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Internet of Things in Telemedicine: A Systematic Review of Current Trends and Future Directions

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ABSTRACT

The main aim of this review paper is to explore the role of Internet of Things (IoT) technologies in telemedicine and their impact on healthcare outcomes, focusing on chronic disease management, elderly care, and emergency services. This study conducted a systematic review following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). The research identified 15 peer-reviewed articles published between 2010 and 2024, focusing on the integration of IoT in telemedicine. Scopus database was chosen because it indexes scientific documents from various disciplines, such as Computer Science, Engineering, and Medicine. The following search terms were used: “IoT” OR “Internet of Things” AND “Telemedicine.” After screening the titles, abstracts, and full texts, 15 studies met the inclusion criteria for analysis. The review found that IoT technologies significantly improve patient outcomes, with chronic disease management showing a 20-30% reduction in complications. Cloud integration enhances scalability and real-time monitoring, facilitating better elderly care, especially in remote areas. However, challenges related to data security, interoperability, and the cost of IoT devices were noted. The findings suggest that IoT holds great potential for transforming healthcare delivery, further research is needed to address data privacy challenges, cost-effectiveness, and integration into existing healthcare systems. These insights are valuable for healthcare providers, policymakers, and technology developers working to implement IoT-based solutions in telemedicine.

1. INTRODUCTION

The Internet of Things has created a revolution in many sectors, and one of the most impacted sectors is the healthcare sector [1]. The application of IoT has especially seen telemedicine, the diagnosis and treatment of patients through telecommunications, make remarkable progress [2]. The IoT facilitates monitoring, data gathering, and analysis in telemedicine, making the services efficient and effective [3]. Telemedicine has leveraged the Internet of Things (IoT) to enable long-distance patient monitoring, thus minimizing in-person consultations and relieving healthcare infrastructures [4]. Wearable sensors and smart health monitoring systems are IoT devices that capture various health data, including heart rate, blood sugar, and physical activity [5]. The collected data is also relayed to healthcare givers in real time to facilitate timely interventional and personalized care [6]. The continuous observation of patients has been most helpful in managing chronic diseases, patient outcomes, and the cost of health care [7, 8]. Combining IoT with telemedicine, though pointing out some promising developments in advancement, also has some issues. The current problems that dominate the industry include data privacy, security, and compatibility [9]. Due to the large amount of data being produced by IoT devices, it is necessary to develop effective security measures to prevent the leakage of patient data [10]. Furthermore, the lack of well-defined policies for interoperability between diverse IoT devices and healthcare systems does not enable the integration of these technologies [11]. Solving these challenges is relevant to IoT's high usage and efficiency in telemedicine [12].

Another critical aspect of the Internet of Things in telemedicine is bridging the gap in healthcare for remote and underserved areas [13]. Besides, the IoT-based telemedicine platform can deliver quality health services to many populations with restricted access to hospitals and other health facilities [14]. For instance, remote diagnosis tools and virtual consultations may considerably reduce the geographical and other barriers related to access to healthcare [15]. The application of IoT in democratizing healthcare could have significantly to the: improved health and decrease the health gap [16, 17]. The future of IoT in telemedicine is expected to be defined by more interaction with other advanced technologies such as AI and ML [18]. In this regard, use of AI and ML algorithms can process the big data produced by IoT devices to offer and to use predictive analytics and identify diseases at an early stage [19]. The combination of IoT and AI/ML will lead to the raise of reliable and effective telemedicine services, therefore proactive and patient-centered model of health care delivery [20]. Besides, the 5G technology will also have a powerful impact on revolutionising the Internet of Things (IoT) concerning telemedicine by providing a way of fast transfer of data, low latency and high connectivity [12]. Improved performances of 5G will are capable of supporting more complex IoT applications including remote medicine and accurate health control, to expand the horizons of telemedicine [12]. With the maturation of these technologies, IoT's contribution to telemedicine will become more and more vital within the matrix of modern healthcare delivery [21]. Despite significant advancements in IoT's integration into telemedicine, critical gaps still need to be in understanding its full potential. While IoT enables real-time patient monitoring, personalized care, and improved access to healthcare, challenges such as data privacy, security concerns, interoperability issues, and the lack of standardized protocols persist. Furthermore, integrating emerging technologies like AI, ML, and 5G into IoT-enabled telemedicine has not been fully explored, nor has the socio-economic implications, such as accessibility and affordability, been thoroughly addressed. This systematic review aims to fill these gaps by examining existing literature, identifying trends, and exploring IoT's future possibilities and challenges in healthcare.

The review seeks to answer specific research questions, including: What are the current applications of IoT in telemedicine, and how are they improving patient outcomes? How do AI, ML, and 5G technologies enhance IoT-enabled telemedicine? What are the main challenges in implementation, and how can they be overcome? How can IoT telemedicine bridge healthcare gaps in underserved areas? What socio-economic barriers exist, and how can IoT make telemedicine more inclusive? Finally, what are the future directions for IoT in telemedicine? The review follows a systematic methodology, using the Scopus database to identify relevant studies published between 2010 and 2024, ensuring a comprehensive field analysis.

2. METHODOLOGY

The section details the search strategy and selection criteria for identifying relevant literature on IoT in telemedicine.

2.1 Search strategy

For this systematic search, the Scopus database was chosen because it indexes scientific documents from a wide range of disciplines, such as Computer Science, Engineering, and Medicine. The Scopus index contains a large number of peer-reviewed journals and other scholarly content in health and medical sciences and, therefore, can be useful when conducting SRs of IoT and Healthcare.

