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SURVEY

The Internet of Things in Elderly Healthcare Applications: A Systematic Review and Future Directions

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ABSTRACT The increase in the elderly population globally and the prevalence of chronic diseases among the elderly have resulted in rising healthcare costs worldwide. Utilizing the Internet of Things (IoT) and smart sensors to reduce healthcare costs and enhance the quality of life for the elderly is a highly effective and valuable solution. Effective monitoring can improve resource management in IoT-based healthcare systems. We conducted a systematic literature review (SLR) for elderly healthcare on the IoT to evaluate its various facets and key areas. The taxonomy of elderly healthcare studies in the IoT comprises six categories: smart homes, security and privacy, remote healthcare system, wearable devices, smartphone, healthcare and healthcare costs. Management of chronic diseases has the highest percentage of evaluation statistics in the field of smart homes, at 61%. In addition, 26% of smart homes in healthcare are devoted to behavioral characteristics and 13% to biological characteristics. Finally, this study highlights the visions and challenges of elderly healthcare articles and future work.

INDEX TERMS Internet of Things, smart home, smartphone, remote healthcare system, security, privacy.

I. INTRODUCTION

The IoT (Internet of Things) integrates multiple computing systems, physical objects, and sensors by collecting and exchanging data between them. With the advancement of technology, IoT has been incorporated into various fields, including the healthcare system. Recently, with the advancement of medical science and technology, researchers in their studies have given insight into the increase in average life expectancy in elders. It is predicted that this average will increase by 16.7% by the year 2050, while in 2015, this statistic was 8.5% [8], [9]. The pressures caused by the increase in the elderly population and their chronic diseases have been alleviated worldwide [1]. With the increase of the aging population, issues such as healthcare, lack of access to medical resources, remote control of chronic diseases, and most importantly, medical treatment costs, the IoT has become a prospective topic in healthcare systems [2]. IoT plays an essential role in many already existing healthcare applications. It provides medical emergency services in the healthcare systems [3], [4] and integrates the IoT and smart sensors while storing data in cloud servers, registering patient information, and extracting data from the doctor's computer or smartphone, and makes decisions based on patient's health status [5]. The role of cloud servers in the healthcare system is to control scalable data, share data resources and store

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integrated data, which has helped solve security and parallel processing problems [6], [7]. The elderly who suffers from chronic diseases such as diabetes, cardiovascular disease, blood pressure, asthma, etc., needs special care and attention if they choose to live independently. High healthcare costs, [8] lack of access to medical resources, and commuting the elderly to hospitals and medical centers have driven the research communities to seek solutions to provide better health and treatment services for cost reduction. By using the IoT system and embedded sensors, a wide range of healthcare services for the elderly are now available in the market for in-home healthcare, an effective role in the independent life of the elderly [10]. The healthcare systems were developed by continuously monitoring diseases regardless of time and place and assisting in detecting patient emergencies. Smart systems are usually exposed to data threats and security vulnerabilities due to wireless network connections. By enhancing security requirements in the design of smart systems, data theft and data diversion can be prevented to ensure data security. Therefore, the data confidentiality of patients is one of the most important concerns in the application of IoT in smart healthcare systems, which calls for special attention [11], [12], [13]. The most important and challenging concerns of elderly healthcare in the IoT include security, privacy, costs, and health monitoring. Despite the progress in IoT, additional research is needed to improve its efficiency in healthcare systems. Very few have been technical articles systematically focused on IoT in elderly healthcare [10], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26]. Existing review articles did not highlight effective evaluations for IoT applications in elderly healthcare, and the research presented lacked systematic organization. Also, in review studies, research questions, open issues, and future works of IoT in elderly healthcare have rarely been investigated. This study presents a novel and systematic approach to examining the applications of the Internet of Things (IoT) in elderly care. Unlike previous studies, which were primarily general and unstructured reviews, this research provides an in-depth analysis of challenges, opportunities, and future directions, offering practical solutions to enhance smart care systems. Introducing a comprehensive and new classification of IoT in elderly healthcare. Developing a precise and structured framework that categorizes IoT applications into six main areas) Smart homes, Security and privacy, Remote healthcare systems, Wearable devices, Smart phones, Healthcare and Cost management in healthcare.(This classification facilitates more structured and focused future research. Moreover, this study identifies the most critical challenges by analyzing research gaps and unresolved issues in digital health for the elderly. Through qualitative and quantitative analysis of previous studies, this research highlights the weaknesses of prior works and provides recommendations for improving this field. This study is structured as follows: Section II describes related work. Section III discusses the background of IoT-based elderly healthcare. The research methodology is presented in Section IV. Section V describes and categorizes IoT studies on elderly healthcare. Section VI discusses the study analysis of IoT in elder healthcare. Finally, Section VII concludes the study.

