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Review

Home Monitoring Tools to Support Tracking Patients with Cardio–Cerebrovascular Diseases: Scientometric Review

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Abstract: Home care and telemedicine are crucial for physical and mental health. Although there is a lot of information on these topics, it is scattered across various sources, making it difficult to identify key contributions and authors. This study conducts a scientometric analysis to consolidate the most relevant information. The methodology is divided into two parts: first, a scientometric mapping that analyzes scientific production by country, journal, and author; second, the identification of prominent contributions using the Tree of Science (ToS) tool. The goal is to identify trends and support decision-making in the health sector by providing guidelines based on the most relevant research.

Keywords: home monitoring tools; patient tracking; cardio–cerebrovascular diseases; scientometric review; home health technology; remote health monitoring; cardiovascular diseases; cerebrovascular diseases

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1. Introduction

According to the World Health Organization (WHO), homecare and telemedicine consist of bringing medical services home in cases where there are difficulties for patients to be transferred to hospitals and medical clinics [1]. Some of the factors that may require care at home are long distances, transportation difficulties in some territories, overcrowding and insufficient resources in hospital centers, and the risk involved in moving high-risk patients from one place to another for their medical treatments. Home care should be part of the integral and permanent health services that must be provided to patients in their homes. These services aim to improve, maintain, or care for the health of human beings in such a way that patients can preserve their independence and reduce the negative impact of the disease. Within home care, services such as promotion, prevention, cure, and rehabilitation can be included [2]. On the other hand, telehealth requires information and communication technologies to transfer medical information for the delivery of clinical and educational services. It attempts to overcome the challenges of healthcare delivery due to time, distance, and difficult terrain, enabling cost-effectiveness and better access in both developed and developing world settings [3]. Pacis et al. [4] expressed the need to incorporate new technologies into medicine. They classified the use of these new technologies into four groups: patient monitoring, healthcare information technology, intelligent assistance diagnostics, and information analysis collaboration. Thus, telemedicine includes various applications and services delivered through telephone lines, two-way video, e-mail, smart phones, wireless devices, and other forms of telecommunication technologies. In addition, telemedicine is successfully used in a wide range of medical specialties [5]. In recent years, there has been increasing interest in the development of precision medicine, telehealth, and telemedicine approaches that focus on the prevention and treatment of various pathologies. Such is the case of cardiovascular medicine, in which telemedicine is applied to all stages of disease development and is defined as telecardiology [6].

Currently, telemedicine is used in patients with heart failure to monitor the daily curves of body weight, blood pressure, O_2 saturation, heart rate/heart rhythm of patients, and the direct or indirect invasive reassessment of left atrial pressure as a turning point for therapy adjustment. Similarly, in patients with systemic hypertension, who need diagnosis, follow-up, and adjustment of therapy, ambulatory blood pressure monitoring is performed. Also, to support diagnosis in patients with arrhythmia including emergency calls in life-threatening situations such as ventricular tachycardia or debilitating conditions such as atrial fibrillation, ECG monitoring and treatment changes are performed [7]. The development of robotics has contributed not only to patient monitoring but also to advancements in telesurgery. Telesurgery is a process where a surgeon can remotely operate a robot via an Internet connection to perform surgery on a patient in another location. With this technology, the surgeon can obtain real-time images remotely and perform the operation using the corresponding equipment [8].

However, despite advances in the fields of telemedicine, home monitoring, and telehealth worldwide, challenges still arise, which relate to the application and validity of findings and the limited sample sizes in existing telehealth research, the cultural and socioeconomic factors of the population, inadequate infrastructure, insufficient funding, inadequate computer systems, lack of connectivity, and the technical knowledge required for the implementation of these technologies [9].

Then, bearing in mind that it is necessary to continually know the state of research progress in topics as important as homecare using new technologies, the objective of this review is to use scientometric methodologies to identify authors, journals, countries, and trends in this field. To achieve this scientometric review, a keyword search equation was used in the Web of Science (WoS) and Scopus databases. From this search, it is possible to extract the most relevant documents and citations on the subject of homecare and telemedicine. Subsequently, the results obtained from WoS and Scopus were joined into a single database to later apply the Tree of Science (ToS) tool and identify the most relevant contributions over time, using the Tosr R package in this case; finally, a scientometric analysis was carried out to determine statistics and research trends in the field of home care and telemedicine. Undoubtedly, the field of telemedicine and remote patient monitoring has seen exponential growth, particularly in the follow-up of cardio–cerebrovascular diseases. This scientometric review aims to comprehensively explore the role of home monitoring tools in the follow-up of patients with cardio–cerebrovascular diseases in the post-COVID era. Our study focuses on examining current trends, identifying relevant research areas, and assessing the impact of these technologies on crucial aspects such as cardiovascular health management and promotion. In addition to analyzing scientific production in this field, we will focus our study on the practical integration of these tools in specific patient follow-up applications, seeking to understand their tangible impact on the experience and management of these diseases. Finally, our goal is to present a holistic view of the relationship between home monitoring tools and the management of cardio–cerebrovascular diseases in the post-COVID era, highlighting their relevance in the current health landscape. The research question guiding our work is as follows: What are the most prominent trends in scientific research related to home monitoring tools for patients with cardio–cerebrovascular diseases in the post-COVID era? This paper is organized into three sections. Initially, the methodology is presented, which includes a step-by-step explanation of the identification and selection of articles and their corresponding scientometric analysis. Subsequently, in the Results part, the scientometric components are shown and studied, including a documentary analysis, which is distributed according to the analogy of the Tree of Science (ToS)—roots, trunk, and branches—while also presenting an analysis of the most relevant results. Finally, the conclusions of the review are presented.

2. Theoretical Information

2.1. Cardio–Cerebrovascular Diseases: Definition and Characteristics

Cardio–cerebrovascular diseases are a group of disorders that affect the heart and blood vessels, including those supplying blood to the brain. These diseases are characterized by their ability to significantly alter cardiovascular and cerebral function, which can result in acute events such as myocardial infarctions (heart attacks) and cerebrovascular accidents [10]. A key feature of these diseases is their progressive and often silent nature, as they can develop over years without showing obvious symptoms. They are generally associated with damage or deterioration of arteries and veins due to processes such as atherosclerosis, which is the accumulation of cholesterol plaques and other substances on the walls of blood vessels. These diseases can be classified into several types, including the following:

Coronary Artery Disease: Affects the arteries that supply blood to the heart muscle. Examples include angina pectoris and myocardial infarction [11].

Cerebrovascular Disease: Involves disorders that affect cerebral blood flow, such as ischemic and hemorrhagic stroke [12].

Peripheral Vascular Disease: Affects blood vessels outside of the heart and brain [13].

Heart Failure: A condition where the heart does not pump blood efficiently [14]. Symptoms of cardio–cerebrovascular diseases can vary depending on the specific type and severity of the disease. However, some common symptoms include chest pain, difficulty breathing, weakness or numbness on one side of the body, difficulty speaking, and sudden loss of vision. Diagnosis is made through a combination of clinical assessment, imaging studies such as echocardiograms or magnetic resonance imaging, and laboratory tests such as cholesterol analysis and markers of inflammation. The progression of these diseases often follows a course that worsens over time, especially if risk factors such as high blood pressure, high cholesterol, diabetes, smoking, and obesity are not controlled. Early prevention and treatment are key to altering the trajectory of these diseases, including lifestyle changes and, in some cases, medication or surgical interventions.

2.2. Traditional Management of Cardio–Cerebrovascular Diseases

In the field of cardio–cerebrovascular diseases, traditional management focuses on a combination of pharmacological strategies and lifestyle modifications, emphasizing the importance of regular monitoring and addressing various challenges in its implementation. Standard treatments for these diseases often include a variety of medications. Antihypertensives are used to control high blood pressure, a key risk factor for both types of diseases [15]. Statins and other lipid-lowering agents play a crucial role in reducing cholesterol levels and preventing atherosclerosis. Anticoagulants and antiplatelet agents are commonly prescribed to prevent the formation of blood clots, which can lead to serious cardiovascular events. In cases of heart failure, specific medications such as ACE inhibitors and beta-blockers are essential for improving cardiac function.

In addition to pharmacotherapy, managing these diseases involves significant attention to lifestyle changes. Patients are encouraged to adopt a healthy diet, engage in regular exercise, quit smoking, and limit alcohol consumption [16]. These measures not only assist in treatment but are also fundamental in the prevention of these diseases.

Regular monitoring is a cornerstone in managing cardio–cerebrovascular diseases. This process includes periodic visits to the doctor, constant monitoring of blood pressure and cholesterol levels, and, in some cases, imaging tests to assess the progression of the disease. This ongoing monitoring is vital for adjusting treatments to the individual needs of the patient and for early detection of any signs of worsening, which can be crucial in preventing complications.

However, the traditional management of these diseases faces several challenges. One of the most notable is long-term adherence to treatment by patients [17]. The chronic nature of these diseases requires a continuous commitment to medication and lifestyle changes, which can be difficult to maintain for some patients. Additionally, the identification and management of medication side effects, as well as coordination between different specialists in cases of complex diseases, can further complicate treatment.

2.3. Home Monitoring Tools: Technologies and Applications

In the field of cardio–cerebrovascular disease research, home monitoring tools represent a significant advancement, facilitating the ongoing management of these conditions. These technologies, ranging from sensors to mobile apps and telemedicine platforms, have revolutionized the way patients and healthcare professionals interact and manage the treatment and monitoring of these diseases [18]. Home monitoring tools are diversified into several categories:

Health Sensors: These devices can be wearables such as smartwatches and fitness bracelets, which monitor vital parameters such as heart rate, blood pressure, and blood oxygen levels. Some are equipped with advanced capabilities, like arrhythmia detection or sleep monitoring [19].

Mobile Applications: There are numerous apps designed to help patients manage their cardiovascular health. These apps can remind users to take their medications, provide educational information, record and analyze health data, and even allow direct communication with healthcare professionals [20].

Telemedicine Platforms: These systems enable remote interaction between patients and healthcare providers. Through telemedicine, patients can have virtual consultations, share data collected by their monitoring devices, and receive counseling and treatment adjustments without the need for in-person visits [21].

The operation of these tools is based on the collection and analysis of health data in real-time or near real-time. Wearable health sensors continuously gather data on heart rate and blood pressure, providing valuable insights into the patient's cardiovascular condition in their everyday life. This allows for early detection of potential issues, such as the onset of cardiac arrhythmias or changes in blood pressure. Mobile apps play a crucial role in personal health management [22]. They can help patients follow a medication regimen, monitor their diet and exercise, and keep a record of their symptoms and progress. Additionally, these apps can analyze the collected data and provide useful insights for both the patient and their medical team.

Telemedicine platforms, in turn, extend the reach of healthcare systems to patients in their homes. They facilitate communication and information exchange, which is especially valuable for patients with reduced mobility or those living in remote areas. These tools not only enhance the effectiveness of monitoring and treating cardio–cerebrovascular diseases but also empower patients to manage their health, thus promoting greater adherence to treatments and a healthy lifestyle. However, it is important to consider challenges such as data privacy, the accuracy of devices, and effective integration with existing healthcare systems to maximize their potential.

2.4. Advantages of Home Monitoring in Disease Management

One of the major advantages of home monitoring is the ability to detect subtle changes in a patient's health that may indicate the development or worsening of a disease. In the case of cardiovascular diseases, regular monitoring of blood pressure and heart rate can alert both patients and doctors to the risk of hypertension or arrhythmias before they become serious issues. This allows for early interventions, such as adjustments in medication or lifestyle changes, which can prevent major complications like heart attacks or strokes. Home monitoring also has a positive impact on the quality of life and autonomy of patients [23]. By being able to actively manage their health in a familiar environment, patients often feel greater control over their illness, which in turn can improve their emotional and psychological well-being. This autonomy is especially valuable for older individuals or those with limited mobility, as it allows them to maintain their independence and reduce their dependence on caregivers or family members.

Another important advantage of home monitoring is the reduction in the need for hospital visits, which in turn can significantly decrease the costs associated with healthcare. By monitoring and effectively managing chronic diseases at home, patients can avoid unnecessary hospitalizations, which not only relieves the burden on health systems but also reduces expenses for patients and their families [24]. Moreover, during health crises such as a pandemic, home monitoring helps minimize the risk of exposure to infections in hospital settings.