The following search terms were used: “IoT” OR “Internet of Things” AND “Telemedicine”. These keywords were chosen to capture all the relevant literature necessary for the study since the focus is on the use of IoT in telemedicine. Using these specific terms, it was expected that only articles, conferences, and review papers that discuss the technological trends, applications, innovative adaptation, and essential research findings in improving telemedicine services through IoT would be retrieved. This approach guarantees a systematic evaluation of current advancements and prospects in the application of IoT in telemedicine.

Each search also encompassed the period of database commencement up to 2024 to capture as many papers published within the given period as possible. Publication types included were only journal articles, conference, and review papers written in English because these types of papers have passed through rigorous peer review and offer more detailed information about research findings in the field of interest.

2.2 Selection criteria

The selection criteria for this systematic review adhered to the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement [22]. Initially, a comprehensive search yielded 1,228 documents. The search was conducted within the timeframe spanning from 2010 to 2024. The selection of this timeframe was based on the significant advancements in IoT and telemedicine during this period, marking a shift in integrating IoT technologies into healthcare practices. The search excluded articles published before 2010, as IoT's application in telemedicine was still nascent, and the volume of relevant literature before this period was minimal. The review ensured that the field's most current and impactful developments were captured by focusing on this period, which included 998 documents. Subsequently, the language was limited to English, reducing the count to 978 papers.

Additional refinement was applied by limiting the source type to journals and conference proceedings, resulting in 903 documents. Further selection based on the publication stage yielded 895 papers. Finally, duplicate documents were identified and excluded, resulting in the exclusion of 4 papers. This systematic process ensured a comprehensive and focused review, leading to the inclusion of 891 relevant records.

2.3 Quality assessment

This study conducted an initial quality assessment and a second assessment based on the following criteria to make the review more reliable. The analysis was performed only on original research articles, conference papers, and review papers. In the context of the quality assessment, certain specific criteria were used to assess the chosen documents. This involved an examination of the method used, how the research related to the goals of the review and the implications of the studies detailed in the literature review for the field of telemedicine IoT. The sources were checked to ensure no duplicate records, and any duplicate records were deleted. Special attention was paid to these records to make the study more rigorous and ensure that each article was reviewed. To make the selection more precise, the abstracts of the identified papers were carefully assessed to determine their suitability to be included in the study. This involved a strict set of procedures for the choice of documents that were considered fit for review during the process. Among the papers reviewed, 567 were rejected for some reason. Duplicates were removed, and the abstracts were reviewed, leading to 324 full-text articles that were assessed for relevance. Each publication was screened using the title, abstract, and keywords for factor analysis to decide whether to include it in the review.

Throughout the trial searches, 343 articles were found. After a thorough screening, 15 of these articles were included in the review. The study was conducted using the steps outlined in the PRISMA statement, ensuring it was rigorous and transparent. Figure 1 illustrates how the PRISMA is used to visually represent the process of including and excluding studies at each stage of the review.

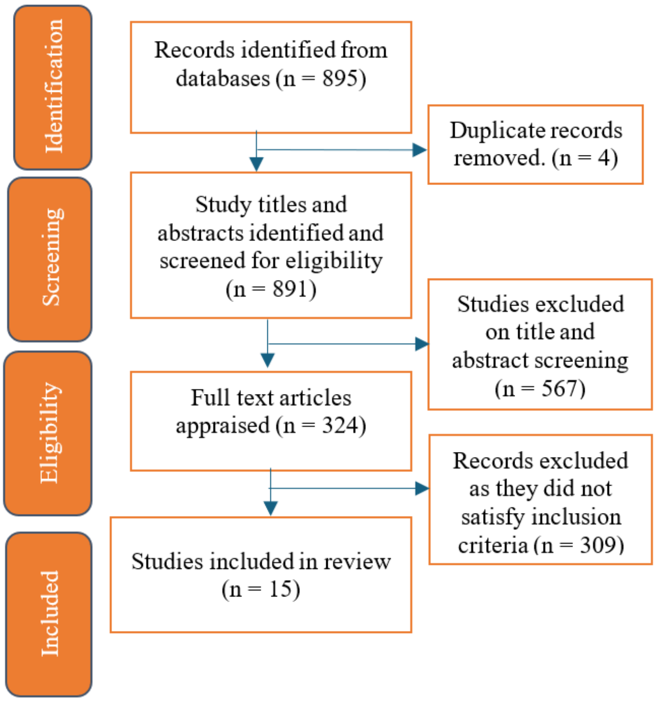

Figure 1. Selection process

3. RESULTS

3.1 Documents and citations per year

Figure 2 illustrates the number of documents published and their citations from 2010 to 2024 in IoT in telemedicine. The number of published documents shows a gradual increase, starting from 3 in 2010 and peaking at 177 in 2023, indicating a growing interest and research activity in this field. The number of citations follows a similar upward trend but with more pronounced fluctuations. Citations peaked dramatically at 3,320 in 2020, reflecting the high impact and relevance of research during that period, possibly due to the increased focus on telemedicine solutions amid the COVID-19 pandemic. Following this peak, there is a notable decline in citations to 1,421 in 2022 and 1,020 in 2023. This may indicate that while new publications continue to emerge, the immediate impact of earlier works is waning. The data for 2024 shows a further drop in citations to 79, suggesting either a plateau or the fact that citations typically accumulate over time, and recent publications have not yet had the time to be widely cited. Overall, the figure highlights a robust and growing body of research in IoT telemedicine, with significant spikes in citation impact correlating with periods of heightened global interest in remote healthcare solutions.