II. RELATED WORK

Shah et al. [14] investigated healthcare using the IoT. IoT is the best solution for security, healthcare smart cities, smart homes, smart health, etc. IoT technology can help monitor chronic diseases and the health state of the elderly remotely. The primary purpose of this study was to examine healthcare frameworks and examine its security challenges in the IoT. The results of the authors' research show that access to the requirements and security frameworks of the IoT can help a lot in receiving and transmitting the health data of the elderly. Security and privacy issues have also been investigated to fully understand healthcare in the IoT. The article's advantage was examining and controlling the health of the elderly using the IoT. The article's drawback was that the healthcare security architecture was not suited for the IoT.

Selvaraj et al. [15] assessed healthcare challenges in the IoT. IoT technology has been developed to provide health services to patients. Research shows that IoT has the potential to improve healthcare efficiency, and its architecture has been evaluated in integrated cloud systems. The authors analyzed the management techniques of healthcare systems using the IoT. The results from this study show that accuracy and energy consumption play an effective role in improving healthcare systems. On the other hand, the limitations of this system include resource availability and healthcare security issues due to the integration of many systems. The benefit of the article is the analysis of the healthcare system in the IoT. The article's drawback is that the data privacy issue in the IoT has not been discussed. Tun et al. [16] onducted a comprehensive review on the use of IoT in elderly care, highlighting its potential to enhance quality of life and reduce healthcare costs. The study explores research opportunities and emphasizes healthcare system analysis as a strategy for elderly support. The article provides valuable insights into IoT services for elderly care but lacks an estimation of daily healthcare costs. Birje et al. [17] investigated and analyzed a distributed healthcare system using the IoT. The healthcare system connects patients' medical data through a distributed database to provide intelligent and reliable services. This system works based on IoT technology and plays an effective role in the healthcare industry. The main goal of this study is to classify distributed healthcare systems and compare them between different systems considering their aspects in the IoT. The benefit of the paper is to analyze the IoT technology in the healthcare system with low-consumption computing methods. The drawback of the paper is that it does not assess the challenges and solutions of the healthcare system in the IoT. Stavropoulos et al. [10] used sensors and wearable devices for elderly healthcare using IoT. The technology of IoT and wearable devices for remote health assessment has helped a lot to improve people's lives. In this study, the identification of various aspects of healthcare, such as chronic diseases, Alzheimer's, muscle weakness, etc., has been evaluated. Also, the authors have reviewed some studies to improve the quality of life of the elderly and their healthcare. The main purpose of this study is to evaluate the physical conditions, prevent the elderly from falling and help improve their health. As a future solution, software and hardware features can be evaluated by the needs of the elderly and their diseases. The benefit of this paper is providing affordable and accessible healthcare services for insights into the elderly and their diseases. The drawback of the paper is that issues related to healthcare security and privacy have not been discussed. Thilakarathne et al. [18] investigated the role and importance of the IoT in elderly healthcare systems. Integrating the IoT with healthcare solutions has created new techniques to monitor chronic diseases in the elderly. In this research, various healthcare challenges in IoT, security, and privacy have been investigated. It also uses cloud computing and fog computing to analyze big data to provide healthcare services. The main purpose of this research is to use the IoT in healthcare to reduce the stress of the elderly and monitor chronic diseases and their physical and mental health. The benefit of the paper is the examination of various aspects of the IoT in healthcare. The drawback of the paper is the lack of investigation into the reliability of big data and the availability of data. Alshamrani et al. [19] developed a remote health monitoring system for elderly care using AI and IoT, addressing issues like long-term hospitalization and staff shortages. The study explores mobile health models for data transfer, aiming to reduce medical errors and improve disease prevention. Findings indicate that IoT-based monitoring offers a low-cost, safe solution. The paper highlights tools enhancing healthcare accessibility but notes the lack of standardized data integration in medical institutions. Kashani et al. [20] conducted a systematic review of IoT applications in geriatric healthcare, emphasizing its role in reducing costs and unnecessary hospital visits. The study classifies and evaluates healthcare approaches, analyzing their challenges, benefits, and limitations. A key focus is on security and privacy in IoT-based healthcare. The paper highlights IoT's impact on elderly health monitoring but lacks discussion on mobility and scalability issues. Verma et al. [21] investigated the protocols of elderly health monitoring systems by presenting an IoT architecture. With the increase in the elderly population and their diseases, we can examine patients' physical