2.5. Artificial Intelligence and the Internet of Things

The convergence of Artificial Intelligence (AI) and the Internet of Things (IoT) is revolutionizing the field of remote patient monitoring for cardio–cerebrovascular diseases. These technologies enable continuous and real-time supervision, which is essential for the early detection of adverse events and the optimization of medical therapy. The application of AI in monitoring cardio–cerebrovascular diseases includes machine learning and deep learning algorithms that analyze large volumes of data from multiple sources. These algorithms can identify complex patterns and predict potential risks with increasing accuracy. For example, predictive models can analyze variations in blood pressure, heart rate, and other biomarkers to anticipate episodes such as strokes or heart failures [25]. Additionally, AI plays a crucial role in the customization of treatment. Based on each patient's medical history and response to treatment, intelligent systems can adjust medication dosages and recommend lifestyle changes to improve cardiovascular health.

On the other hand, IoT provides the necessary infrastructure for the effective deployment of monitoring solutions. Devices such as smartwatches, fitness bracelets, and blood pressure monitors are equipped with sensors that collect physiological data and transmit it to centralized platforms. This constant flow of information allows doctors and patients to receive real-time alerts and act quickly on any anomalies. Additionally, the integration of IoT devices in the home, such as smart scales and voice assistants, facilitates the monitoring of weight and medication adherence, which are crucial for managing cardiovascular and cerebrovascular diseases. The synergy between AI and IoT creates an advanced and highly interconnected monitoring ecosystem. AI leverages data collected by IoT devices to improve prediction models and tailor interventions more effectively. Likewise, this integration allows for the development of advanced alert systems that can predict and prevent complications before they become critical emergencies [26]. The combination of artificial intelligence and the Internet of Things is laying the foundation for a future where home monitoring of patients with cardio–cerebrovascular diseases is more proactive, personalized, and effective. This technology not only improves the quality of life for patients but also optimizes healthcare system resources by reducing the frequency of hospital visits and the duration of hospital stays.

3. Contribution and Evolution over Time

For many years, various methods have been identified in medicine for performing effective diagnostics and treatments to address different pathologies. The purpose of the study in this literature review is to focus precisely on how a line of work centered around data processing can contribute and add value to medical developments aimed at improving the quality of life of patients. The evolution of publications related to this topic is closely linked to the development of computer science and data mining. As shown in Figure 1 one can observe the evolution of articles published from 2000 to 2020, spanning two comparative decades. During the first 10 years, 2000–2010, there was a scant and emerging number of publications related to the study topic (12 publications), primarily due to the lack of computer developments that could support these various applications. Later, from 2011 to 2018, there was a significant advance that allowed for new ways to integrate

IoT to provide solutions in medicine and care (99 publications), resulting in a 900% increase. The COVID-19 pandemic was a catalyst that enabled the widespread acceptance of using technologies for remote patient care, which in turn led to a significant global increase in publications, as can be seen in the last years, 2019–2022, with 190 publications, achieving a 191% increase in scientific production from the previous period, see Figure 1.

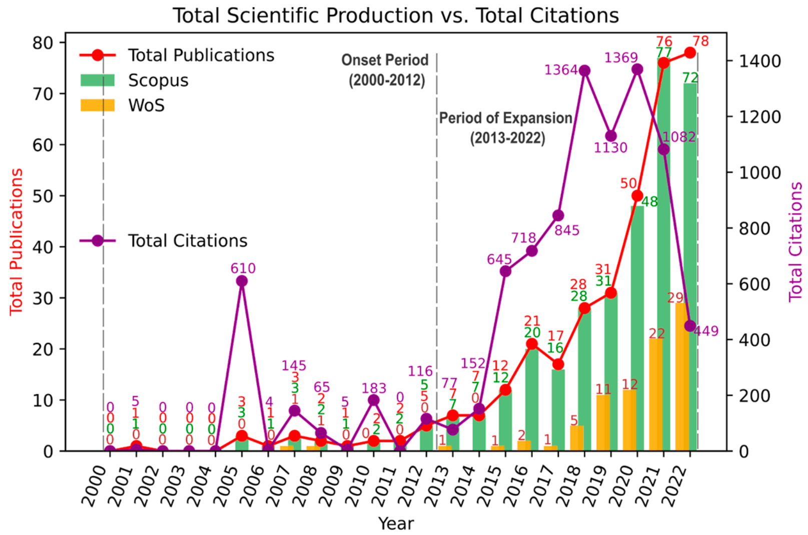

Figure 1. Total Scientific Production vs. Total Citations.

Growth Phase (2000–2010): It is important to note that the scarce number of publications is mainly due to the incipient development and unification of remote sensor technology applied to medicine. During this period, 12 articles were published, of which 10 were published in the Scopus database and 2 in WoS. The lack of publications during this study period allows us to identify that these articles have many citations (1012). The most cited article in this period was by Lin [27], which describes the development of a portable healthcare system based on integrated fabric sensors, supporting many processes of remote patient care using data such as electrocardiograms, respiration, and activity. This article currently has 589 citations, accounting for more than 50% of the citations from the first decade of development in this research theme, making it highly relevant. Among the most notable contributions to this research topic in this phase are, see Table 1:

Table 1. Significant contributions in the field of remote medical technology from 2001 to 2009.

Ref.	Year	Author	Description of Contribution
[28]	2001	Wilson	The article introduces the "Hospital Without Walls", a healthcare model that allows patient care at home through remote monitoring of vital signs. This system aims to improve the quality and efficiency of healthcare, providing comfort and quality care in a familiar environment. The technical features and potential applications of this teleassistance approach are discussed.
[29]	2005	Paradiso	The article describes a health monitoring system integrated into clothing through fabric sensors, allowing discreet and non-invasive tracking of vital signs and other health indicators, combining functionality with comfort for the user.
[30]	2006	Villalba E	The article discusses the design and development of user interaction for a heart failure management system that uses wearable and mobile technologies to monitor vital signs daily. It highlights successful connectivity through the Internet and web services and notes significant improvements in user interaction and interface compared to previous versions, including a more attractive appearance and the introduction of avatars.
[31]	2007	Zheng JW	The article describes a portable mobile health care system designed to continuously monitor vital signs over the long term in patients at high cardiovascular risk. Using a portable patient unit and a special shirt, the system monitors the electrocardiogram, respiration, and activity without causing discomfort.

Table 1. *Cont.*

Ref.	Year	Author	Description of Contribution
[32]	2008	Taccini N	The article discusses the Wealthy textile platform, equipped with piezoresistive sensors for monitoring pulmonary and cardiovascular diseases. It evaluates two types of textile sensors for plethysmography through lab tests and in vivo measurements. The platform enables remote monitoring of electrocardiograms and impedance pneumography using textile electrodes and differentiates breathing patterns with piezoresistive sensors on the abdomen and chest. Results were compared with standard BIOPAC® MP30 respiratory transducers under baseline conditions.
[33]	2009	Villalba E	The article examines the iterative validation of user interaction in a heart failure management system that uses wearable and mobile technologies for daily vital sign monitoring. This continuous monitoring allows for constant evaluation of the disease's status. The system's results are crucial in motivating patients to adopt healthier lifestyles and facilitating the self-management of their chronic condition.

Initial development phase (2010–2018): From 2010 to 2018, there was a notable increase in publications related to this line of research. A total of 99 articles were published, of which 69 are referenced in the Scopus database and 30 in the WoS database, with 2553 citations. Significant advancements were made during this period in using the Internet of Things to identify and treat various pathologies, especially those related to cardio–cerebrovascular diseases. The most outstanding work during this period was by researcher Yildirin [34], who implemented convolutional networks to analyze signals from long-duration ECGs to detect cardiac arrhythmias, see Table 2.

Table 2. Significant contributions in the field of remote medical technology from 2010 to 2018.

Ref.	Year	Author	Description of Contribution
[27]	2010	Lin	This work presents a wireless telecardiology system with a lightweight ECG device and automatic alarm connected to a mobile platform that effectively detects atrial fibrillation, enabling rapid alerts for early interventions.
[35]	2011	Zhao	The article discusses the Diabetic Telemedical Information System (DTMIS), which monitors health in real time using a sensor-equipped shirt, Bluetooth, and GSM and identifies abnormal data to provide suggestions to patients.
[36]	2012	Lobodzinski	This review article details prominent wearable electrocardiogram (ECG) devices in both the recording and wireless transmission categories. Additionally, it provides a brief explanation of their potential uses in arrhythmia monitoring, ST-T segment variations, and treatment.
[37]	2013	Lee	The authors present a method for predicting body mass index (BMI) using vocal features and machine learning. This approach can provide valuable medical information for the treatment and prognosis of diseases such as cardiovascular conditions, diabetes, and strokes without relying on traditional weight and height measurements.
[38]	2014	Huang	The article introduces We Care, a telecardiology system for mobile networks that detects ECG with high accuracy and optimizes medical resources, which is useful for patients at cardiovascular risk.
[39]	2015	Martin	This study on a mobile health intervention in cardiology shows that text messages improve short-term physical activity, providing preliminary data on its effectiveness and feasibility.
[40]	2016	Mortazavi	The study compared the effectiveness of machine learning and traditional methods, such as logistic regression, in predicting heart failure readmissions, using data from the Tele-HF trial and exploring improvements in ML through hierarchical techniques.
[41]	2017	Vegesna	The article reviews remote patient monitoring (RPM) using noninvasive digital technologies, highlighting the lack of evidence on health improvements and cost-benefit studies, and emphasizes the need for more research.
[34]	2018	Yildirim	The article details a deep learning method that uses a 1D-CNN model to detect 17 types of cardiac arrhythmias in ECG signals, achieving 91.33% accuracy and rapid classification.

Incremental Development Phase (2019-today): As previously described, this research topic is currently very relevant due to the external push generated by the COVID-19 pandemic, particularly in developments related to cardiac pathologies, a significant comorbidity for deterioration and cause of death in many patients worldwide. Consequently, the scientific community focused on creating numerous devices and mechanisms to safeguard patients with cardiac issues. As a result, 190 articles were published, significantly exceeding the publication volume of nearly two decades, with 63 of these articles indexed in the WoS database and 127 in the Scopus database. The most notable work during this period is by researcher Fan [42], with 246 citations, who focused his research on the development of clothing containing washable sensors for precise monitoring of epidermal physiological signals. These garments allow for the simultaneous tracking of arterial pulse waves and respiratory signals, see Table 3.

Table 3. Significant contributions in the field of remote medical technology from 2019 to today.

Ref.	Year	Author	Description of Contribution
[43]	2019	Shan	The article reviews mobile health interventions for type 1 and type 2 diabetes, including apps, glucose meters, text messages, and virtual counseling. Of 13 interventions in trials, eight were effective, and five did not significantly reduce HbA1c. The importance of personalized content, social support, and gamification for patient engagement is highlighted.
[42]	2020	Fan	The study introduces integrated textile triboelectric sensors (TATSA) embedded in clothing, which monitor pulse and breathing and assess cardiovascular diseases and sleep apnea. These sensors offer high sensitivity and stability, are aesthetically incorporated into garments, and transmit data to mobile devices, thus advancing wearable textile electronics for health.
[44]	2021	Bayoumy	This review discusses wearable sensors in cardiology, highlighting challenges such as accuracy and privacy, and offers recommendations and an "ABCD" guide for their integration into clinical practice.
[45]	2022	Yang	This review addresses POC microfluidic devices, their applications in diseases, and their potential integration into wearable devices and telemedicine, highlighting the need for standards.
[46]	2023	Brunetti	This document from the Italian Society of Cardiology emphasizes the importance of ICT and artificial intelligence in cardiology, discusses machine learning for remote monitoring, and highlights its utility in selecting hospital admissions.
[43]	2019	Shan	The article reviews mobile health interventions for type 1 and type 2 diabetes, including apps, glucose meters, text messages, and virtual counseling. Of 13 interventions in trials, eight were effective and five did not significantly reduce HbA1c. The importance of personalized content, social support, and gamification for patient engagement is highlighted.
[42]	2020	Fan	The study introduces integrated textile triboelectric sensors (TATSA) embedded in clothing, which monitor pulse and breathing and assess cardiovascular diseases and sleep apnea. These sensors offer high sensitivity and stability, are aesthetically incorporated into garments, and transmit data to mobile devices, thus advancing wearable textile electronics for health.
[44]	2021	Bayoumy	This review discusses wearable sensors in cardiology, highlighting challenges such as accuracy and privacy, and offers recommendations and an "ABCD" guide for their integration into clinical practice.
[45]	2022	Yang	This review addresses POC microfluidic devices, their applications in diseases, and their potential integration into wearable devices and telemedicine, highlighting the need for standards.
[46]	2023	Brunetti	This document from the Italian Society of Cardiology emphasizes the importance of ICT and artificial intelligence in cardiology, discusses machine learning for remote monitoring, and highlights its utility in selecting hospital admissions.