3.2 Documents by subject area

Figure 3 highlights the distribution of research documents across various disciplines, with the majority being in Computer Science (26.4%), followed by Engineering (20.2%) and Medicine (12.2%). This distribution aligns well with the multidisciplinary nature of IoT in telemedicine and emphasizes the role of Computer Science in developing secure communication systems and data analytics for telemedicine. Engineering plays a significant role in designing and implementing IoT devices and infrastructure. The substantial representation of Medicine reflects the critical application of IoT in healthcare for disease management and patient monitoring. However, other fields such as Biochemistry (4.7%), Mathematics (4.7%), and Physics (7.2%) are less represented, indicating a potential area for more interdisciplinary collaboration to further enhance IoT telemedicine solutions. This data suggests that while current research is heavily concentrated in Computer Science and Engineering, there is ample opportunity for other scientific domains to contribute to this evolving field.

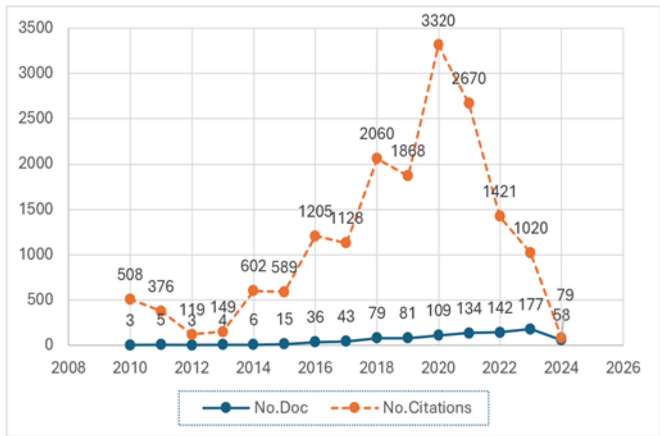

Figure 2. Documents and citations per year

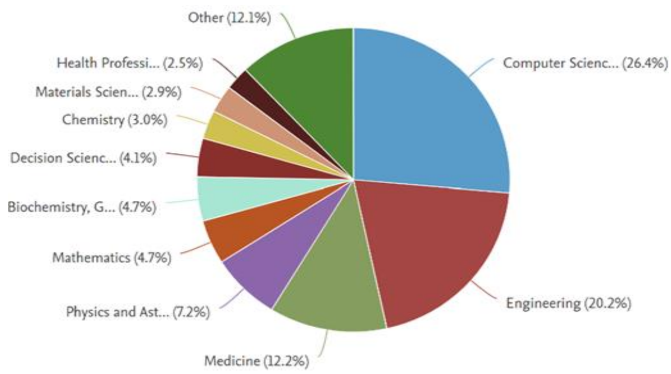

Figure 3. Documents by subject area

3.3 Documents by affiliation

Figure 4 illustrates the contributions of various universities to the field of IoT in telemedicine, with Debreceni Egyetem leading with nine documents, followed by Fudan University and King Saud University with seven each. Other significant contributors include SRM Institute of Science and Technology, Menoufia University, and the Faculty of Electronic Engineering with six documents each, and the University of Electronic Science and Technology, Chinese Academy of Sciences, and the Ministry of Education of the People's Republic of China also contributing six documents each. The University Politehnica of Bucharest contributed five papers. This distribution highlights a diverse international effort, with substantial contributions from institutions across Europe, Asia, and the Middle East, reflecting a global recognition of IoT's potential in transforming healthcare. The even distribution among these leading institutions indicates a widespread and collaborative effort, aligning with the multidisciplinary nature of IoT in telemedicine, bringing together expertise from various technological and medical fields.

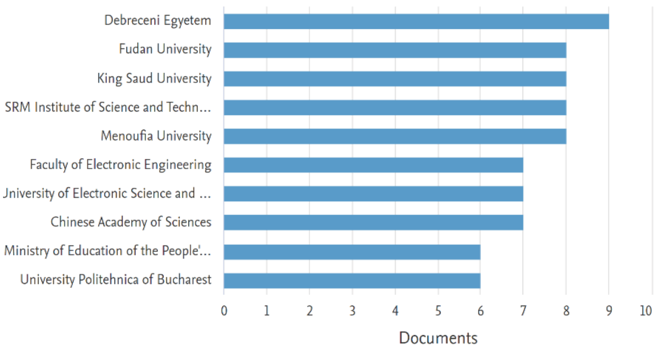

Figure 4. Documents by affiliation

3.4 Documents by country or territory

Figure 5 also illustrates the contributions made by various countries in the smarter world associated with IoT in telemedicine. India contributes to more than 200 documents, China contributes to about 150 documents and United States contributes to about 100 documents. Italy and the United Kingdom can also be seen to have contributed significantly with about fifty papers each. Other contributors are Saudi Arabia, South Korea, Canada, Malaysia, and Spain that contributed between twenty five and thirty documents. This distribution shows a high level of international interest in IoT telemedicine research with both developed and developing countries participating. The first two contributions from India and China are indicative of the speed at which technology is developing and research is being conducted in these countries. On the other hand, the articles originating from the United States, Italy, and the United Kingdom represent the well-developed research systems and the current developments in the telemedicine field. The distribution of remains more or less balanced between the remaining countries shows that they also have high concern and synergy to bring improvement in use of IoT in healthcare sector internationally.