condition using wearable sensors to monitor their health. This includes measuring their blood pressure, blood sugar, body temperature, etc., and initiating treatment as quickly as possible through doctors to prevent irreparable harm to the patient. This study investigated the elderly health monitoring system using ZigBee, LoRawan, and RFID approaches and using machine learning algorithms. Therefore, using different machine learning algorithms to support healthcare data effectively. Also, by presenting a health monitoring system architecture, the authors examined various challenges, such as the heterogeneity of devices, medical costs, interoperability, and the high volume of data. The benefit of the paper is the examination of communication techniques and their importance in remote health monitoring systems. The disadvantage of the paper is that, despite the importance of machine learning in health monitoring systems, the machine learning algorithm is insufficiently focused on predicting the early stages of the disease. Sahu et al. [22] analyzed the use of IoT in elderly healthcare. The increase in the population of older adults suffering from chronic diseases has necessitated the need for healthcare. Research communities should look for ways to provide quality health services to the elderly at the lowest cost. With the advancement of technology, a large part of the healthcare field, remote health monitoring systems, and providing services at home has been considered to some extent. By providing different solutions, the IoT has helped the elderly live and carry out daily activities independently. Therefore, this article was aimed at investigating IoT's role in healthcare systems. In this study, the authors investigated various healthcare issues and possible limitations of smart devices, health challenges, and solutions for affordable services. The benefit of the paper is the evaluation of techniques and technology based on the IoT in the healthcare field. The drawback of the paper is that, despite the advancement of IoT systems, the challenges of advanced system usability and acceptability have not been resolved. Saeed et al. [23] conducted a systematic review of blockchain technology in the healthcare sector, examining its applications in medical data management, information sharing, security, and privacy. The authors analyzed existing studies and evaluated the challenges and opportunities of using blockchain in healthcare systems. Additionally, the article explored the impact of blockchain technology on improving interoperability, reducing administrative costs, and increasing transparency. The results indicate that by utilizing smart contracts and common standards, the exchange of medical data among different systems can be improved. The strength of the article lies in its proposals for enhancing the implementation of blockchain in healthcare systems. However, a weakness of the article is the lack of a comprehensive economic analysis regarding the costs of implementing and maintaining blockchain-based systems. Olmedo et al. [24] investigated healthcare for the elderly using wearable devices. With the increase in the elderly population and their chronic diseases, healthcare costs have increased greatly and become a concern and challenge for society to overcome. With the IoT and sensor technology development, it is possible to remotely monitor diseases and improve the quality of life of the elderly by diagnosing the type of disease. The authors identified and diagnosed dangerous diseases by measuring physiological parameters in their study. Many diseases can be monitored remotely due to the available systems on the market and FDA approval of these systems. The benefit of this paper was examining the method of detecting diseases in the elderly using the IoT. The drawback of the paper is that many diseases cannot be monitored remotely. Villarreal et al. [25] provided a comprehensive review of the use of blockchain in healthcare management systems, focusing on the challenges of interoperability and security. The authors examined various blockchain implementation methods in healthcare systems and analyzed related technologies such as smart contracts and cryptography. Additionally, the article discussed existing standards to enhance interoperability among blockchain-based healthcare systems and proposed solutions to overcome security challenges. The results indicate that blockchain, through cryptography and a decentralized structure, enhances the security of medical data. The strength of the article lies in its detailed analysis of interoperability and security challenges and its practical solutions for improving the security and performance of blockchain in healthcare management. However, a weakness of the article is the lack of a practical evaluation of the proposed solutions. Nagpure et al. [26] examined tele-surgery and remote surgical procedures, addressing the challenges of remote surgery in improving access to surgical care worldwide. This article emphasizes that tele-surgery can bring surgical expertise to remote and underserved areas, thereby reducing existing disparities in healthcare services. The findings indicate that advancements in communication and robotic technologies have enabled the execution of complex remote surgeries. A key strength of the article is that the authors effectively highlight the potential of tele-surgery in reducing healthcare inequalities and providing specialized care in disadvantaged regions. However, a notable weakness of the paper lies in its limited discussion of the technical details regarding the necessary infrastructure for the large-scale implementation of remote surgery, which may present certain shortcomings.