4. Methods

4.1. Search Chain

To conduct the scientometric analysis focused on the use of support technologies for monitoring patients at home, using the Internet of Things and the models based on machine learning to make significant contributions to the care and quality of life of patients, a process of consultation and classification of articles published in the WoS and Scopus databases is carried out. These two databases have been used due to their wide acceptance in the scientific community, and they aggregate many bibliographic resources internationally. The results issued by these databases have been analyzed by different tools such as Bibliometrix [47] and the Tosr package, which has provided a global view of the different relationships between authors and their references worldwide. Specifically, this review article has provided a global view of how the use of technology can contribute to the monitoring of various cardio–cerebrovascular pathologies and can help determine what the barriers, challenges, and trends are in this type of solution.

In Table 4, the different concepts that are part of the search chain used for this scientometric review, which is associated with the use of machine learning techniques for home monitoring of patients with cardio–cerebrovascular diseases, can be identified. The keywords used in the search equation were as follows: ("telehealth" OR "homecare" OR "Telemedicine" OR "Teleconsultation" OR "Home health care" OR "In-home care" OR "Home care services") and ("machine learning" OR "iot" OR "wearable") and ("cardiovascular" OR "cerebrovascular"), which allowed the selection of 95 records in the WoS database and 366 in the Scopus database, obtaining a total of 462 files. After reducing file duplicity, an optimized search of 376 documents was achieved. Delving into the typology, we detail the following distribution: scientific articles (163, 43.1%), Review Paper (108, 28.5%), Conference Paper (66, 17.41%), Editorial (12, 3.7%), Book Chapter (8, 2.11%), Note (7, 1.85%), Conference Review (5, 1.32%), Letters (4, 1.06%), Early Access (3, 0.79%), Editorial Material (1, 0.26%), Erratum (1, 0.26%), and Short Survey (1, 0.26%) see Table 4.

Table 4. Search results for the parameters in the databases.

Parameter	WoS	Scopus
Range	2020–2023	
Date	3 May 2024	
Type of Document	Article, Book, Book Chapter, Conference proceedings	
Words	"telehealth" OR "homecare" OR "Telemedicine" OR "Teleconsultation" OR "Home health care" OR "In-home care" OR "Home care services" and ("machine learning" OR "iot" OR "wearable") and ("cardiovascular" OR "cerebrovascular")	
Results	95	366
Total (WoS + Scopus)	462	

To conduct the scientometric analysis focused on the use of support technologies for monitoring patients at home using the Internet of Things and models based on machine learning, clear inclusion and exclusion criteria were defined. Regarding the inclusion criteria, articles that specifically addressed the use of these technologies applied to cardio–cerebrovascular pathologies were considered. Only publications indexed in the WoS and Scopus databases were included due to their wide acceptance in the scientific community and their capacity to aggregate bibliographic resources internationally. The types of documents included scientific articles, reviews, conference papers, editorials, book chapters, notes, conference reviews, letters, early access articles, editorial material, errata, and short surveys. Additionally, the documents had to contain specific keywords in the search equation such as "telehealth", "homecare", "telemedicine", "teleconsultation", "home health care", "in-home care", "home care services", "machine learning", "IoT", "wearable", "cardiovascular", and "cerebrovascular". The publication period was also considered to ensure the relevance of the data and trends investigated. On the other hand, articles that did not focus on the use of IoT and machine learning for home monitoring of patients or that were not related to cardio–cerebrovascular pathologies were excluded. Duplicated documents between the WoS and Scopus databases were removed to maintain an optimized set of documents. Additionally, non-scientific documents such as news articles, non-peer-reviewed opinion pieces, and non-academic publications were excluded. Sources not indexed in WoS or Scopus that did not meet the required quality and scientific rigor standards were also discarded. Finally, publications in languages not accessible to the research team were excluded unless reliable translations were available. These criteria ensured the inclusion of high-quality and relevant literature, providing a comprehensive and accurate view of the use of advanced technologies in the home monitoring of patients with cardio–cerebrovascular diseases, identifying key barriers, challenges, and trends in this field.

To achieve these objectives, the methodology based on the metaphor of the Tree of Science was used, which provides information focused on two perspectives. Firstly, it describes detailed information associated with the most representative authors in the research line, along with analysis by country, journals, and number of citations. Additionally, it also provides relevant details on the evolution of the study topic, allowing us to understand how it has matured over time and thus identify knowledge gaps and potential contributions for future work.

4.2. Tree of Science

Tree of Science (ToS) is a web platform for searching scientific literature created at the National University of Colombia. This tool is designed to facilitate the search for relevant literature using graphic algorithms that present results through a tree metaphor. The platform can be used to recommend relevant literature through scientometric techniques, measure the impact of articles, journals, and institutions, and map scientific areas, thus facilitating the classification of search results [48]. It is based on graph theory metrics, with which articles in a field of knowledge are visualized as the roots, trunk, and leaves of a tree, placing each article according to certain characteristics. Classic articles with key research information are in the roots. The trunk represents research that fosters growth in the field or is considered structural publications. The leaves contain recently published articles that are highly connected to the trunk and roots [49].

This platform was specifically developed for literary searches in Web Of Science and Scopus, where search strings defined for the research are entered [50]. After obtaining the results, the articles from both Web of Science (WoS) and Scopus were downloaded. These files were then uploaded to ToS (http://tos.manizales.unal.edu.co, accessed on: 3 May 2024). With these data, ToS produced the results in the form of a tree: root, trunk, and leaves [51].

In addition to obtaining the tree, the tool allows for the analysis of the most cited articles, the countries where research has been developed, the most relevant journals, the leading authors in the area, and the collaboration networks that have been established on the topic. A large network is constructed from the reference citations where articles are represented by nodes and references by edges. The algorithm filters the network by eliminating articles with one citation and zero references to other articles. In addition to this, ToS extracts the most connected subnet, representing it in a larger form to eliminate small islands in the research topic. It is applied with a clean citation network to identify subcommunities of densely connected nodes (clusters) [49].

4.3. Scientometric Analysis

Scientometrics is based on the quantitative analysis of scientific production, aiming to investigate the development, structure, dynamics, trends, and relationships of scientific practice [52]. Scientometrics is useful for quantitatively analyzing and understanding the scientific output of a research topic and identifying emerging areas of science. With the advancement of technology, it is now possible to apply scientometric techniques in various research fields, such as health, artificial intelligence, home care, and cardiovascular diseases [53].

In the case of this review, the search for analysis was conducted between 2001 and 2023 in the Web Of Science and Scopus databases, using the previously mentioned search string, which initially yielded 462 files and 376 after deduplication. The scientometric analysis was performed using the R tool with its Bibliometrix and Tosr packages version 4.3.1 (Beagle Scouts), which were used for the scientific mapping that includes citation analysis, authors, words, country production, collaboration networks, and journals [27]. The analysis of the most relevant literature was carried out through the implementation of a mature data preprocessing process developed by Core of Science, following the PRISMA method (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [34], to select documents that are most aligned with the theme of the review, see Figure 2.

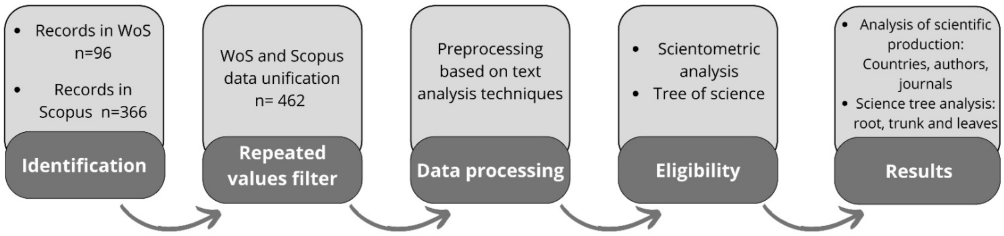

Figure 2. PRISMA flow diagram.

5. Results

5.1. Country Analysis

Cardio–cerebrovascular diseases are among the leading causes of mortality worldwide and thus impose a significant budgetary burden on the healthcare system. That is why, from different sectors, there is a search for solutions focused on different phases or stages of the disease, whether in the early detection of symptoms to ensure a treatment that can support the non-deterioration of the patient's health, in the intermediate phase where it is possible to identify how to monitor treatments administered by health personnel to ensure a halt in the deterioration of health, or in the critical phase where alarm protocols are defined for exhaustive monitoring of the critical condition of patients. Technology is a highly relevant ally in these processes, having become a crucial support in all phases of medical intervention, which is why this country analysis seeks to identify which countries have had significant development in the implementation of different applications associated with technology for these types of pathologies.

As can be seen in Table 5, the countries leading scientific production are those traditionally characterized as world leaders in technological development. The United States is the main producer of articles in this line, with 106 representing 25.79% of global scientific production. Additionally, it is the country with the highest number of citations at 3258. Of the one hundred six publications, fifty-eight are in Q1 journals (55%), fourteen in Q2 (13%), six in Q3 (6%), and one in Q4 (1%). Among these publications, the article by Bobak J. Mortazavi et al. [29] stands out; they conduct an analysis based on machine learning to analyze variables related to the readmission process of patients with heart failure.

Table 5. Production by Countries.

Country	Production		Citation		Q1	Q2	Q3	Q4
USA	106	25.79%	3258	39.23%	58	14	6	1
China	46	11.19%	1248	14.96%	16	11	4	1
Italy	33	8.03%	940	11.32%	8	7	3	1
United Kingdom	21	5.11%	370	4.46%	14	2	2	0
India	20	4.87%	88	1.06%	0	2	1	5
Germany	16	3.89%	84	1.01%	5	3	4	0
Australia	14	3.41%	123	1.48%	6	1	0	1
Korea	14	3.41%	204	2.46%	5	3	1	0
Canada	11	2.68%	167	2.01%	5	1	1	0
France	9	2.19%	78	0.94%	2	2	0	0

The second country in terms of scientific publications is the Asian giant China, with 46 publications (11.19%), which is still quite far behind the United States in terms of publication level. China is not only the second country with the highest number of publications but also with the highest number of citations at 1248. Of the forty-six publications, sixteen are in Q1 (35%), eleven in Q2 (24%), four in Q3 (9%), and one in Q4 (2%). The work of Fan et al. [54] stands out again; it is a highly cited article related to the use of clothing, and it uses textiles to analyze different risk factors in patients.

The third representative country is Italy, where 33 publications (8.03%) have been made, and it is also the third country with the highest citation index at 940 (11.32%). Italy, being one of the countries most affected by being the epicenter of COVID-19 in Europe, stimulated the generation of new products and processes based on technology for these types of pathologies that directly impact the survival of patients with COVID-19. Of the thirty-three publications, eight are in Q1 journals (24%), seven in Q2 (21%), three in Q3 (9%), and one in Q4 (3%). The article by Paradiso et al. [55] is also highlighted, who, like the most notable author in China, shows the application of textiles using sensors to detect risk factors in cardiovascular patients.

The fourth representative country is the United Kingdom, which has 21 publications (5.11%). Additionally, it is also the fourth country with the highest number of citations at 370 (4.46%). Of the 21 publications, 14 are in Q1 journals (67%), 2 in Q2 392 (10%), and 2 in Q3 (10%). The most representative article is by Michael V. McConnell et al. [56], who analyzes the viability of obtaining lifestyle measures using an app developed for mobile devices. The fifth country in scientific publications is India, with 20 publications (4.87%); however, being the fifth country in the number of publications, the citations have been lower, ranking eighth at 88 (1.06%). Of the twenty publications, two are in Q1 (10%), one in Q3 (5%), and five in Q4 (25%). The work of D. Sobya [57] is highlighted, which shows the development of a wireless monitoring system based on ECG signals, combining the use of IoT for real-time data acquisition.