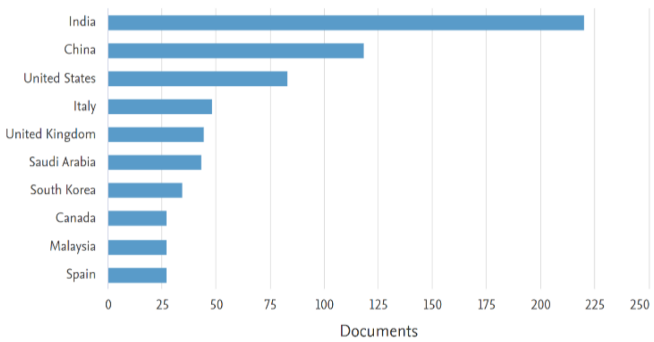

Figure 5. Documents by country or territory

3.5 Documents by type

Figure 6 illustrates the distribution of research documents on IoT in telemedicine, categorized into articles, conference papers, and reviews. Articles constitute the largest portion, making up 48% of the documents, indicating a strong emphasis on detailed, peer-reviewed research studies in this field. Conference papers follow with 38%, reflecting the dynamic nature of ongoing research and the frequent dissemination of preliminary findings and innovative ideas in conferences. Reviews, comprising 14% of the documents, highlight the efforts to synthesize existing research and provide comprehensive overviews of current trends and future directions in IoT telemedicine. This distribution underscores the balanced approach in the research community, where extensive studies, emerging research, and comprehensive reviews all contribute to advancing the field.

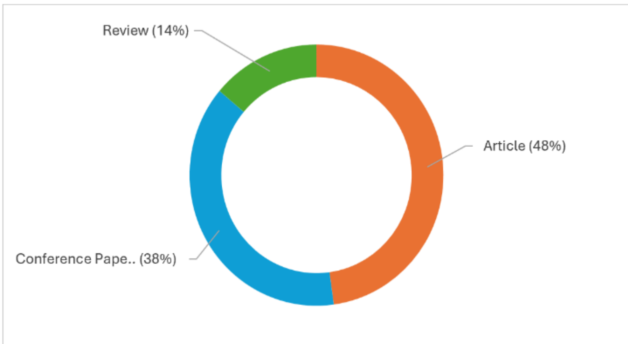

Figure 6. Documents by type

In line with these findings, IoT in telemedicine is transforming remote health monitoring and chronic disease management through systems like "Saleem" for diabetes and "TeCa" for cardiovascular care, enabling better patient self-management and reducing hospital visits. Elderly care systems, monitoring heart rate and blood flow, are improving health interventions in vulnerable populations. Key advancements in system design focus on secure communication and network integration, with 5G-IoT and cloud computing improving reliability, especially in remote areas. Wearables and low-cost devices like the "Smart Chair" and telemedicine robots are bridging healthcare access gaps, especially in underserved regions. In emergency response, IoT enhances EMS with real-time data transmission and AI-powered systems, like soft cyborgs, to monitor at-risk individuals and alert caregivers during emergencies. AI and big data are increasingly integrated for predictive health outcomes, with federated learning enhancing scalability and effectiveness in disease management.

Future research should focus on expanding IoT systems, improving data security and privacy with technologies like blockchain, and validating their impact through clinical trials. Affordable IoT solutions are essential for accessibility, particularly in low-resource settings, while scalable telemedicine devices like robots and rehabilitation systems offer significant potential for broad adoption. The methodological approaches across the studies showcase a combination of systematic reviews, clinical trials, experimental designs, and feasibility studies. These methodologies evaluate the effectiveness, reliability, and feasibility of various IoT applications, with clinical trials offering insights into real-world patient outcomes and systematic reviews synthesizing existing findings to provide comprehensive overviews. Studies also use AI algorithms, real-time data collection, and sensor technologies to test the operational viability of IoT systems in diverse healthcare settings. Integrating these methods ensures a multi-faceted exploration of the capabilities and challenges of IoT in healthcare.

This section, as shown in Table 1, summarizes the objectives, methodologies, key findings, and recommendations of the 15 selected papers on the role of IoT in telemedicine, focusing on various applications, technological advancements, and future research directions.