Table 1 provides an overview of studies on various topics of elderly healthcare in the IoT. According to this table, we explain why we wrote this paper by highlighting the weaknesses of the previously mentioned review articles as follows:

(1) Several reviewed studies lacked a systematic organization for the healthcare of the elderly in the IoT.

(2)The quantitative and qualitative evaluation criteria of elderly healthcare studies in IoT have not been investigated in several reviewed studies.

(3)The classification of elderly healthcare studies in the IoT has not been evaluated in several reviewed studies.

TABLE 1. Related published papers on elderly healthcare in IoT.

REASERCH	PUBLISHER	PUBLICATION YEAR	COVERED YEAR
Shah et al. [14]	Springer	2019	2006-2019
Selvaraj et al. [15]	SN Applied Science	2019	2005-2019
Tun et al. [16]	Springer	2020	2009-2020
Birje et al. [17]	Springer	2020	2010-2020
Stavropoulos et al. [10]	MDPI	2020	2009-2020
Thilakarathne et al. [18]	IJEMR	2020	2004-2020
Alshamrani et al. [19]	Elsevier	2021	2003-2021
Kashani et al. [20]	Elsevier	2021	2012-2021
Verma et al. [21]	Springer	2021	2005-2021
Sahu et al. [22]	Hindawi	2021	2011-2021
Saeed et al. [23]	PLOS	2022	2008-2022
Olmedo et al. [24]	MDPI	2022	2015-2022
Villarreal et al.[25]	IEEE	2023	2018-2023
Nagpure et al. [26]	Malque	2025	2002-2021

III. BACKGROUND

With the increase in the elderly population and chronic diseases globally, in addition to the high cost of healthcare, demands for hospital beds and medical services also increase, especially for patients with heart problems, diabetes, and those who need special care [27], [28]. As IoT advances, most elderly healthcare problems, such as increased healthcare costs, elderly healthcare in remote areas, and a lack of medical staff, have been resolved. Medical measuring devices such as blood pressure devices, blood sugar regulation, or motion sensors through the IoT have made it possible for a patient's health status to be checked remotely at the comfort of their home [18], [29], [30].

A. HEALTHCARE TRENDS IN IoT

Figure 1 shows the trend of the healthcare system in the IoT. The healthcare system with IoT technology examines the condition of the disease in real-time or early diagnosis for chronic disease. Cloud servers are essential for the processing and storing healthcare data and creating health records. Using integrated sensors and smart medical systems, medical and health services, can be more easily provided to patients and strengthened. Therefore, medical systems and sensors can be considered smart systems that form the main part of healthcare in the IoT [29], [30].

B. HEALTHCARE SYSTEM ARCHITECTURE IN IoT

In Figure 2, the architecture of different IoT healthcare layers is analyzed. In the first layer (Focusing Area 1), sensors implanted in the patient's body, medical systems, or wearable sensors are placed to obtain the patient's medical information. Patients' data are collected through a data processing layer, then passed through a wireless network access point and a gateway located in the second layer (Focusing Area 2) and delivered to the cloud server for processing. Then, in the third layer (Focusing Area 3), the data is provided to the end user (doctor, specialist, family member, or ambulance service) for checking and taking necessary actions. In this scenario, doctors can view the patient's data on their computer, and