The sixth country in scientific publications is Germany, with 16 publications (3.89%); however, it is the penultimate country in terms of publications. Of the sixteen publications, five are in Q1 (31%), three in Q2 (19%), and four in Q3 (25%). The work of Shannon Wongvibulsin [58] is highlighted; it disseminates a systematic review of digital health in the cardiac patient rehabilitation processes. The seventh country with the most scientific production is Australia, with 14 publications (3.41%), and it is also the seventh in terms of citation index at 123 (1.48%). The most notable work is that of Santoso [59], who has reviewed the development of indoor environments for remote patient monitoring, showcasing different works that are important for the development of future applications.

The eighth country with the highest number of publications is Korea, with 14 (3.41%); it is important to note that even when it has a smaller number of publications, they have been well received by the scientific community, ranking as the sixth country in citations at 204 (2.46%). The article by Sang Hoon Chae [60] is highlighted, which shows the development and clinical evaluation of a web-based upper limb home rehabilitation system using a smartwatch and a machine learning model for survivors of chronic cerebrovascular accidents. The ninth country in publications is Canada, with 11 publications (2.68%), but it is important to note that they rank sixth in citations at 167 (2.01%). Of the eleven articles, five are published in Q1 journals (45%), one in Q2 (9%), and one in Q3 (9%). Among the published articles, the article by Lee H Schwamm [61] stands out, who proposes interesting recommendations concerning the application of teleassistance for cardiovascular patients.

Finally, France is the last country in producing articles related to this theme with 9 (2.19%) and is also coincidentally the last country in the citation index at 78 (0.94%). Of the nine published articles, two are in Q1 journals (22%) and two in Q2 (22%). Among the published articles, a literary review by Emmanuel Andrès [62] stands out; the review analyzes different perspectives of telemedicine applications in chronic cardiac conditions.

Figure 3 shows the scientific collaboration network among countries. It depicts six communities, with the largest comprising mainly the USA, Australia, China, and Belgium.

An example of this scientific collaboration is the work on the adoption of digital devices in the field of telemedicine and artificial intelligence [61]. The communities by size graph display the size of the six communities, where community 1 has 20 countries and community 2 has 12. The nodes and links through the time figure show that until 2011, the academic community was working in isolation without creating links between countries. However, since 2012, the proportion of links began to grow significantly, and by 2021, the proportion of new countries starting research on telemedicine and artificial intelligence was surpassed.

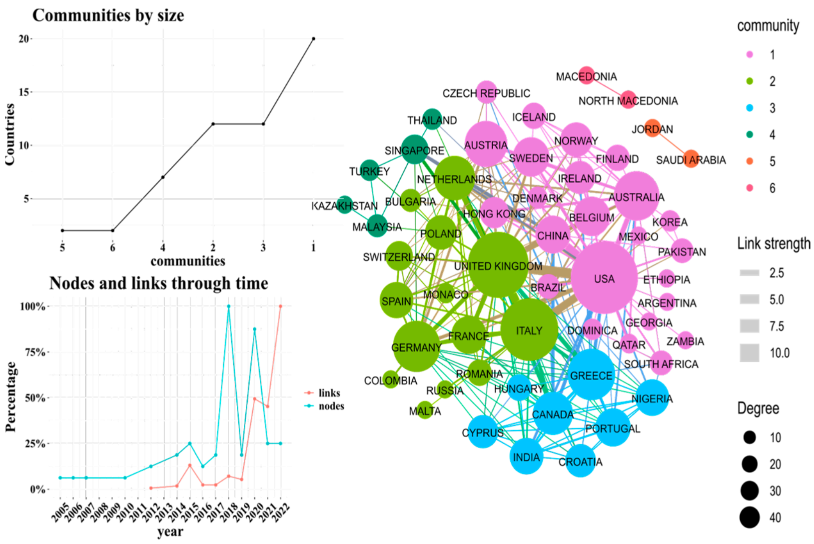

Figure 3. Country collaboration network.

In the first community (pink), led by the United States, there are significant contributions from authors in this country with authors in Australia and Austria. Many of the works in this community are focused on IoT-based developments to detect risk factors associated with cardiac arrhythmia. Highlighted in this community are works relating to authors from countries like the USA and Australia, such as Ali [63], who presents a system that allows real-time assistance for continuous ECG monitoring and arrhythmia detection. Similarly, Christophe Leclercq [64] implements artificial intelligence to detect heart failure, with researchers from both the USA and Austria. As for the second community (green), led by European countries, the United Kingdom has had the most collaborations, specifically with authors from Italy and Germany, focusing on the use of mobile devices to support remote treatment and detection processes for cardiac arrhythmia. The work of Larissa Fabritz [56] stands out, showing how wearable devices can be used to monitor adult patients for cardiac arrhythmia.

The third community is led by Greece, where joint work has been developed with authors from countries like Canada and Nigeria, with significant systematic reviews of the literature analyzing different risk factors for cardiovascular diseases in older adults. Among the most representative works are those of Guasti [65], who analyzes how teleassistance can help prevent cardiovascular diseases in older adults, and Wongvibulsin [66], who examines how remote monitoring can support cardiac rehabilitation of patients. The fourth community is led by Singapore, where joint work has been conducted with authors from Thailand and Turkey, addressing issues related to user perceptions of using sensors to monitor relevant health indicators. The work of Rama Greenfield [44] is highlighted, analyzing truck drivers' perceptions of using wearable devices to improve their health monitoring indicators.

5.2. Analysis by Journals

In the analysis of journals conducted, 83 indexed journals were found that feature publications related to the theme. Out of these, 20 journals contain articles only in the

Scopus database and 74 in WoS. It is noted that from the 83 journals, only 10 are selected for the analysis shown in Table 6, considering the highest indices of impact factor, H-index, and Quartile. In addition, it is clarified that the journals analyzed are indexed journals. However, there may be relevant research on home care for cardiovascular diseases in journals that are not registered.

Table 6. Production by Journals.

Journal	Wos	Scopus	Total	Impact Factor	H Index	Quartile
International Journal of Environmental Research and Public Health	2	10	10	0.83	167	Q2
Jmir Mhealth and Uhealth	3	7	8	1.51	84	Q1
Journal of Medical Internet Research	3	8	8	1.99	178	Q1
Studies in Health Technology and Informatics	0	8	8	0.29	64	Q3
Sensors	6	4	7	0.76	219	Q1
Ieee Journal of Biomedical and Health Informatics	0	6	6	1.67	146	Q1
Telemedicine and E-Health	5	6	6	1.24	87	Q1
Cardiovascular Digital Health Journal	2	5	5	0.61	6	Q2
Journal of the American Heart Association	0	5	5	2.08	118	Q1
The Lancet Digital Health	0	4	4	6.43	48	Q1

Regarding Table 6, which is organized by the order of the number of publications, the International Journal Of Environmental Research And Public Health has the highest number of publications related to the main theme of the review. This journal, from Switzerland, is multidisciplinary, open access, covers areas of environmental health and public health, and links disciplines such as biology, biochemistry, biotechnology, cellular and molecular biology, chemistry, computer science, ecology, engineering, epidemiology, genetics, immunology, microbiology, oncology, pathology, pharmacology, and toxicology. Despite having the highest number of publications, this journal is in the Q2 quartile and has an H-index of 167, a low value compared to other journals in the table that have fewer articles published on the main topic.

Regarding the impact factor, the journal with the highest value in this aspect (6.43) is the UK journal The Lancet Digital Health, which is open access, Q1 quartile, and focuses on decision sciences, health information management, and health informatics. Despite its impact factor, this journal has only four publications in the area of the review and an H-index of forty-eight, which indicates that it does not have a high number of citations. On the other hand, in second place, with 2.08, is the Journal Of The American Heart Association, also from the UK, open access and whose thematic areas focus on cardiology and cardiovascular medicine; this journal is in the Q1 quartile and has an H-index of 118, making it a relevant journal given its impact and citation level. In third place regarding the impact factor is the Journal Of Medical Internet Research, a journal from Canada is open access and focuses on emerging technologies, medical devices, applications, engineering and computer applications for patient education, prevention, population health, and clinical care. It belongs to the Q1 quartile and has an H-index of 178, the second-highest of the journals analyzed.

In terms of the H-index value, the journal Sensors, with an index of 219, has the highest citation index compared to the journals analyzed in this review. This open-access journal from Switzerland has seven publications on the main topic, but despite having the highest H-index and being in the Q1 quartile, it has a low impact factor. Finally, although the American journal IEEE Journal Of Biomedical And Health Informatics does not have the highest indexes of publications, impact factor, and H-index, the values in these last two factors are of interest given that it is a journal with a high number of citations and impact, making it an interesting journal for publishing research in the field of telemedicine focused on cardiovascular diseases.

In Figure 4, we can observe the citation network of the journals where three groups or communities are identified, interlinked by specific themes. Community or group 1 focuses mainly on the use of artificial intelligence as a telemedicine tool for cardiovascular diseases, with journals such as J MED INTERNET RES and STROKE standing out, which have published works like the one by Eunjeong Park [67], who developed an automatic classification system for cardiovascular accident symptoms through machine learning to assess motor weakness and NIHSS and MRC scores for four limbs. On the other hand, community 2 focuses on themes related to digital tools for the remote control of cardiovascular diseases, with the most impactful journals being CIRCULATION and J AM COLL CARDIOL, among which a strong link is observed and publications like the one by Karim Bayoumy [39], focused on the study of smart wearable devices for cardiovascular care.

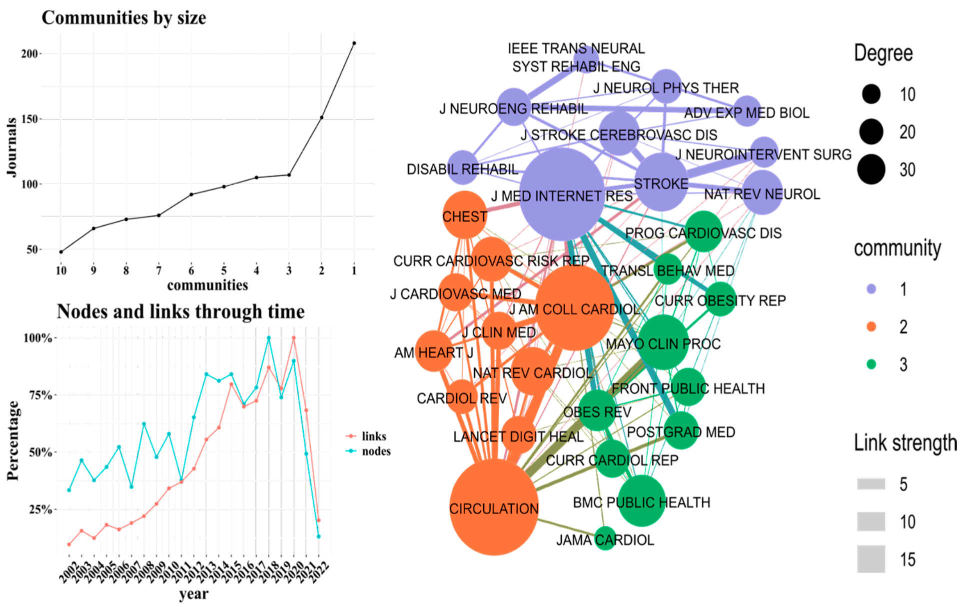

Figure 4. Journal collaboration network.

Lastly, community 3 bases its research on themes such as the study of lifestyles related to cardiovascular diseases and telemedicine linked to them, highlighting journals like MAYO CLIN PROC and BMC PUBLIC HEALTH, where works are found such as the one published by Sarah Edney [68], which conducts a review of digital interventions aimed at movement behaviors and their influence on health. Figure 4 also shows the behavior of the nodes and the links of the journals over time, with 2018 being the year in which the highest percentage of articles were published and 2020 seeing the most collaborations among journals on the subject. Conversely, in the years 2021 and 2022, there is a significant decrease in both the percentage of citations and cooperation networks, which may be due to a decline in telemedicine research in the years following the pandemic or a shift in thematic focus for the collaboration of the journals.