Table 1. A content review of the selected articles

References	Objectives	Methodology	Findings	Recommendations
[23]	Identify research priorities and open issues in IoT-based telemedicine, focusing on networks, healthcare services, and applications, and discuss innovative solutions for future research to support healthcare for various diseases.	The paper conducted a systematic review of IoT-based telemedicine, searching three major databases (Science Direct, IEEE Xplore, and Web of Science). After removing duplicates, 141 relevant articles were identified through title, abstract screening, and full-text reviews.	The paper highlights IoT's potential in remote health monitoring, rehabilitation, and chronic disease management, noting that non-communicable diseases cause most global fatalities. It is estimated 4 million patients will use IoT-based remote health monitoring by 202.	The paper Recommended using big data for disease monitoring, developing cyber-physical systems for neurodegenerative disorders, designing affordable stroke rehabilitation wearables, creating home-based medical data systems, and enabling emergency health monitoring with ubiquitous platforms and consolidated health records.
[24]	Propose a privacy-preserved ID-based secure communication scheme in 5G-IoT telemedicine to integrate EMS, ensure immediate emergency signal transmission, secure patient information, preserve privacy, assure healthcare quality, support emergencies, and resist attacks.	System initialization phase. Registration phase. Key update phase. Emergency signal sending phase. Secure ambulance communication phase	The proposed scheme ensures immediate emergency signal transmission, reduces secret key leakage risk, securely transmits patient information, preserves privacy, assures healthcare quality, uses key insulation and federated identity management to prevent key exposure, and is secure against attacks.	Leverage big data and cloud computing for disease management, and develop secure, affordable IoT devices for telemedicine. Ensure privacy and resist attacks in 5G-IoT systems for both emergency and normal healthcare situations.
[25]	Establish a novel telemedicine system that is jointly driven by multinetwork integration and remote control. -Conduct a feasibility study and evaluation of this new telemedicine system	Develop a multilink aggregation algorithm (MLA-BWV) and overlay network (ONTMS) to improve telemedicine stability, implement non-intervention IoT control, and establish network performance testing. Assess satisfaction with a questionnaire and analyze data using the Kolmogorov-Smirnov test, descriptive statistics, and t-tests or Kruskal-Wallis tests.	The new telemedicine system is feasible, reliable, and easily deployable with stable real-time transmission and remote control. It achieved high satisfaction among patients and doctors and addresses uneven medical resource distribution, reduces costs, and supports special scenarios.	Expand the study to include patients from other hospitals and regions for generalizability, incorporate satisfaction data from more doctors across multiple centers, and evaluate the system's performance and effectiveness during non-epidemic periods, not just COVID-19.
[26]	Assess the reliability of the expert system (ES) in creating monitoring plans matching general practitioners (GPs), evaluate ES-supported telemonitoring in reducing GP-patient contacts and hospitalizations, and document satisfaction and safety for patients and medical professionals.	The study develops an expert system (ES) to adjust monitoring intensity for COVID-19 patients at home, using 61 static and dynamic variables from patient data. The ES, consisting of 11 reasoning blocks, evaluates data to provide a risk assessment and determine the monitoring plan. It is implemented as a software module with a REST API for integration into telemedicine systems.	The expert system accurately recommended the best monitoring intensity for COVID-19 patients at home, proving feasible and applicable in telemonitoring. The clinical trial aims to quantify its benefits on clinical practice. Results could be improved by integrating more data sources and using upstream patient risk stratification techniques.	Future research should integrate the expert system with IoT telemonitoring, conduct clinical trials for reliability and effectiveness, prioritize patient satisfaction and safety, and develop innovative solutions for a resilient healthcare ecosystem during infectious disease outbreaks.
[27]	Propose a telemedicine platform using IoMT to connect patients and doctors, enable sensor connections via Wi-Fi, Bluetooth, or GSM, integrate wearable and implanted electronics, compare the communication technologies, and recommend the best one.	The study used a telemedicine platform connecting patients and doctors via IoMT with Wi-Fi, Bluetooth, and GSM. Sensors (heart rate, humidity, temperature, blood pressure, alcohol) on Arduino boards collected data, transmitted to a server, and accessed by doctors through a MATLAB and C# GUI. The performance of the technologies was compared on transmission delay, throughput, cost, range, and infrastructure.	The paper proposes a telemedicine platform connecting patients and doctors using an IoMT system with sensors connected to a server via Wi-Fi, Bluetooth, or GSM. Bluetooth and Wi-Fi are recommended as the best communication technologies for high data rates in video streaming, without needing long-distance coverage or extensive infrastructure.	The authors recommend adding a secure payment mechanism for patients and integrating GPS to improve accuracy and help EMTs locate patients in emergencies.
[28]	Designing a common standard for patient risk scoring during traversal to the hospital To explore the application value of an Internet of Things-based telemedicine management system in the treatment of overweight/obesity in type 2 diabetes mellitus (T2DM) using empagliflozin combined with liraglutide.	Inclusion: T2DM patients with BMI ≥ 24 kg/m² and HbA1c 7-10%. Control: Liraglutide alone (0.6 mg/day, increased to 1.2 mg/day after 1 week). Intervention: Liraglutide + empagliflozin 10 mg/day. Duration: 3 months. Follow-up: Every 4 weeks, monitoring blood glucose and adverse events. Hypoglycemia: blood glucose ≤ 3.9 mmol/L.	Empagliflozin and liraglutide together reduced blood sugar, weight, blood pressure, and improved insulin resistance and beta cell function better than liraglutide alone in overweight/obese type 2 diabetes patients. The IoT-based telemedicine system improved patient self-management and individualized treatment.	Empagliflozin and liraglutide together reduced blood sugar, weight, blood pressure, and improved insulin resistance and beta cell function better than liraglutide alone in overweight/obese type 2 diabetes patients. The IoT-based telemedicine system improved patient self-management and individualized treatment.