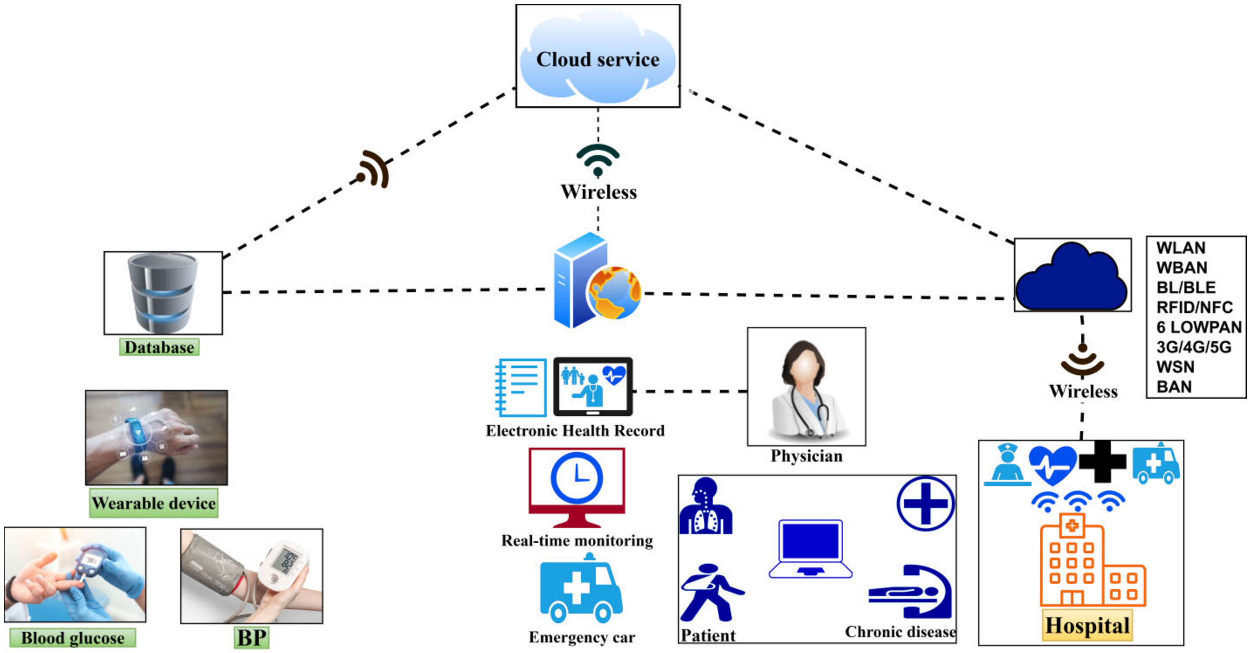

FIGURE 1. Healthcare system trends in IoT [18].

family members or specialists can view it on their respective smart devices [31], [32].

C. HEALTHCARE APPLICATION IN IoT

Figure 3 shows some of the healthcare applications of the IoT. Below we describe each of the applications [23].

1) ECG MONITORING

Electrocardiogram, as an indicator for heart abnormalities, shows the heart's electrical activity and provides information about the rhythm of the heart muscles. An electrocardiogram based on the IoT operates through wireless data collection and a receiver processor and displays cardiac abnormalities in real time [33], [34], [35].

2) BLOOD PRESSURE MONITORING (BP)

Blood pressure measurement is one of the mandatory steps in any diagnostic process. Many blood pressure measurement methods have changed with the integration of the IoT, fog and cloud computing, and embedded sensors. It is now possible to measure a person's blood pressure through wearable sensors and store the recorded information in a cloud server [36], [37].

3) GLUCOSE LEVEL MONITORING

two common diseases in people are type 1 and type 2 diabetes. Diabetes is a condition where the blood glucose level is heightened for a long time. Diabetes can be diagnosed with oral glucose tolerance tests, plasma glucose detection, and fasting plasma glucose. Finger pricking is one of the most widely used methods of measuring blood glucose levels in the body. With the advancement of IoT technology and wearable sensors, patients' blood sugar can be fully monitored by these devices. Sensors embedded in the IoT are the most convenient, safe, and non-invasive methods to measure blood sugar [38], [39], [40], [41].