5.3. Analysis by Authors

To conduct the author analysis, two sessions will be held: (i) Initially presenting researchers with the highest output in the field of homecare and telemedicine; (ii) In the second part, an analysis of the academic collaboration networks of the researchers (ego network) is carried out. According to Table 4, of the top ten researchers, four are from the United States; the others are from Korea, Australia, China, and Germany. Among the researchers, Martin and Turakhia, both from the United States, show the highest productivity, with 9 and 6 publications, respectively. Martin S has published works like the randomized clinical trial of a fully automated mobile health (mHealth) intervention with tracking and text messaging components to increase physical activity [69], which, according to Google Scholar, has 264 citations.

On the other hand, Turakhia M, together with MCCONNELL [27], conducted a review on advances in mobile health with mobile and wearable devices to assess and promote physical activity and fitness and to monitor heart rate and rhythm for the detection and treatment of atrial fibrillation, which has 124 citations. However, even though the authors have the highest productivity in this case, it is noteworthy that authors such as Hindricks G and Lin C, from Germany and Australia, respectively, have a higher Scopus Index. Hindricks has a total of 150,716 citations, an H-index of 111, and has recently published works like the TeleWear project [27], which involves integrating health data collected by mobile devices and mHealth-guided standardized measurement for patients with cardiovascular diseases. As for Lin C, according to Google Scholar, he has an H-index of 91 due to the 35,179 citations his publications have received, among which is the research article describing an intelligent telecardiology system using a wireless and portable ECG to detect atrial fibrillation [27], see Table 7.

Table 7. Production by authors.

No.	Researcher	Total Articles *	Scopus-Index	Affiliation
1	Martin S	9	53	Johns Hopkins Medical Institutions, Baltimore, United States
2	Turakhia M	6	51	Stanford University School of Medicine, Stanford, United States
3	Kim J	5	4	Soonchunhyang University, Asan, South Korea
4	Lin C	5	70	University of Technology Sydney, Sydney, Australia
5	Mcconnell M	5	47	Stanford University School of Medicine, Stanford, United States
6	Chen C	4	21	Fudan University, Shanghai, China
7	Hindricks G	4	99	Herzzentrum Leipzig, Leipzig, Germany
8	Kim Y	4	5	Asan Medical Center, Seoul, South Korea
9	Lovell N	4	58	Unsw Sydney, Sydney, Australia
10	Marvel F	4	14	Johns Hopkins School of Medicine, Baltimore, United States

Figure 5 displays a personal scientific collaboration network among the most productive researchers in the field of homecare and telemedicine. In this network, a large component connects most researchers, indicating a high level of interdisciplinary and multi-institutional collaboration. This suggests a well-integrated and active research community where knowledge exchange and co-authorship are common. Professor Lovell, despite his significant contribution in terms of publication numbers, appears isolated from the main component. This could be due to various reasons, such as specialization in a unique subfield of telemedicine or homecare, or it may reflect geographical or institutional differences that limit collaboration. It is also possible that his collaborations are with researchers or institutions not included in the underlying dataset or not as active in the same thematic area.

The main component shows a pattern of collaboration where researchers tend to work together or with colleagues who are already connected in the network. This is a typical characteristic of scientific collaboration networks, where existing collaboration encourages new connections, often referred to as the "small world" phenomenon in social networks. The presence of a "large component" means that there is a path of collaboration linking almost all researchers, facilitating the diffusion of knowledge and potential for joint projects. These connection patterns reflect not only current professional relationships but also may indicate emerging research areas and trends in homecare and telemedicine.

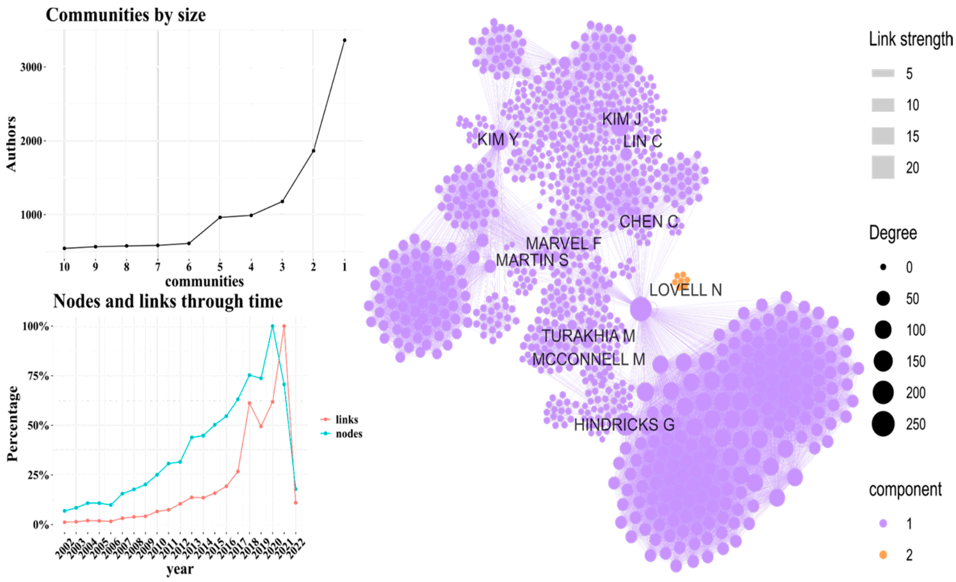

Figure 5. Author collaboration network.

6. Tree of Science Analysis

Using the metaphor of the "Tree of Science", we can examine the trajectory of the Internet of Things (IoT) in the context of patient care for cardio–cerebrovascular diseases over time. In this analysis, we focus our attention on the roots of the tree, a period during which this technology faced significant challenges due to low technological adoption, see Figure 6.

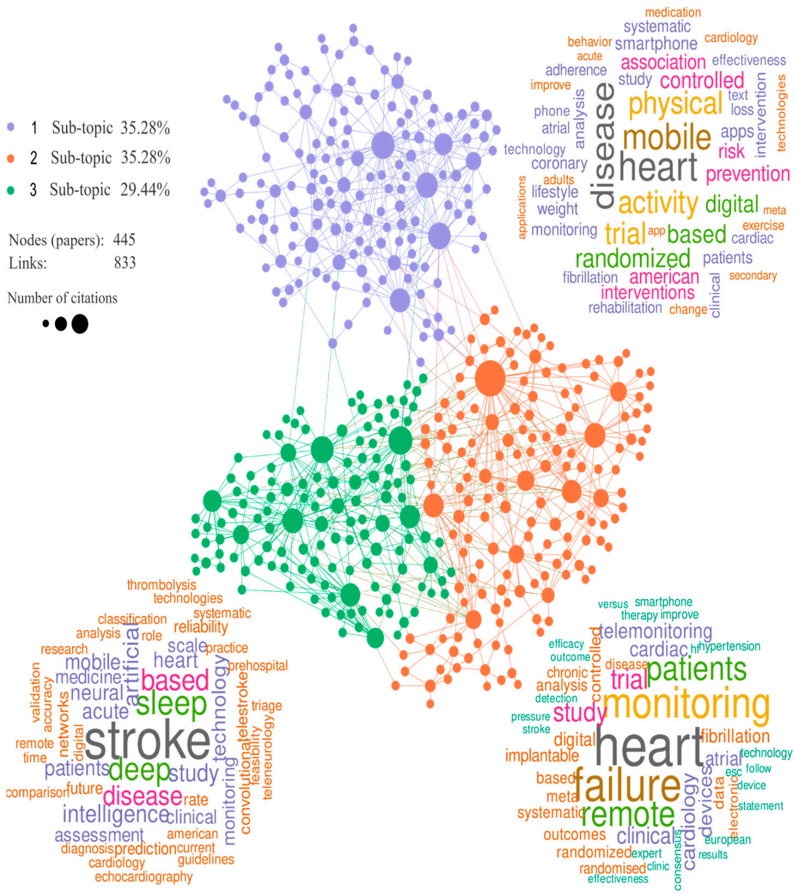

Figure 6. Tree of Science representation.

6.1. Root: The Evolution of IoT in Patient Care for Cardio–Cerebrovascular Diseases

Using the "Tree of Science" metaphor, we can explore the trajectory of the Internet of Things (IoT) in patient care for cardio–cerebrovascular diseases over time. In this analysis, we focus on the roots of the tree, a period during which this technology encountered significant challenges due to low technological adoption. During a substantial period, the adoption of IoT in healthcare faced notable resistance to change globally. Healthcare systems and professionals tended to cling to traditional methods, often overlooking the potential advantages of technology. This reluctance to adopt IoT solutions for patient care limited the capacity for innovation in healthcare. Furthermore, another key factor was the availability and appropriation of the necessary technological resources. Internet connectivity and the proliferation of connected medical devices became essential for the success of IoT in patient care for cardio–cerebrovascular diseases. Reliable connectivity allowed real-time data transmission and communication between medical devices and healthcare systems, which significantly improved patient care and monitoring. As these barriers have been eliminated, IoT has flourished in the healthcare sector, improving the quality of care and offering new opportunities for monitoring and treating patients with cardiac and cerebrovascular conditions. Therefore, the theoretical foundations for many of the solutions currently in use were laid.

Among the most notable contributions is the work of Perez [70], who focuses on a large-scale evaluation of the use of a smartwatch for atrial fibrillation detection. Atrial fibrillation is a common and potentially dangerous cardiac arrhythmia that can increase the risk of stroke and other cardiovascular complications. Early detection of atrial fibrillation is essential for providing appropriate treatment and preventing serious complications. In this study, the authors conducted extensive research evaluating the performance of a smartwatch in detecting atrial fibrillation in a large number of participants. A large-scale approach was used to collect portable electrocardiogram data generated by the smartwatch, aiming to determine its ability to identify episodes of atrial fibrillation compared to traditional detection methods. The study's results provide valuable insight into the effectiveness of smartwatch technology in detecting cardiac conditions, specifically atrial fibrillation. This is important in the context of cardiovascular health, as it may offer an early detection tool that could be widely accessible for continuous monitoring of individuals' cardiac health. Meanwhile, Chow [71] focuses on a randomized clinical trial investigating the impact of lifestyle-focused text messages on modifying risk factors in patients with coronary disease. Coronary disease is a common and potentially serious cardiac condition associated with modifiable risk factors, such as diet, physical activity, smoking, and elevated blood pressure. Modifying these risk factors is crucial for reducing the risk of subsequent cardiovascular events in patients with coronary disease. In this study, the researchers conducted a clinical trial where patients with coronary disease were randomly assigned to two groups: one that received lifestyle-focused text messages as part of a behavioral health intervention and a control group that did not receive these messages. The text messages included reminders and advice related to diet, exercise, weight control, and stress management. The study's goal was to assess whether the text message intervention had a significant impact on modifying risk factors compared to the control group. Parameters such as blood pressure, body mass index (BMI), physical activity, and other health indicators related to coronary disease were measured. The study's results provided evidence that lifestyle-focused text messages can have a positive effect on modifying risk factors in patients with coronary disease. This text messaging-based intervention approach proved effective in promoting healthy behavioral changes and improving disease management.

Other authors, like Burke [72], address the increasing relevance of mobile applications and devices in promoting cardiovascular health, highlighting how these technologies can empower consumers to manage and control risk factors such as blood pressure, physical activity, diet, and weight. The scientific statement provides a comprehensive review of the existing scientific literature and underscores the importance of mobile applications, health monitoring devices, online platforms, and telemedicine in promoting cardiovascular health and preventing heart disease, thus supporting the growing role of mobile technology in enhancing the population's cardiovascular health. Figure 7 and Table 8 illustrate the evolution of personal health monitoring devices during the early years of the 21st century, highlighting key technological advancements from 2000 to 2004.