References	Objectives	Methodology	Findings	Recommendations
[29]	Develop a configurable IoT system for remote respiratory monitoring, enabling real-time therapy adjustments and patient feedback. Provide clinicians with continuous assessments to modify therapy in real-time, addressing technical challenges and ambient noise interference in home or clinical settings.	The study uses MEMS microphones, a microcontroller, and Bluetooth for a remote acoustic imaging system to record lung sounds. It processes raw inputs with a multi-stage software filtering pipeline.	The MEMS microphone array system allows real-time therapy adjustments and continuous remote respiratory monitoring, outperforming single-point digital stethoscopes in noise immunity and regional specificity. It accurately detects airway obstruction and proves feasible for continuous remote lung function assessment.	The study recommended a solution using 6G technology for high-fidelity acoustic data transmission and real-time AI analysis to improve diagnosis and early detection of lung diseases.
[30]	To Evaluate patients' emergency responses in life-or-death situations using soft cyborg systems, analyze data from door sensors to monitor the behavior of people living alone and notify caregivers of emergencies, and develop a system to detect emergencies like falls, strokes, and unconsciousness in older adults living alone.	The study's methodology includes evaluating emergency responses with soft cyborgs, designing an Android monitoring terminal, testing a hybrid emergency vehicle location system, using AI and soft cyborgs, analyzing development with a data glove, surveying MR and visually impaired patients, and developing an IoT and machine learning system for home emergency detection.	The study evaluated emergency responses using soft cyborg and telemedicine systems, enhancing patient-medical staff communication. It proposed using door sensors to monitor people living alone and notify caregivers of emergencies.	Future research should expand the telemedicine monitoring system to monitor natural disasters and other emergencies, coordinate emergency responses, and target older adults living alone to detect emergencies like falls or strokes.
[31]	To develop an IoT-based telemedicine system to monitor the health of elderly people living alone by tracking key physiological signals like heart rate, myoelectric signals, and blood flow. Establish baselines for normal signals, detect significant deviations, send alerts to doctors, and store data in the cloud for future reference.	The methodology uses a telemedicine system to monitor heart rate, myoelectric signals, and blood flow in elderly people living alone. It compares real-time signals to baselines, notifying doctors and storing data if deviations exceed 30%, and measures pulse rate by detecting blood flow changes.	The telemedicine system monitors heart rate, myoelectric signals, and blood flow in the elderly, notifying doctors and storing data in the cloud if deviations exceed 30%. It measures pulse rate and blood flow, communicating health status to the patient's family.	Future research should integrate more sensors, enhance data analytics, optimize user interfaces, and conduct clinical trials. Improving data security, exploring cost-effectiveness, developing remote consultation features, integrating with existing systems, and enhancing emergency response are also recommended to refine the IoT-based telemedicine system for elderly care.
[32]	To develop a telemedicine robot for remote monitoring and assistance, enabling real-time video conferencing, remote diagnostics, and control over robot movement. Allow remote administration of injections and emphasize a low-cost, modular design with customizable sensors.	The methodology uses an Arduino platform to remotely control a telemedicine robot via a mobile device. It monitors vital signs with MAX30100 and LM35 sensors, controls movement through motors and Blynk IoT, and administers injections with a syringe pump system. Sensor data is sent to Blynk and stored in a MySQL database accessible via a website.	The telemedicine robot has a low-cost, modular design. Doctors can remotely control it to monitor patients, save data, and administer injections. Its affordable, flexible design allows easy, scalable adoption.	Future research should improve user interfaces, integrate more sensors, enhance data security, and conduct clinical trials to validate effectiveness. Additionally, exploring cost-effectiveness is recommended for broader adoption.
[33]	To develop a system for cardiovascular patients to monitor their health remotely, study system dynamics using the Treatments Conceptual Model (TCM), and define system entities, attributes, and relationships using the Conceptual Data Model (CDM).	This study uses an AD8232 ECG sensor and Arduino Uno to collect patient ECG data, process and store data in a distributed database. Develop a web application using Django in Python, with potential AI extensions, and include features like doctor selection, caregiver chat, ECG usage with video, and electronic prescription delivery.	The study developed TeCa, a telemonitoring system for cardiovascular patients that automatically monitors ECG and stores data in a distributed database. TeCa is user-friendly, enabling patient interaction with doctors, ECG sensor use, and electronic prescriptions. It aims to help patients manage cardiac health remotely, offering healthcare, smart equipment, and remote medical operations.	The study recommends on to Incorporate federated learning for distributed AI training across healthcare centers. To enhance TeCa with machine learning to replace doctors with "robots" for heart disease prediction and use cloud storage for large medical datasets.
[34]	Design a telemedicine platform for diabetes management to help patients record vital signs, receive feedback, and get notifications. Provide a dashboard for physicians to monitor and communicate with patients, offer visual behavior illustrations, and include modules for recommendations, prediction, detection, classification, and clustering.	Develop the "Saleem" mobile app to sync with IoT devices for diabetes data collection, cleanse and feature-extract data, apply data mining for classification and clustering, visualize data for patients and doctors, and use machine learning to predict complications and recommend treatments.	The paper proposes "Saleem," a telemedicine platform for diabetic patients to monitor their diabetes and vital signs, with feedback and notifications to control complications. It offers a dashboard for physicians and includes modules for recommendation, prediction, detection, classification, and clustering to enhance diabetes management.	Developing predictive models for diabetic complications based on the data collected through the Saleem system.
[35]	Design an IoT and telemedicine-based health monitoring system in the form of a "Smart Chair" Develop a low-cost and affordable health monitoring system for people in developing nations with limited access to healthcare.	The methodology uses biomedical sensors for physiological signals, analog pre-processing and digitization with microcontroller ADC, digital filtering to remove noise, calculating vital parameters, and transmitting data via Wi-Fi, Bluetooth, and GSM. It includes oscillometric and height-based algorithms for blood pressure and a 5-point digital median filter to reduce noise.	The study presents the "Smart Chair," a low-cost IoT-based telemedicine system for monitoring vital physiological parameters. Designed for affordability in developing nations with limited healthcare access, the results show that the Smart Chair is a cost-effective solution compared to existing systems.	Attaching a keypad to the Smart Chair to allow users to enter their name and create a personalized health record database, and creating a custom-made web server instead of using an existing one to eliminate the need for an API key and reduce system complexity.

