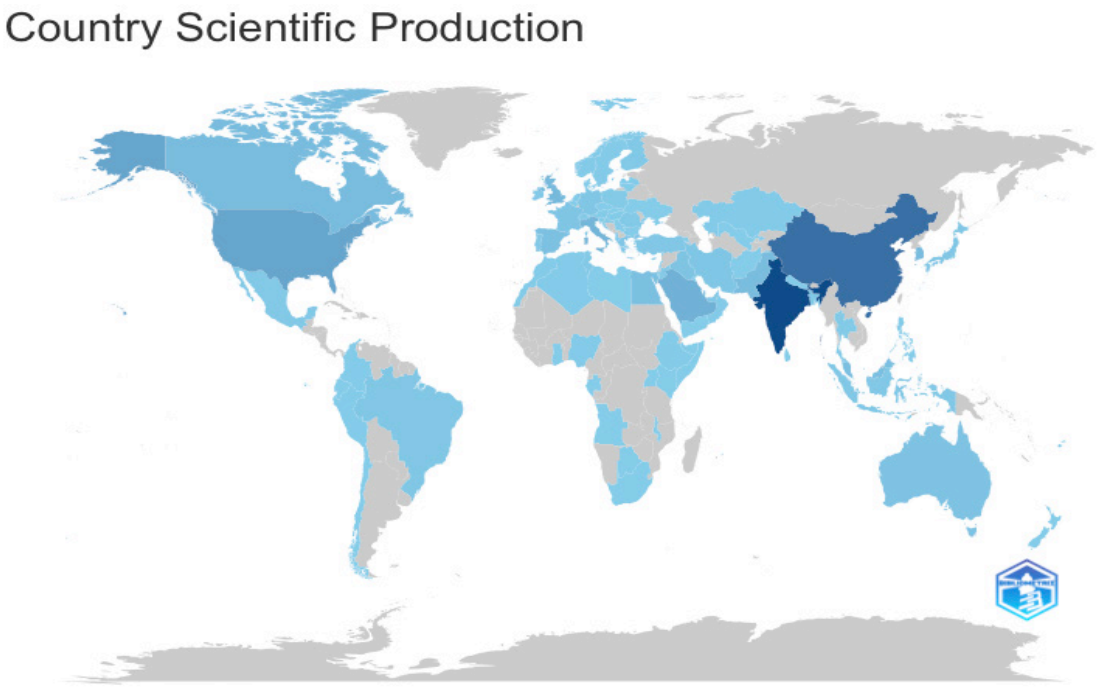
The analysis of the most influential journals reveals that a few specialized journals have played a pivotal role in disseminating research on IoT-based health monitoring. Journals such as Sensors, IEEE Access and IEEE Internet of Things Journal have consistently ranked among the top sources in terms of both publication volume and citation impact. These journals have served as primary outlets for cutting-edge research, covering a wide range of topics from wearable devices to AI-integrated health systems, reflecting their relevance to the field's technological and clinical innovations.

In terms of author influence, a core group of researchers has significantly contributed to advancing the field. Authors such as Pasi Liljeberg, Amir M. Rahmani, and Iman Azimi have been identified as key figures, with numerous publications focused on IoT applications in chronic disease management and real-time health monitoring systems. These authors are not only prolific in terms of publication output but also exhibit high citation rates, indicating the broad recognition and influence of their work within the academic community.

Geographical Distribution of Research

The geographical analysis (figure 3) highlights that the leading contributors to IoT-based health monitoring research are concentrated in a few key regions. India, China and The United States emerge as the top producers of scientific output, collectively accounting for a significant portion of global publications in this field. The strong research infrastructure in these countries, coupled with their focus on technological innovation in

healthcare, has positioned them as frontrunners in advancing IoT applications for health monitoring.



Note: This map illustrates the geographical distribution of scientific publications related to IoT-based health monitoring technologies from 2014 to 2024. The varying shades of blue represent the volume of research output from different countries, with darker shades indicating higher publication counts.