4) TEMPERATURE MONITORING

An important part of many diagnostic processes is monitoring the body temperature, which can typically be measured with a thermometer. Any change in body temperature may be a precursor of disease or illness. Monitoring body temperature over time helps healthcare workers and doctors learn about patients' health conditions. With the advancement of the IoT and smart sensors, many solutions for measuring body temperature have replaced traditional methods. The patient's body temperature can now be measured through wearable sensors placed on the ear.

Using the recorded information, the temperature data is stored and displayed on a web page or mobile devices of doctors and healthcare workers [42].

5) OXYGEN SATURATION MONITORING

One of the non-invasive methods for measuring blood oxygen levels is pulse oximetry, as blood oxygen is a vital factor considered in healthcare. The applications created in the healthcare industry result from the integration of IoT-based technology. By measuring the blood oxygen level, the oximeter transmits the patient's recorded information to the cloud server using various technologies. Then, using the recorded data, the medical staff observes and diagnoses the patient's health status [43].

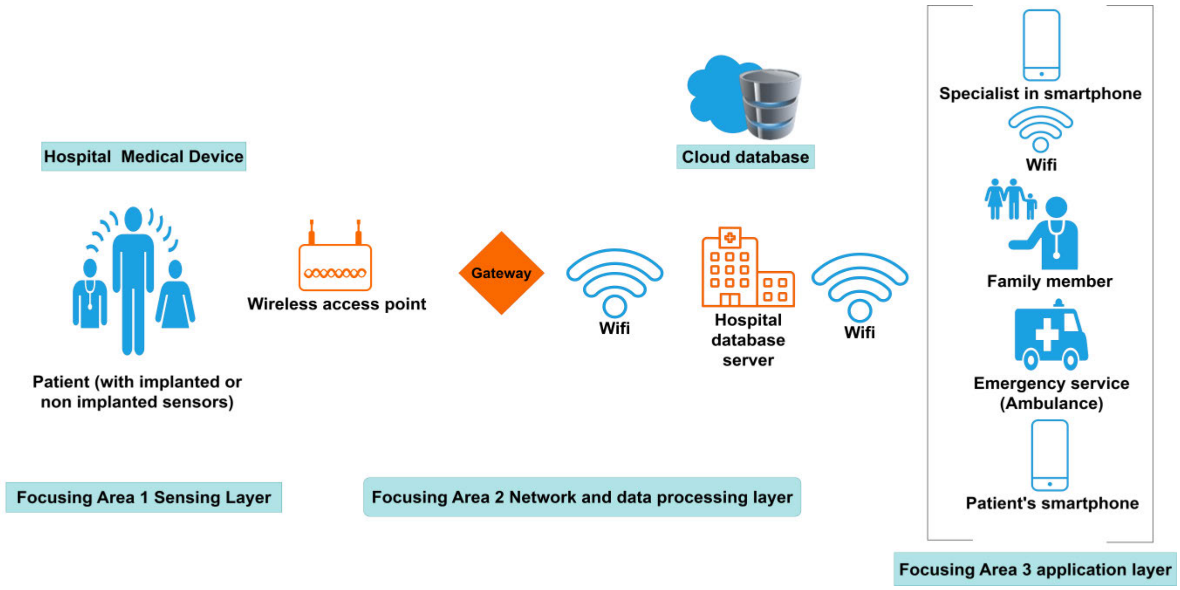

FIGURE 2. IoT Healthcare architecture [28].

6) MEDICATION MANAGEMENT

Drug management is one of the most important subjects in healthcare, and failure to comply can cause adverse patient outcomes. Non-compliance with medication schedules is more visible in the elderly with Alzheimer's. Many studies on patient medication compliance through the IoT [48-45] show patients' medication schedules using a smart medical box. In another study, researchers investigated the exact time of drug administration for specific diseases that require medication around the clock using IoT technology [48]. In this example, the smart system reminds the patients of their daily medication and injections and tracks their medication consumption in real-time.

7) OTHER NOTABLE APPLICATIONS

IoT applications in the healthcare industry are expanding as technology advances. Integrating the IoT and new technologies makes treating many diseases, such as cancer and remote surgery, possible [49]. Another noteworthy application of healthcare in the IoT is using advanced algorithms to diagnose lung cancer [53-51].