References	Objectives	Methodology	Findings	Recommendations
[36]	The main objective is to provide a safer patient monitoring system that keeps the medical specialist connected to all their patients, allowing the doctor to perform multiple tasks in parallel without losing control over the anesthetized patients.	The methodology includes developing an Android app with Android Studio and a web app using JavaScript, HTML, and CSS. Pryv middleware is used for backend data sharing. A Raspberry Pi drives the TDM system, programmed with Qt. The simulation uses a Galaxy Note Pro tablet, Sony Smartwatch 3, Raspberry Pi TDMs, and a laptop for web app access.	The system aims to enhance patient monitoring by keeping doctors connected to all patients, enabling multitasking without losing control. It uses a Raspberry Pi-driven TDM system to measure anesthetic compound concentrations, interfaced with an Android app. Anomalies trigger notifications on the doctor's smartwatch, ensuring rapid medical intervention.	Future research should expand the IoT telemonitoring system to integrate more medical devices, enhance data analytics and user interfaces, and prioritize security. Clinical trials should be conducted to validate effectiveness, explore cost-effectiveness, and enhance scalability. Emerging technologies like 5G and blockchain should also be integrated to improve patient care.
[37]	Develop a telemonitoring system for a portable FES-based wrist rehabilitation device, store wrist torque and movement data in a structured database, display the data via a web application, establish an IoT-based telemonitoring system, and trial the system on actual devices for future database optimization.	The methodology uses a Node MCU ESP8266 microcontroller to transmit simulated rehabilitation data and a web-based application with multiple use cases and a relational database. Components are integrated to remotely monitor and store data from a portable FES-based wrist therapy device.	The IoT-based telemonitoring system for wrist rehabilitation was successfully designed and implemented. It stored user accounts, rehabilitation data, and therapist-patient relationships in a database. The simulated data produced accurate graphs, indicating the system can be used with real subject data.	Integrating an actual FES-based wrist joint rehabilitation device into the proposed telemonitoring system, storing the rehabilitation data of actual subjects in the database, and optimizing the database and data transmission method.

4. DISCUSSION

The adoption of IoT solutions in telemedicine has significantly impacted healthcare by providing diverse solutions for various health problems and care methods. Patient surveillance, information security, and treatment delivery have been central considerations in numerous studies. IoT-based telemedicine systems have shown great promise in the monitoring and management of chronic diseases, physical exercise regimes, and overall patient health outcomes due to real-time monitoring and analysis [24-26]. However, concerns about information security during the implementation of IoT-based telemedicine, particularly with the use of 5G-IoT networks, have been highlighted. Increased patient confidentiality and information assurance are critical to safeguarding personal and medical data, mainly as patient data is transmitted over networks. Secure communication is essential for maintaining trust in healthcare systems, especially given the various regulatory concerns discussed in the literature [25, 27].

While cloud integration with IoT systems has proven effective in providing scalability and flexibility to telemedicine, the issue of patient data access remains critical. The ability to electronically store and share health records allows medical practitioners to access patient information from any location, optimizing teleconsultations and ensuring continuous care [28]. IoT integration ensures that patients receive care anytime, anywhere, which is particularly useful in hospitals where efficient patient surveillance and treatment are vital. Integrating multinetwork systems in telemedicine helps healthcare providers address multiple patient needs simultaneously, reducing time and improving care quality, especially in emergency care environments. The ability to provide real-time patient monitoring in hospitals demonstrates IoT's potential to increase operational effectiveness in critical care settings [29].

When examining the care of patients with chronic diseases like diabetes and cardiovascular conditions, IoT-based telemedicine has shown positive outcomes [30, 31]. The model of ongoing health assessments combined with personalized action plans has proven successful in enhancing patient care. For instance, IoT applications in managing type 2 diabetes have effectively reduced complications associated with overweight and obesity, emphasizing the role of IoT in preventative care [32]. These findings underscore the transformative potential of IoT to not only manage but prevent chronic diseases through early intervention. However, contradictory findings across studies suggest differing views on the accuracy and effectiveness of IoT-based telemonitoring systems. While some studies emphasize the reliability of expert systems for diagnosis and individualized treatment [33], others point out challenges in integrating IoT data processing to improve diagnostic precision, particularly in the context of the COVID-19 pandemic.

The design of IoT-based systems for elderly care has also gained attention. Systems that provide daily health checks, emergency alerts, and telemedicine robots for live supervision offer significant improvements in care for elderly individuals, particularly those living alone. Such systems, highly automated and responsive, are vital in offering constant supervision and urgent medical interventions, thus improving the quality of care for vulnerable populations [34, 35]. However, there are conflicting findings regarding the effectiveness of these solutions. Some studies show that telemedical robots add significant value to elderly care. In contrast, others suggest that their high cost and technical complexity might limit their widespread adoption, especially in low-resource settings.

Similarly, IoT applications for particular health problems, such as Respiratory illnesses and wrist rehabilitation, highlight the Versatility of IoT in addressing diverse healthcare needs. Real-time lung sound imaging for respiratory disorders and telemonitoring for wrist rehabilitation show that IoT not only manages disease but also provides accurate care and regular check-ups for various health conditions [36, 37]. However, some restrictions on the efficiency of those solutions persist, especially on the integration front challenges associated with current healthcare infrastructures and the reliability of data transmitted through IoT devices. Several studies also investigated the price and affordability of the feasibility of IoT-based telemedicine. Innovations like Smart chairs for telemedicine and low-cost remote health monitoring solutions are critical to scale healthcare. solutions in low-resource settings. These systems can be particularly advantageous in regions where healthcare access is restricted, facilitating the broad acceptance in marginalized communities [38]. Nevertheless, the cost-effectiveness of IoT solutions does remain a debated topic, with some studies advocating for further research to evaluate cost-benefit ratios and long-term sustainability of such systems. Implications for Practice and

Research. The results show that despite IoT solutions holding considerable potential for transforming healthcare, several critical challenges need addressing. These include improving data security, improving the accuracy of telemonitoring systems, and integrate IoT systems more smoothly into the current Health practices are critical. It's crucial for practitioners to focus on Maintaining trust with patients through secure systems while simultaneously Managing the technical complexities associated with these systems. Future research should focus on clinical trials to validate the real-world effectiveness of IoT solutions, especially for chronic disease management and elderly care, and is also delving Cost-effective models that can be scaled across various diverse Settings.