Figure 3. Global Distribution of Research on IoT-Based Health Monitoring

In terms of international collaboration, the data reveals that cross-country partnerships have played a central role in the dissemination of IoT research. The United States and China, in particular, have established strong collaboration networks with European countries such as the United Kingdom and Germany. These collaborations are often reflected in co-authored publications, which enhance the global exchange of knowledge and drive the development of more sophisticated IoT technologies for healthcare.

Despite the dominance of a few regions, there is a growing interest in IoT health monitoring research from emerging economies, particularly in Latin America and Southeast Asia. Countries like Brazil and Malaysia are beginning to contribute more significantly to the field, driven by the need for scalable and cost-effective health monitoring solutions in regions with limited healthcare access. This global distribution indicates that IoT research in health monitoring is becoming more diverse, with increasing contributions from developing nations.

Thematic Evolution and Emerging Topics

The thematic analysis (figure 4) provides a comprehensive view of the major research themes in IoT-based health monitoring and how they have evolved over the past decade. Early research in this field focused heavily on the technological foundations, with key themes such as **"sensor networks," "IoT architecture,"** and **"wearable devices"** forming the backbone of IoT health monitoring. These topics laid the groundwork for developing systems that could capture and transmit health data in real-time, particularly for remote patient monitoring.

As the field matured, new themes emerged around data processing and analysis. From 2018 onwards, the focus shifted towards more advanced applications, with topics such as **"machine learning," "big data analytics,"** and **"artificial intelligence in healthcare"** gaining prominence. These themes indicate a move toward leveraging IoT-generated data for predictive modeling, early diagnosis, and personalized treatment plans. The integration of AI with IoT systems represents a critical development, as it allows for more accurate health predictions and better management of chronic conditions through continuous data monitoring.

In recent years, the emergence of themes such as **"data privacy," "cybersecurity,"** and **"interoperability"** reflects the growing concern over the ethical and technical challenges associated with IoT health systems. As these technologies become more widespread, ensuring the security and privacy of patient data has become a priority, along with the need for standardized protocols to ensure seamless communication between different IoT devices and platforms. These emerging topics underscore the importance of addressing both the technological and ethical dimensions of IoT in healthcare, signaling future directions for research and development in this

rapidly evolving field.