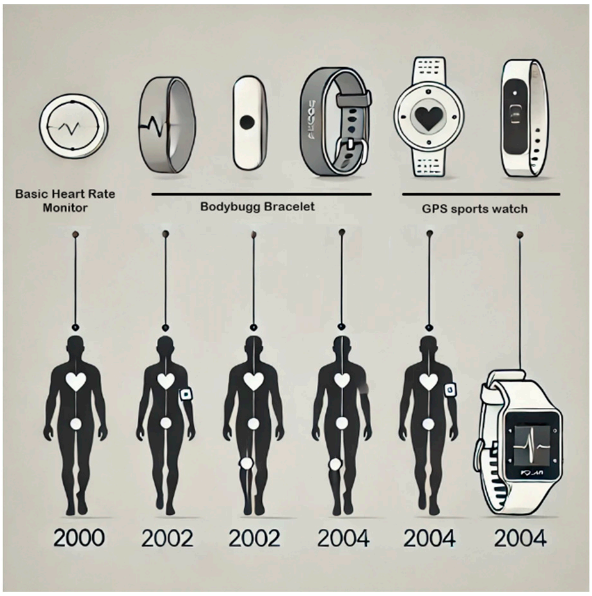

Figure 7. First developments.

Table 8. The beginnings.

Year	Reference	Description
2000	[73]	Launch of basic heart rate monitors such as those from Polar, used mainly by athletes. These devices offered limited functionality, such as real-time heart rate monitoring.
2002	[74]	The introduction of the Bodybugg bracelet, one of the first devices to track physical activity and estimate calorie consumption.
2004	[75]	The first sports watches with integrated GPS, such as the Garmin Forerunner 201, began to offer route and distance tracking in addition to heart rate monitoring.

6.2. Evolution of IoT Technology in Cardiovascular Patient Monitoring

The evolution of IoT (Internet of Things) technology in monitoring cardiovascular patients has significantly revolutionized healthcare and the management of cardiovascular diseases. This advanced technology enables the real-time collection of vital patient data such as heart rate, blood pressure, oxygen saturation, and other key parameters through connected medical devices. This information is remotely transmitted to healthcare professionals and healthcare systems, allowing constant monitoring and a quick response to any changes in the patient's condition. Furthermore, the implementation of wearable devices and smart sensors has empowered patients, allowing them to actively participate in managing their cardiovascular health. This technological evolution not only improves the quality of care but also reduces medical costs, minimizes the need for unnecessary hospitalizations, and ultimately saves lives by providing more proactive and personalized care to those with cardiovascular conditions. During this stage of evolution, various authors made significant contributions that enabled the development of various solutions that have directly impacted the quality of life of treated patients.

Lobelo, F [76] focused on the integration of software applications and wearable health devices (mHealth) to support assessment, advice, and interventions to reduce the risk of cardiovascular diseases. In this context, the article addresses the growing adoption of mobile and wearable technologies in the health sector, especially in promoting physical activity and preventing cardiovascular diseases. It proposes a framework that seeks to leverage these technological tools to improve physical activity assessment, provide personalized advice, and design effective interventions to reduce the risk of heart disease. The article highlights the importance of this integration in modern healthcare and emphasizes the potential of mobile technologies to drive a positive change in lifestyle and cardiovascular health.

Rawstorn [77] focuses on designing and developing content for an innovative mobile health (mHealth) platform for exercise-based cardiac rehabilitation. The article discusses creating a cardiac tele-rehabilitation system that allows patients to carry out rehabilitation programs remotely using mobile devices and mHealth technology. It describes the design and development process of the platform, which includes specific content for cardiac rehabilitation, such as exercise programs, health monitoring, and virtual counseling. The article highlights the importance of this technology in expanding access to cardiac rehabilitation and improving patient adherence to these essential programs for recovery after cardiovascular events.

On the other hand, Alshurafa [78] focuses on the application of remote monitoring technology for patient health management and assesses this technology's efficacy in predicting positive or negative health outcomes. The study uses health data collected from patients over a month, along with baseline data before the start of monitoring. The goal is to develop a predictive model that can identify which patients are more likely to experience health improvements through remote monitoring. This approach has significant implications for personalized healthcare and chronic disease management using remote monitoring technology.

Figure 8 and Table 9 present a clear and concise outline of the evolution of IoT technology in cardiovascular patient monitoring from 2006 to 2018. Through a timeline, key milestones are highlighted in three distinct phases, showing the progression from wearable devices and mobile health technologies through the consolidation of tele-rehabilitation systems to the implementation of smart sensors and the development of predictive models for personalized care. This visual representation provides an overview of how these innovations have transformed cardiovascular health management over the years.

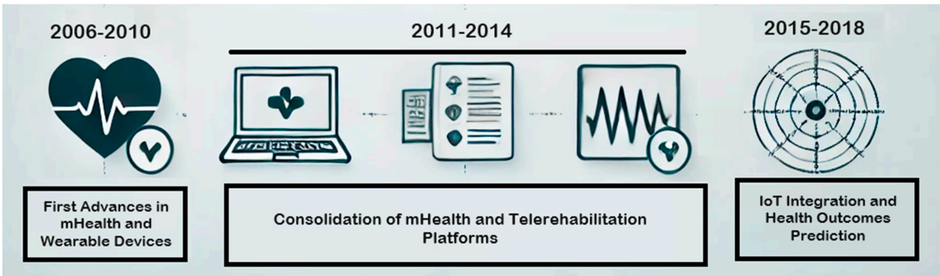

Figure 8. IoT Technology in Cardiovascular Patient Monitoring.

Table 9. Advancements in mHealth, wearable devices, and consolidation of tele-rehabilitation Platforms.

Reference	Milestone	Description
[79]	First Advances in mHealth and Wearable Devices	The beginning of the integration of portable devices (wearables) in health monitoring. The first basic cardiac and physical activity monitoring devices.
[80]		Increase in the use of mobile technologies (mHealth) in health promotion and prevention of cardiovascular diseases.
[81]		Development of initial frameworks to integrate wearable devices with health applications, facilitating the collection of vital data in real time.

Table 9. *Cont.*

Reference	Milestone	Description
[82]	Consolidation of mHealth and Tele-rehabilitation Platforms	Expansion of mobile applications for health monitoring and chronic disease management, including cardiac tele-rehabilitation.
[83]		Development of cardiac tele-rehabilitation systems that allow patients to participate in rehabilitation programs at a distance.
[84]		Greater focus on designing specific content for mHealth platforms, including exercise programs and virtual counseling for cardiac rehabilitation.
[85]	IoT Integration and Health Outcomes Prediction	Massive implementation of smart sensors and advanced wearable devices, allowing continuous monitoring of vital parameters such as heart rate and blood pressure.
[86]		Creation of predictive models based on data collected by remote monitoring devices, focusing on the identification of patients with a greater probability of improving their health.
[87]		Consolidation of remote monitoring systems in personalized care, with a focus on reducing unnecessary hospitalizations and improving the quality of life of patients with cardiovascular diseases.

6.3. Branch 1: Mobile Applications for the Prevention of Heart Disease Risk and Physical Health Management

In the current digital era, mobile applications have become fundamental allies in healthcare, playing a vital role in preventing heart diseases and managing physical health. These innovative technological tools offer individuals the ability to monitor and enhance their cardiovascular well-being from the convenience of their devices. With a growing awareness of the importance of maintaining a healthy heart and preventing cardiovascular conditions, mobile applications provide information, real-time tracking, and personalized advice, empowering users to make informed decisions about their health. This topic has seen a high level of commitment from many researchers worldwide who have focused their efforts on developing solutions that can contribute to the prevention of complications associated with heart diseases.

Authors like Gardner [88] have focused on the development of an affordable foot sensor printed with ink, coupled with the implementation of machine learning techniques. This device aims to contribute to telemedicine and health monitoring in an accessible and effective manner. The article describes how this sensor is built and integrated into telemedicine devices to allow the continuous monitoring of patient health, especially in areas where resources are limited. The focus on ink sensor printing opens new possibilities for more economical and widely accessible healthcare solutions. Seetharam [89] focuses on the use of emerging technologies in the field of echocardiography. The article explores how mobile health, telemedicine, and artificial intelligence are being applied to enhance and optimize the acquisition and analysis of echocardiographic images. These technologies allow greater accessibility to cardiac care, diagnosis, and patient monitoring in remote settings or areas with limited resources. Additionally, the article examines how artificial intelligence is used to automate the interpretation of echocardiographic images, which can lead to more accurate diagnoses and more efficient medical care in cardiology. In summary, the article highlights the importance of the convergence of these technologies in improving cardiac care and clinical decision-making.

On the other hand, Hinchliffe [90] addresses the relationship between obesity and cardiovascular problems, exploring the essential role that digital health technology can play in the care and management of obesity, a major risk factor for cardiovascular diseases. The article examines how digital health solutions, such as mobile apps, tracking devices, and online programs, can provide effective tools for weight management and promoting healthier lifestyles. It also discusses how these technologies can contribute to the prevention of cardiovascular diseases by helping individuals manage their weight, exercise regularly, and improve their overall health. In summary, the article emphasizes the importance of digital health in combating obesity and its positive impact on reducing the risk of cardiovascular diseases.

In recent years, mobile applications have played a crucial role in transforming cardiovascular health care. Since 2018, we have witnessed a rapid evolution in how these technologies not only monitor patient health but also predict, diagnose, and prevent heart diseases. This timeline illustrates the key technological milestones achieved between 2018 and 2024, highlighting significant advances in areas such as artificial intelligence, telemedicine, and personalized health care, see Figure 9 and Table 10.

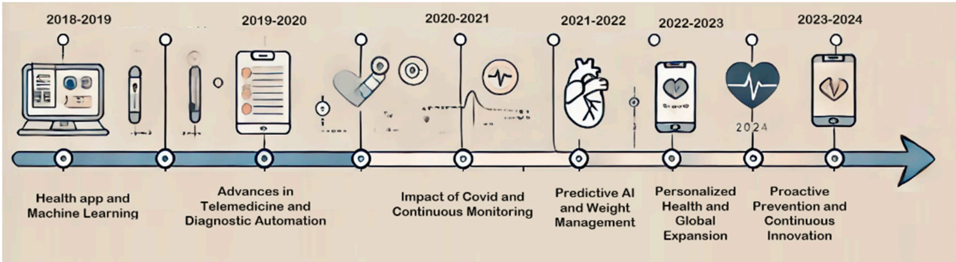

Figure 9. Evolution of Mobile Applications for the Prevention of Heart Disease Risk.

Table 10. Milestone of Mobile Applications for the Prevention of Heart Disease Risk.

Reference	Milestone	Description
[91]	Health App and Machine Learning	Increasing use of apps to monitor cardiovascular health, such as heart rate and blood pressure. Personalization of exercise and diet plans.
[92]		Improved monitoring accuracy through AI and sensors.
[93]	Advances in Telemedicine and Diagnostic Automation	AI and telemedicine improve diagnosis and accessibility in remote areas.
[94]		AI optimizes the interpretation of cardiac images.
[95]	Impact of COVID and Continous Monitoring	Accelerating the use of remote monitoring and telemedicine to avoid hospital visits.
[96]		Continuous Monitoring becomes the norm to ensure continuity of care.
[97]	Predictive AI and Weight Management	AI models are incorporated to identify the risks of cardiovascular diseases.
[98]		Mobile applications support weight management, which is crucial for the prevention of heart disease.
[99]	Personalized Health and Global Expansion	Technology focused on personalizing care according to individual responses.
[100]		Improved accessibility and availability worldwide
[101]	Proactive Prevention and Continous Innovation	Evolution toward applications that actively prevent heart disease through AI and wearable devices.
[102]		Integration of new technologies such as AR and VR in cardiac health education and prevention.