D. THE FORMULAS AND DEFINITIONS OF EVALUATION CRITERIA

In IoT-based healthcare systems for elderly care, evaluating criteria is crucial. These metrics need to be designed to ensure the effective and reliable delivery of services. Below is the definition of each criterion contextualized with real-world applications:

1) PRIVACY

Privacy in elderly healthcare systems refers to the protection of individuals' personal and sensitive data, including medical information, health status, geographical location, and daily behaviors. Ensuring privacy involves securely collecting, storing, and transmitting this data while restricting access to authorized personnel only. For instance, wearable systems that monitor vital signs (e.g., blood pressure and heart rate) must encrypt data during transmission to cloud servers and implement multi-factor authentication (MFA) to prevent unauthorized access. This ensures that sensitive health data remains confidential and secure [23].

2) SECURITY

Security is an essential issue in healthcare systems, which prevents threats and attacks with encryption and authentication mechanisms and maintains data privacy [23], [53].

3) SCALABILITY

Scalability refers to the system's ability to expand and support additional devices, sensors, and users without performance degradation. In an elderly care environment, the system should be able to handle an increasing number of devices (e.g., heart rate sensors, blood pressure monitors) as the population under care grows. This ensures that the system remains efficient and effective over time [20].

4) ACCURACY

The amount of real measurement and absolute measurement, accuracy is defined as one of the most widely used criteria of classification performance and shows the ratio of correctly classified samples to the total number of samples [54] and is expressed as the following equation It is calculated: [55], [56].

$$Accuracy = \frac{\mathrm{TP} + \mathrm{TN}}{\mathrm{TP} + \mathrm{TN} + \mathrm{FP} + \mathrm{FN}} \tag{1}$$

In equation (1), TP (true positive) is the true positive rate that accurately detects an abnormal disease. TN (true negative) is defined as an abnormal disease feature from the set of features. Also, the FP (false positive) false positive rate, which is related to misclassification, i.e., the normal feature of the disease as abnormal, has been collected from medical data. FN (false negative) has detected the false negative rate, which means the natural presence of an abnormal disease.

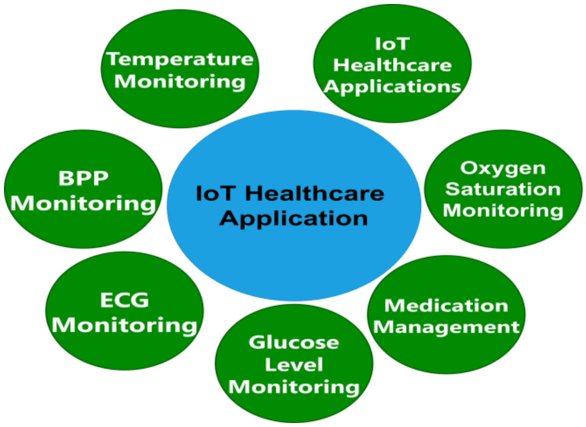

FIGURE 3. IoT healthcare applications [23].

5) SENSITIVITY

Sensitivity is a measure to evaluate the accuracy that shows the presence or absence of disease. The presence of disease is considered "positive", and the lack of disease is considered "negative" [57], [58].

$$Sensitivity = \frac{\mathrm{TP}}{\mathrm{TP}+\mathrm{FN}} \tag{2}$$

Susceptibility means to predict a positive load which means the presence of disease and is known as a true positive (TP), and to predict a negative load when the disease is not present and is known as a true negative (TN) to be.

6) COST

Cost in elderly healthcare systems encompasses the expenses associated with system installation, maintenance, and updates. IoT systems must balance affordability with functionality to ensure continuous availability and accessibility. To address cost challenges, we propose the use of low-cost technologies, such as inexpensive sensors and edge computing for data processing. For example, replacing high-cost surveillance cameras with affordable wearable sensors can reduce the financial burden on care systems while maintaining effective health monitoring [59].