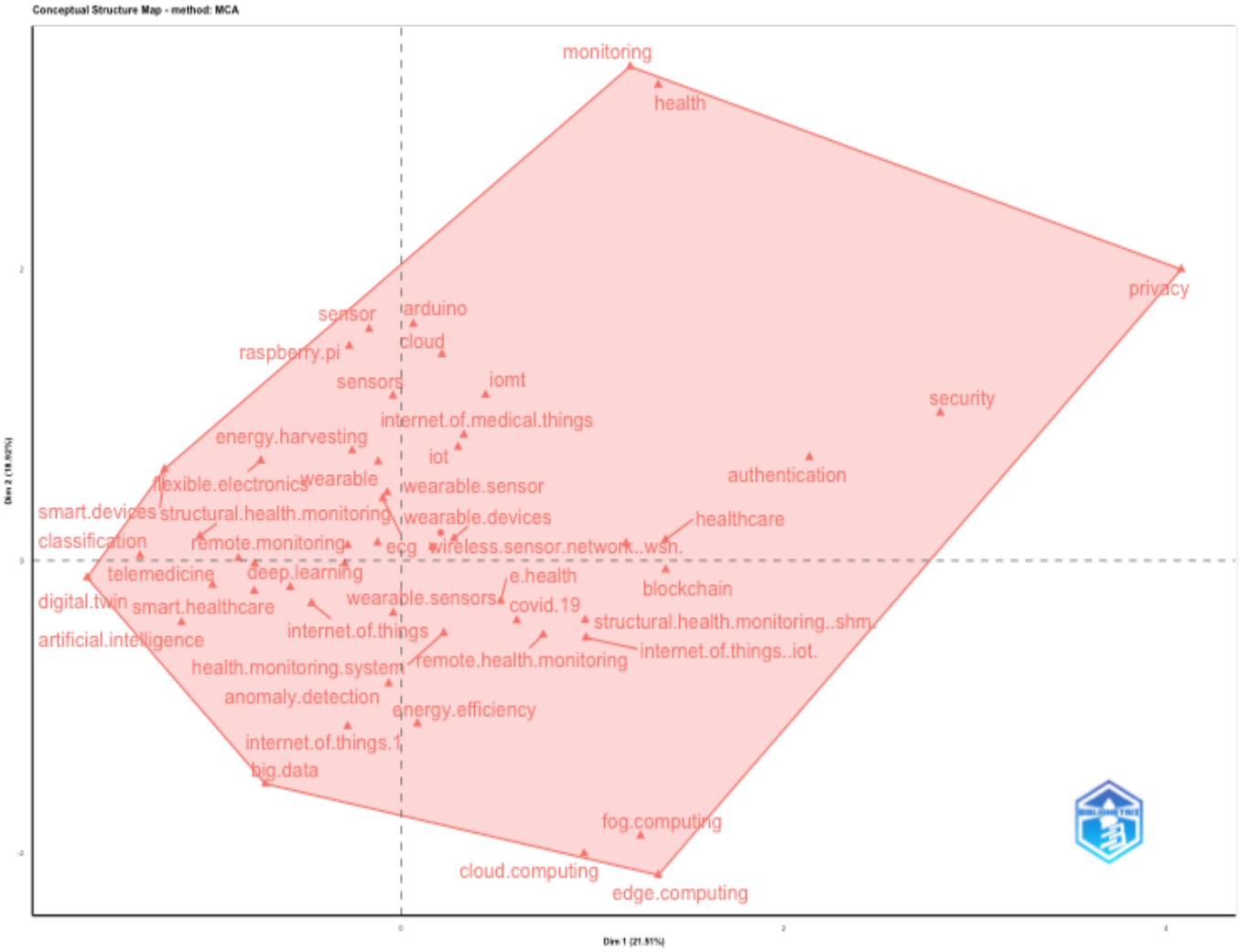


Figure 4. Thematic Map of IoT-Based Health Monitoring Research

DISCUSSION

The bibliometric analysis presented in the previous sections provides a comprehensive overview of the research landscape on IoT-based health monitoring technologies. The observed trends highlight the growing interest in this field and its potential to transform healthcare delivery, particularly in chronic disease management and remote patient monitoring. Building upon these findings, the discussion section delves deeper into the specific applications of IoT in chronic disease management, exploring its role in empowering patients and healthcare providers alike.

Furthermore, this section addresses the ethical and technical challenges that accompany the widespread adoption of IoT health technologies. By examining issues such as data security and interoperability, the discussion aims to identify potential solutions and future research directions that can facilitate the responsible and effective integration of IoT in healthcare.

IoT and Chronic Disease Management

The Internet of Things (IoT) has emerged as a pivotal technology in the management of chronic diseases, offering innovative solutions that enhance patient care and improve health outcomes. Chronic diseases, such as diabetes, cardiovascular diseases, and chronic obstructive pulmonary disease (COPD), require continuous monitoring and management to prevent complications and ensure effective treatment. IoT technologies facilitate this by enabling real-time data collection through connected devices, which can monitor vital signs, medication adherence, and lifestyle factors.[32,33]

One of the advantages of IoT in chronic disease management is its ability to provide remote monitoring capabilities. Patients can use wearable devices and home-based sensors to track their health metrics, such as blood glucose levels, heart rate, and oxygen saturation, without the need for frequent hospital visits. This not only enhances patient convenience but also allows healthcare providers to receive timely data, enabling them

to make informed decisions regarding treatment adjustments and interventions.[32,34] For instance, studies have shown that remote monitoring systems can lead to better management of diabetes by allowing for immediate feedback and support from healthcare professionals. [35,36]