6.4. Branch 2: Remote Cardiac Monitoring Devices for Clinical Tracking of Cardiovascular Patients

Remote Cardiac Monitoring Devices (RCMDs) play a vital role in the clinical care of patients with cardiovascular diseases, and their increasing adoption has transformed how these conditions are approached and managed. In a world where cardiovascular diseases are among the main causes of morbidity and mortality, remote monitoring offers a series of crucial advantages that have revolutionized cardiovascular health care. One of the most significant aspects of the importance of RCMDs lies in their ability to detect cardiac issues early. Heart diseases, including atrial fibrillation and other arrhythmias, can present subtle or intermittent symptoms that often go unnoticed in conventional medical care. However, these devices allow continuous monitoring and, therefore, early identification of any abnormalities, which in turn facilitates a more timely and accurate diagnosis. This early detection is crucial, as appropriate treatment in the early stages can make a difference in the prognosis and quality of life of the patient. In addition to early detection, RCMDs provide the possibility of constant and comprehensive monitoring of patients with chronic cardiovascular diseases. For those living with long-term cardiac conditions, remote monitoring becomes an essential tool for continuously assessing their health status. Physicians can access real-time data on heart rate, blood pressure, and other relevant parameters, allowing them to make informed decisions about adjustments in treatment, medication, and lifestyle for their patients. This level of control and monitoring not only improves clinical care but also empowers patients to actively participate in their care and decision-making. Mobility and accessibility are key features of RCMDs as they allow patients to keep a constant record of their cardiovascular health from the comfort of their home or wherever they are. This eliminates the need for frequent visits to medical centers, which in turn reduces the financial burden and stress associated with travel. Additionally, in emergency situations, these devices can automatically alert healthcare professionals, which could be crucial for saving lives. Another significant advantage is the customization capability that RCMDs offer. Each patient can benefit from a monitoring approach tailored to their specific needs, meaning that the most relevant data for their condition can be recorded and analyzed. This ensures more accurate care and a more effective intervention when necessary. In this line of work, various advances in technological development have been made.

Moghadam [103] focuses on the development and validation of an automated monitoring system based on deep learning to assess cortical activity in neonates. Monitoring brain activity in premature or neurologically at-risk newborns is crucial for identifying potential health issues and providing early and appropriate medical care. The tool developed in this study uses electroencephalography (EEG) to record the electrical activity of neonates' brains. What distinguishes this research is the application of advanced deep learning techniques to automatically classify and analyze brain activity patterns, reducing the need for manual interpretation by specialists. The article describes in detail the methodology used, including the construction of a classification model based on deep neural networks and its training with neonatal EEG data. Additionally, an external validation of the model is performed using an independent cohort of neonatal patients, which strengthens the reliability of the results. The relevance of this study lies in its contribution to the field of neonatal care and evidence-based medicine. The automation of EEG analysis can accelerate the detection of neurological issues in neonates and, ultimately, improve medical care and clinical outcomes. The article provides a comprehensive overview of the methodology and results, making it a valuable contribution to medical research and high-quality neonatal care.

Meanwhile, Shiwani [104] addresses a highly relevant topic in the field of healthcare and cardiovascular disease management. This study focuses on the review and analysis of recent technologies that allow continuous monitoring of health and mobility indicators in patients with cardiovascular diseases. Traditionally, this monitoring was performed in periodic clinical settings, which limited the amount of data available and made it difficult to detect early changes in patients' health. The article examines a range of innovative technologies and devices that have emerged in recent years to address this challenge. These devices can range from wearable sensors and remote monitoring devices to mobile apps and cloud platforms. Their main goal is to enable the continuous collection of data related to the health and mobility of patients with cardiovascular diseases. The review provides a detailed overview of the current technologies available and how they are applied to measure key indicators, such as heart rate, blood pressure, physical activity, and other health-related parameters. Additionally, the advantages and challenges associated with implementing these technologies in clinical care and cardiovascular disease management are discussed. The importance of this article lies in its contribution to improving medical care for patients with heart diseases. Continuous monitoring and the availability of real-time data can facilitate more timely and personalized intervention, which ultimately can improve patients' quality of life and reduce the risk of complications. This study provides valuable insights for healthcare professionals, researchers, and technology developers interested in monitoring cardiovascular diseases.

Sheikh [105] focuses on a fundamental aspect of cardiovascular health: blood pressure variability and its relevance in clinical practice. The study addresses a topic of great importance, as blood pressure is a key indicator of cardiovascular health, and its variability can have significant implications for the diagnosis and management of cardiovascular diseases. The article begins by exploring the evolution in our understanding of blood pressure variability over time, from early clinical observations to current advances in measuring and analyzing this variability. It highlights how blood pressure variability has evolved from being an underestimated concept in the past to being recognized as an important factor in assessing cardiovascular risk. The study analyzes the clinical importance of blood pressure variability in various contexts, including predicting cardiovascular events, assessing treatment response, and its impact on brain health. Additionally, the tools and techniques available for measuring and quantifying blood pressure variability in clinical practice are discussed, which can help healthcare professionals make more informed decisions about patient management. A significant part of the article focuses on future perspectives in the field of blood pressure variability. Emerging research areas and advanced technologies that are enabling more accurate and continuous monitoring of blood pressure, such as wearable devices and telemedicine, are highlighted. These advancements promise more personalized medical care and a better understanding of blood pressure dynamics over time.

Figure 10 and Table 11 illustrate the evolution of Remote Cardiac Monitoring Devices (RCMD) technology from 2018 to 2024, highlighting key advancements that have transformed cardiovascular care. During this period, the technology has seen consolidation, with innovations improving accessibility and personalized care. The mass adoption driven by the COVID-19 pandemic underscored the importance of RCMDs, enabling continuous and remote care. As technology advances, there has been an increased emphasis on the integration of artificial intelligence and proactive prevention, marking a shift toward more comprehensive and personalized management of cardiovascular health.

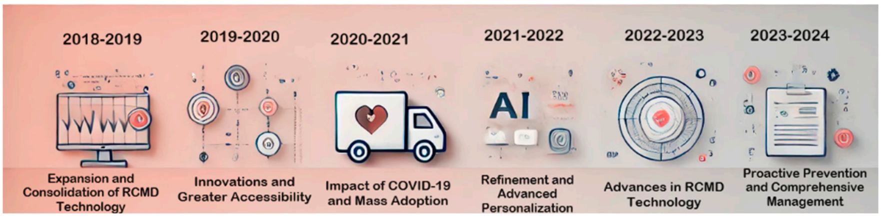

Figure 10. Evolution of Remote Cardiac Monitoring Devices for clinical tracking of cardiovascular patients.

Table 11. Timeline analysis of Remote Cardiac Monitoring Devices (RCMDs).

Reference	Milestone	Description
[106]	Expansion and consolidation of RCMD Technology	Early Detection and Continuous Monitoring: In recent years, RCMD technology has begun to consolidate, with a focus on the early detection of cardiac problems such as atrial fibrillation and other arrhythmias. The devices allow for continuous monitoring, capturing essential data that facilitates more accurate and timely diagnoses.
[107]		Advances in Personalization: Personalized monitoring of patients with chronic cardiovascular diseases becomes a priority, with RCMDs providing real-time data on heart rate and blood pressure, improving clinical decision-making.

Table 11. *Cont.*

Reference	Milestone	Description
[108]	Innovations and Greater Accessibility.	Integration of New Technologies: During this period, more advanced and accessible devices are introduced, including wearable sensors and cloud-based monitoring platforms. These innovations enable continuous data collection, improving the ability of healthcare professionals to intervene in a timely manner.
[109]		Reduction of Geographic Barriers: The implementation of these devices reduces the need for frequent visits to medical centers, offering patients greater autonomy and access to monitoring from anywhere.
[110]	Impact of COVID-19 and Mass Adoption	Pandemic Acceleration: The COVID-19 pandemic drives mass adoption of RCMDs, as health restrictions increase the need for remote monitoring. The devices become essential to avoid exposing patients to hospital environments, allowing continuity of care from home.
[111]		Emergency Comprehensive Monitoring: RCMDs are used for more comprehensive monitoring, assessing not only cardiac health but also other vital indicators, reinforcing their role in overall health management.
[112]	Refinement and Advanced Personalization	Development of Predictive Algorithms: Advanced algorithms based on artificial intelligence (AI) are integrated into RCMDs to identify risk patterns in real time, offering preventive alerts and personalized recommendations to patients and doctors.
[113]		Comprehensive and Personalized Monitoring: Devices now allow for a more personalized approach to care, with the ability to adjust monitoring and interventions based on each patient's specific needs.
[114]	Advances in RCMD Tecnology	Continued Technology Innovations: RCMDs incorporate new technologies, such as augmented reality (AR) and virtual reality (VR), to improve heart health education and training. Additionally, more sophisticated sensors are being developed to capture data with greater precision.
[45]		Global Expansion: These devices become more accessible globally, with efforts to reduce costs and improve availability in developing countries.
[115]	Proactive Prevention and Comprehensive Management	Focus on Proactive Prevention: RCMDs are evolving to not only monitor and diagnose but also actively prevent the onset of heart disease by integrating AI and data from wearable devices.
[116]		Comprehensive Patient Management: The combination of technologies allows for more comprehensive and personalized management of cardiovascular health, marking a change toward more preventive and less reactive care.

6.5. Branch 3: Deep Sleep-Based Technological Heart Monitoring for Stroke-Related Diseases

Deep sleep-based technological heart monitoring plays a crucial role in the care of stroke-related diseases due to a series of interconnected factors that positively impact patients' cardiovascular health. Firstly, this monitoring mode is essential for the early detection of sleep disorders, such as sleep apnea, which can disrupt the deep sleep cycle, alter blood pressure regulation, and significantly increase the risk of stroke. Detecting these disorders during deep sleep provides a crucial opportunity for their timely diagnosis and treatment. Moreover, during this sleep phase, the heart may experience cardiac arrhythmias that, if not identified and appropriately treated, can contribute to the development of strokes and other severe cardiovascular problems.

Heart monitoring devices enable the early detection of abnormal heart rhythm patterns, allowing for immediate medical intervention and the implementation of appropriate treatment. Additionally, continuous monitoring during deep sleep offers a comprehensive assessment of a patient's cardiovascular risk by measuring heart rate variability, providing valuable information about the health of the autonomic nervous system and the risk of cardiovascular events, such as strokes. For patients who have survived a stroke, technological heart monitoring is essential to prevent recurrent cerebrovascular events. Constant monitoring can identify signs of risk and allow health professionals to adjust treatment and provide specific recommendations to reduce the risk of a second stroke. Moreover, this type of monitoring offers long-term care and continuous tracking of patients' cardiovascular health, facilitating the early identification of any changes in their condition and the adaptation of their care plan.

Lastly, but importantly, technological heart monitoring during deep sleep can significantly improve patients' quality of life. It provides patients and their doctors with peace of mind knowing that proactive steps are being taken to protect their cardiovascular health, which can reduce the anxiety and stress associated with the risk of stroke and ultimately enhance their overall well-being. In summary, deep sleep-based technological heart monitoring is an essential tool in the prevention, diagnosis, and treatment of stroke-related diseases. It offers a unique window into the heart's functioning during a critical sleep phase and allows for more personalized and effective care for patients at risk of stroke or those who have experienced a cerebrovascular event, which can have a significant impact on their quality of life and well-being.

Among the most notable works in this subline, those carried out by Doobie [117] address the relationship between physical activity, obesity, and the use of technology in health services, focusing on sleep analysis in cardiovascular patients. Obesity is a significant risk factor for cardiovascular diseases, and physical activity is a crucial strategy for preventing and treating obesity, as well as improving cardiovascular health. However, for exercise programs to be effective, it is essential to monitor and assess patients' progress, and this is where technology comes into play. Sleep analysis plays a crucial role in this context, as inadequate or interrupted sleep can contribute to obesity and increase the risk of cardiovascular diseases. Technology offers tools such as wearable sleep monitoring devices and mobile apps that can help patients track their sleep patterns and identify potential issues, such as sleep apnea, which may be related to obesity and cardiovascular diseases. The article also discusses how technology can be used to create personalized exercise programs and monitor the physical activity of patients with obesity and cardiovascular diseases. Physical tracking devices, such as smartwatches and activity sensors, allow the recording of the amount of exercise performed, heart rate, and other relevant parameters, providing health professionals with valuable information to tailor exercise programs according to the individual needs of each patient.

Itchhaporia [118] focuses on the digital transformation in medicine and how it can improve quality of life, longevity, and health equity. Although the article does not explicitly mention sleep and cardiovascular diseases, it is relevant in this context. The digital transformation in medicine encompasses a wide range of technologies and approaches that have a significant impact on healthcare and the management of chronic diseases, including cardiovascular diseases. One area where technology has proven particularly useful is in monitoring and managing cardiovascular diseases, and this is where it relates to sleep. Sleep quality is essential for cardiovascular health. Sleep disorders, such as sleep apnea, can increase the risk of cardiovascular diseases, including hypertension and heart disease. Digital technology, such as sleep monitoring devices and mobile apps, allows patients and doctors to assess and manage sleep patterns effectively. These devices can record sleep duration, heart rate during sleep, and other relevant data, providing valuable information to identify sleep-related problems associated with cardiovascular health. Additionally, telemedicine and virtual medical consultations, which are part of the digital transformation in medicine, allow patients to access medical care and evaluate their sleep issues conveniently and efficiently. This is especially important for individuals who may have difficulty accessing traditional healthcare, thus contributing to health equity.