Limitations of Current IoT Applications in Telemedicine despite the promising advancements, there exist several limitations in the present application of IoT to telemedicine. First, data privacy and security remain very critical issues. especially as patient information is transmitted over possibly vulnerable networks. Secondly, interoperability among IoT to devices and existing healthcare systems continues to pose challenges that hinder smooth integration. Thirdly, technical Reliance on IoT systems could potentially reduce human interaction, which can influence patient satisfaction and the the overall quality of care. Lastly, although IoT systems are significantly as effective in some environments, their cost and scalability in resource-poor settings require more research to make sure fair access to these technologies.

5. CONCLUSION

The use of IoT in telemedicine revolutionized health care, providing innovative solutions for a wide range of ailments and health care scenarios. Most studies reviewed show a large role for IoT in the areas of continuous monitoring, real-time data analysis, and improvement of outcomes for patients with chronic diseases and in elderly care. These have greatly increased the potential of health systems, reduced the need for face-to-face consultations, and eased pressure on health facilities because they facilitate home monitoring of patients. Real-time collection and transmission of health data ensure that appropriate medical care is rendered in a timely manner and changes are effected in response to the needs of the patients, especially those with chronic diseases.

Also underlined by the research is how imperative security is in Internet of Things (IoT) systems and how it is increasingly important for 5G-IoT networks, while both safety and confidentiality among telemedicine services are mandatory, required to sustain citizens' trust in such practices and services. Various authors emphasized the demand to avoid breaches and leakage in health data. Furthermore, when integrated with cloud systems, IoT technologies are expected to bring better scalability and flexibility, allowing practitioners to access patient information and offer teleconsultations from any location, thus making health care more accessible and streamlined.

Moreover, IoMT has the potential to reduce health disparities, especially in underserved and remote areas. The use of IoT devices for remote diagnostics and virtual consultations can bring health services to people who would otherwise be barred from accessing health facilities, especially in low-income communities. The improvement helps overcome geographical and financial barriers and thus promotes better health and reduces disparities. This again proves the potential cost savings with IoT-based telemedicine systems and technology's ability to bring better health care to the general public, especially in underserved regions.

This systematic review depicts the immense potential of the Internet of Things in telemedicine, especially in managing chronic diseases, elderly care, emergency services, and rehabilitation. The included studies underline the benefits of IoT, which include better patient outcomes, improved health monitoring, and greater access to and affordability of healthcare services. However, data privacy, security challenges, and technical implementation barriers remain. The findings of this review provide an important context for understanding the integration of IoT into different healthcare domains. At the same time, though, it underlines the challenges that must be overcome to reap its full potential for transforming healthcare delivery.

Future research in IoT for telemedicine should focus on several key areas to enhance the effectiveness and scalability of these solutions. One important direction is enhancing interoperability across different IoT devices and healthcare systems. Standardized communication protocols and frameworks are needed to ensure seamless integration and data exchange, improving system efficiency and reducing technical barriers. Another critical area is data security, particularly as IoT systems handle sensitive patient information. Future studies should explore advanced encryption methods and blockchain technologies to bolster data protection and ensure patient confidentiality, especially in environments utilizing 5G-IoT networks. Additionally, there is a need for more comprehensive research on the cost-effectiveness and scalability of IoT-based telemedicine, particularly in low-resource settings. Research should evaluate the long-term sustainability of these systems and explore models that can make IoT solutions affordable and accessible in developing countries. Patient acceptance and satisfaction with IoT-enabled telemedicine is another important area for future investigation. Understanding how patients perceive remote healthcare, including their trust in technology and comfort with virtual consultations, will be crucial for widespread adoption. Finally, integrating AI and machine learning into IoT systems can enhance their capabilities, particularly in diagnosis accuracy and predictive health analytics. Research should focus on how AI can be effectively integrated into IoT-based telemedicine solutions, particularly in managing chronic diseases, to improve personalized care and early intervention.

Several practical steps should be prioritized for the successful implementation of IoT in telemedicine. First, healthcare providers must focus on implementing robust security frameworks to safeguard patient data. This includes using multi-factor authentication, data encryption, and secure cloud storage solutions to ensure the privacy and integrity of sensitive medical information. Additionally, training and education for healthcare professionals is essential to maximize the benefits of IoT technology. Medical staff should be well-equipped to operate IoT devices, interpret real-time health data, and use telemedicine platforms effectively. Collaboration between healthcare providers, technology developers, and regulatory bodies is crucial for ensuring IoT systems are effective and compliant with legal and ethical standards. Governments and organizations should also focus on making IoT systems accessible and affordable, particularly in underserved areas. This could involve subsidizing IoT devices, improving internet infrastructure, and providing financial support to make telemedicine solutions more accessible. Finally, addressing healthcare disparities through the widespread deployment of IoT in telemedicine will require a multi-stakeholder approach to ensure equitable access to quality healthcare for all populations, regardless of geographic location or income level. By focusing on these practical recommendations, the healthcare sector can optimize the use of IoT to improve patient outcomes, enhance operational efficiency, and reduce healthcare costs.

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