Moreover, IoT technologies can facilitate personalized healthcare by leveraging data analytics and machine learning algorithms. These systems can analyze the collected data to identify patterns and predict potential health risks, allowing for proactive management of chronic conditions. For example, machine learning models can be employed to detect anomalies in a patient's health data, prompting early intervention before a critical situation arises.[37] This predictive capability is particularly decisive in chronic disease management, where timely interventions can significantly reduce hospitalizations and improve quality of life.

Addressing Ethical and Technical Barriers in IoT Healthcare: Data Security and Interoperability

The integration of Internet of Things (IoT) technologies in healthcare presents opportunities for enhancing patient care and operational efficiency. However, it also introduces critical ethical and technical barriers, particularly concerning data security and interoperability. Addressing these challenges is essential for the successful deployment of IoT healthcare applications and for ensuring the protection of sensitive patient information.

Data security is a paramount concern in IoT healthcare systems, where vast amounts of personal health data are collected, transmitted, and stored. The interconnected nature of IoT devices increases the risk of cyberattacks, which can lead to unauthorized access to sensitive health information, potentially compromising patient privacy and safety. To mitigate these risks, robust security measures must be implemented at multiple levels, including the medical sensors, the network of IoT nodes, and cloud services. This necessitates the development of comprehensive security protocols that encompass encryption, secure authentication, and continuous monitoring for vulnerabilities.[38]

Moreover, the integration of advanced technologies such as blockchain can enhance data integrity and security by providing a decentralized framework for managing health records, thereby reducing the risks associated with data breaches.[39,40]

Interoperability is another barrier that hinders the effective implementation of IoT in healthcare. The diverse range of devices and systems used in healthcare settings often lack standardized communication protocols, making it challenging to share data seamlessly across different platforms.[41]

This fragmentation can lead to inefficiencies, as healthcare providers may struggle to access comprehensive patient data necessary for informed decision-making. To address interoperability issues, it is fundamental to establish common standards and frameworks that facilitate data exchange among various IoT devices and healthcare information systems.[42] Initiatives such as the Fast Healthcare Interoperability Resources (FHIR) standard aim to promote interoperability by providing a consistent way to structure and share health information.

Furthermore, ethical considerations surrounding the use of IoT in healthcare must be addressed. The collection and analysis of personal health data raise questions about consent, ownership, and the potential for misuse of information. Patients must be informed about how their data will be used and must have control over their personal information.[43] Establishing clear policies and guidelines regarding data usage and patient consent is essential for fostering trust and ensuring ethical practices in IoT healthcare applications.

CONCLUSIONS

This bibliometric analysis has illuminated the significant growth and transformative potential of IoT-based health monitoring technologies. The rapid increase in research output, particularly after 2017 and during the COVID-19 pandemic, underscores the growing interest and investment in this field. The identified influential journals, authors, and institutions, along with the geographical distribution of research, provide a valuable overview of the key contributors shaping the development and application of IoT in healthcare.

The thematic analysis revealed a clear evolution of research focus, from initial concerns over IoT architecture and device functionality to more recent emphasis on data privacy, cybersecurity, and interoperability. This shift reflects the growing recognition of the ethical and technical challenges that accompany the widespread adoption of IoT health technologies. Addressing these challenges through standardized protocols, robust security measures, and ethical data handling practices will be decisive for realizing the full potential of IoT in improving healthcare delivery and patient outcomes.

Future research should prioritize the development of secure, interoperable, and user-friendly IoT health monitoring systems that cater to the diverse needs of patients and healthcare providers. By fostering collaboration among technologists, healthcare professionals, and policymakers, we can ensure the responsible and effective integration of IoT in healthcare, paving the way for a future where technology empowers individuals to take control of their health and well-being.

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