Rosenberger [119] focuses on a study that investigates sleep behavior, sedentary behavior, and physical activity over a 24 h period using nine wearable devices (wearables). The study focuses on the use of wearable technology to assess and understand sleep patterns and physical activity in a daily living environment. The nine wearable devices used in the study are used to collect data on the sleep, inactivity, and physical activity of participants over a full day. The main objective of the study is to provide a detailed and accurate insight into how people sleep, how much time they spend in sedentary behaviors, and how much time they dedicate to physical activity throughout the day. These data are crucial for understanding the health and wellness habits of individuals and can be useful for health professionals, researchers, and physicians. The article focuses on the importance of using wearable devices as valuable tools for monitoring and real-time data collection on sleep behavior and physical activity. The information obtained through these devices can help individuals make informed decisions about their lifestyle and health.

Figure 11 and Table 12 illustrate the evolution of deep sleep-based cardiac monitoring from 2018 to 2024. Over these six key years, important milestones are highlighted in the consolidation and expansion of this technology, advancing toward innovation, personalization, and accelerated digital transformation. Technological refinement and continuous evaluation enabled sustained global expansion, culminating in a proactive approach to the prevention and comprehensive management of cardiovascular health. This visual representation summarizes how these developments have transformed cardiac monitoring, improving the precision and scope of patient care.

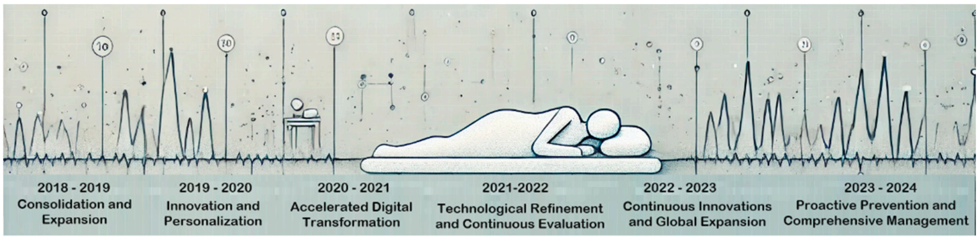

Figure 11. Evolution of deep sleep-based technological heart monitoring for stroke-related diseases.

Table 12. Timeline analysis of the evolution of deep sleep-based cardiac monitoring technology for stroke-related diseases.

Reference	Milestone	Description
[120]	Consolidation and Expansion	During these years, the focus on deep sleep monitoring consolidated, primarily in the early detection of sleep disorders such as sleep apnea, which increases the risk of stroke. Continuous monitoring allowed for the detection of cardiac arrhythmias during deep sleep, providing crucial opportunities for early medical interventions.
[121]	Innovation and Personalization	In this period, technology advanced with the integration of portable devices that allowed for more precise and personalized monitoring. In addition to heart rate variability, the health of the autonomic nervous system began to be analyzed more thoroughly, offering a more comprehensive view of cardiovascular risk. This personalized monitoring facilitated more targeted and effective interventions.
[122]	Accelerated Digital Transformation	The impact of the COVID-19 pandemic in 2020 accelerated the adoption of remote monitoring technologies, including those focused on deep sleep. Telemedicine and digital monitoring allowed patients to continue their care from home, highlighting the importance of sleep in managing cardiovascular health. The ability to remotely track sleep and cardiac health became crucial for the continuity of care.
[123]	Technological Refinement and Continuous Evaluation	During these years, technology continued to be refined with the use of advanced algorithms for more precise and continuous cardiovascular risk evaluation. Studies demonstrated the utility of portable devices for monitoring sleep and physical activity, providing critical data for physicians to adjust treatment plans and prevent stroke events.
[124]	Continuous Innovations and Global Expansion	Technological innovation continued during 2022 and 2023, with advances in the integration of artificial intelligence and augmented reality to improve cardiovascular risk assessment during sleep. These devices became more globally accessible, helping to reduce healthcare disparities and improve the availability of monitoring tools in developing regions.

Table 12. *Cont.*

Reference	Milestone	Description
[125]	Proactive Prevention and Comprehensive Management	In the final stretch of this period, the focus shifted toward proactive prevention and comprehensive management of cardiovascular health. Deep sleep-based monitoring devices are now used not only to detect existing problems but also to prevent the onset of cardiovascular diseases through the integration of AI and real-time data. This holistic approach has marked a shift toward more preventive and personalized care.

7. Discussion

7.1. Technological Challenges

The review presents research that includes telehealth and the use of technological tools for the monitoring and treatment of diseases. However, it is still necessary to solve the problems related to the cybersecurity of medical devices linked to telehealth. In the case of IoT implementation in healthcare, recent research conducted in the U.S. concluded that 75% of IoT medical devices had known security breaches. Additionally, there is a lack of adequate guidance and regulation for these devices, an issue that policymakers around the world must address to prevent the vulnerability of new digital health solutions to cyberattacks [90].

Another challenge in telehealth relates to telerobotics. The lack of relevant clinical experience and the uncharted legal territory for telerobotics in real life may represent significant and potentially fatal barriers to its widespread implementation [126]. Adoption of the technologies also becomes a challenge, as the elderly population with limited information literacy finds it difficult to adopt and use telehealth tools. The availability and accessibility of tracking and monitoring technologies in the markets is another challenge. Another problem to be addressed is the handling of large volumes of data in both data mining and analysis [127]. There are also limitations related to the monitoring sensors, which include lack of control over ambient temperature, obstruction of signals, poor contact between sensors and skin, sensors that record activity but do not take into account the time that participants are resting or practicing sedentary activities, and results that cannot be generalized to all patients, since the individuals in the sample considered in the study may be in more or less advanced stages of the disease [128].

7.2. Data Security

The use of telemedicine raises a number of new issues and challenges related to its implementation or the regulations governing it, including the protection of medical record data containing patients' personal data. This makes patient security and privacy a critical issue in telemedicine given such risks as the theft of patient security data, including text, audio, and image/video data. This is of particular concern when sensitive patient data such as histories of sexually transmitted diseases and mental disorders are involved [129,130]. Studies by various authors have analyzed the privacy and security challenges and risk factors of telehealth, finding three main factors. The first is the environmental factor related to the lack of private space for some populations and the difficulty of sharing information remotely in confidential conversations. The second is the technological factor including data security issues, which limited Internet access and technology. The third is the operational factor related to accessibility to technology [131].

Seeking solutions to these challenges, Nittari et al. propose informed consent inserted in the patient's electronic record [132]. Hua Zhang et al. propose a scheme that integrates a data hiding algorithm into the telemedicine system for the protection of patient information [95]. Jing has reviewed the security problems at the application, transport, and network layers, stating that the direction to overcoming the security problems in telemedicine is to research on lightweight algorithms to maximize security with fewer resource usage considerations. Yan et al. suggested various methods, such as data cryptography and authentication protocols, as a solution to reduce security threats. On the other hand, Zhang et al. proposed an approach to use biometrics derived from the patient's body to generate high-quality but different random numbers at each step as a key to protect wireless communication. Komal has used an intrusion detection system (IDS) as a tool to monitor traffic and protect the cloud [133].

7.3. Post-COVID Impacts

The COVID-19 pandemic was an exceptional, unforeseen, and unexpected event that marked a milestone in world history. This event set a precedent in various fields, especially in the area of health, since it caused profound changes in hospital facilities as well as in their organization. It also brought to light the deficiencies of hospital and territorial systems in all their articulations [134]. This event, in addition to altering healthcare, generated an accelerated development of telemedicine and its services. Since before the pandemic, in the last decade, many telemedical services have been gaining ground, including tools such as teleconsultations, electronic prescriptions, teleradiology, and telecardiology. However, these digital telemedical technologies had low market penetration, and there was a lack of user awareness [135]. As the pandemic progressed, there was increased interest from physicians and healthcare in increasing telemedicine and the use of handheld devices in patient care [136].

The above can be analyzed with research such as that of Lilas Dagher et al., in which they developed a cardiovascular clinic patient survey to assess the challenges and opportunities of digital health adoption during the COVID-19 pandemic. This study found that only 10.8% of participating patients reported using telemedicine for clinical care prior to the onset of COVID-19. Post-pandemic, a significant increase of 24.3% of patients were found to initiate telemedicine use. Additionally, when asked about barriers to care alleviated by telemedicine, the majority of participants recorded that telemedicine helped overcome challenges in finding reliable physicians (75.2%), resolving transportation issues (67.9%), and maintaining social distancing measures (63.3%) [137]. With the successful implementation and deployment of these emerging technologies during the evolution of the pandemic and acceptance by users, the burden on healthcare systems can be reduced, and clinical outcomes can be improved by timely intervention, identifying any deterioration and exacerbation at an early stage; diagnosis and treatment can be rapid with detection of suspected and asymptomatic/presymptomatic cases; and contacts between medical personnel and patients can be minimized by remote monitoring and care. Because of this, the use of telemedicine holds great promise for reducing costs, promoting patient follow-up and prevention, and combating pandemics such as COVID-19 [137].

7.4. Socioeconomic Factors

According to Lilas Dagher et al., there are significant demographic differences in current and previous use of portable health devices and telemedicine, as well as in attitudes toward these digital health tools. In this research, it is observed that prior to COVID-19, there were no statistical differences in telemedicine use among the different demographic groups of participants. However, it was determined that patients with a higher educational level and younger patients made more frequent use of telemedicine. This is due to greater economic barriers that have generated a lower educational level and lower accessibility to the Internet, as well as the ease with which young people adapt to technology. In addition, the perceived cost-benefit ratio and literacy [138,139]. The economic and technological development gaps between developed and developing countries also generate limitations and challenges in the use of digital health. One of the main barriers is the lower public spending on health compared to developed countries. Low literacy rates, a lack of trained and qualified personnel for the implementation of digital health services, and a lack of availability of digital tools and services such as cell phones, computer systems, and Internet connections in rural and remote areas make these systems work suboptimally. Therefore, it is necessary to analyze the environmental factors for the implementation of telehealth [140,141].

8. Conclusions

The evolution of Internet of Things (IoT) technologies in monitoring cardiovascular patients has been transformative, revolutionizing the prevention and management of cardiovascular diseases. However, to maximize the impact of these innovations, it is crucial to provide clear recommendations for future research and practical implementation.

Continuous and Specific Technological Improvement: Although current technologies have proven effective in early detection and continuous monitoring, future research must focus on improving the accuracy and predictive capabilities of these devices. This could include the development of more sophisticated artificial intelligence and machine learning algorithms that not only identify risks but also predict the onset of cardiovascular events with greater precision.

Expansion of Access and Global Adoption: The integration of advanced technologies in cardiovascular monitoring must be accessible to a global audience, especially in regions with limited resources. Future research should explore ways to reduce the production and distribution costs of these devices, as well as ensure their interoperability across different healthcare systems.

Practical Application in Healthcare: To maximize the benefits of these technologies, it is essential that healthcare professionals are trained in their use. Medical institutions should develop training programs that include the management of IoT devices and real-time data interpretation to optimize clinical decision-making and reduce the need for invasive interventions.

Interdisciplinary Research for Continuous Innovation: Promoting collaboration between disciplines such as biomedical engineering, computer science, and medicine will be crucial in driving innovation in this field. This collaboration can accelerate the development of more advanced technologies and ensure that solutions are both scientifically sound and clinically applicable.

Ethics and Data Security: As monitoring technologies become more ubiquitous, future research must address ethical and data security concerns. It is vital to develop robust protocols that protect patient privacy while maximizing the value of the data collected to improve health outcomes.

Long-Term Impact Evaluation: Longitudinal studies are needed to evaluate the long-term impact of these technologies on cardiovascular health. This research will help refine clinical practice recommendations and identify areas where adjustments are needed to improve outcomes.

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