7) ACCURACY

Accuracy refers to the classification model's capacity to retrieve patient data from a particular segment. It is defined as the ratio of the number of recovered correct samples (TP) to the total number of recovered samples (TP) and (FP), and its equation is calculated as follows [55], [56], [57]:

$$Precision = \frac{\mathrm{TP}}{\mathrm{TP}+\mathrm{FP}} \tag{3}$$

8) RELIABILITY

Reliability shows the measurement of each data set collected [61], [62].

9) AVAILABILITY

It guarantees continuous access to data even during the denial-of-service attack for authorized personnel [28]. There are a wide variety of classifications and definitions of accessibility. Therefore, the most suitable item for this definition is operational accessibility [61], [62].

$$\text{Availability} = \text{Uptime}\big/(\text{Operating\_Cycle}) \tag{4}$$

Here Operating Cycle represents the overall period of the operation, and Uptime is the total time that the system works during the operating cycle.

10) PERFORMANCE

Effective and efficient short response time of health data processing systems. The term performance is defined. Data performance by optimizing resources allows for processing a large amount of data [59], [60], [61], [62], [63].

11) RESPONSE TIME

The response time in the healthcare system refers to the variable time that the system must execute the fast-processing task at that time [64].

12) INTEROPERABILITY

The ability of two systems to communicate and share services, interoperability is defined. The IoT system is a cooperation between networks, devices, and platforms [30], [65].

13) MOBILITY

Mobility means using the support of healthcare system networks at any time and place to connect to the Internet [30].

IV. RESEARCH METHODOLOGY

This section presents the research methodology for the study review and evaluation of various characteristics of the IoT in the elderly. The following keywords were used to determine the areas of the IoT in elderly healthcare: "Internet of things, security, privacy, smart home, remote healthcare, smartphone, wearable devices, and healthcare costs". The list of analytical questions (AQs) healthcare-related for the elderly in the IoT is provided below; then, the complete and comprehensive answers to these questions are given.

AQ1: How are the main areas of elderly healthcare categorized in the IoT?

AQ2: Which assessment tools have been used for elderly healthcare in the IoT?

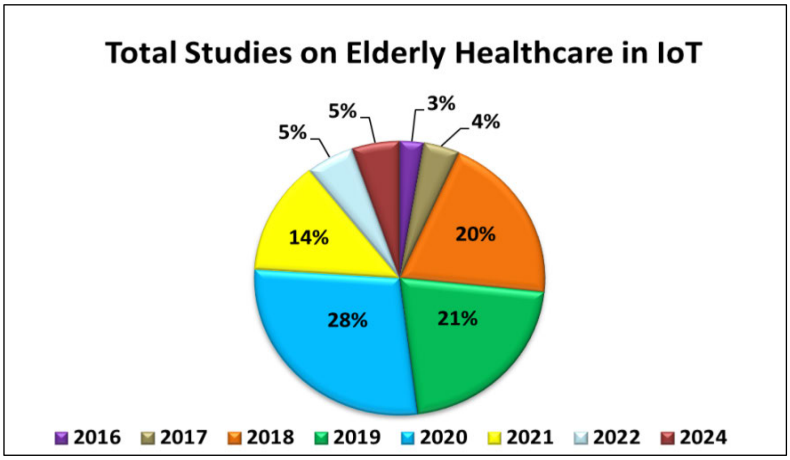

FIGURE 4. Evaluation of research studies by publishers.

AQ3: What evaluation criteria have been used in elderly healthcare studies on the IoT?

AQ4: What are the open issues, challenges, and future work of elderly healthcare studies in IoT?

Figure 4 depicts the distribution of published articles in the field of the elderly in the IoT between 2016-2024. After applying inclusion/exclusion criteria, 75 reviewed articles were selected for analysis. Assessments show that the number of research studies on elderly healthcare in the IoT has significantly increased in 2020, reaching 28% (equivalent to 21 studies). This growth trend has shown the importance of elderly healthcare research areas in the IoT during the last few years. The exclusion section included survey articles, survey articles, non-English articles, and book chapters.

The final criteria for inclusion articles are:

- Publication between 2016 and 2024: Only articles published between 2016 and 2024 were included in the analysis. This time frame ensures that the research findings are recent and reflect the latest advancements in IoT-based elderly healthcare.
- Research focused on IoT applications in elderly healthcare: Articles were included if they focused on the development, application, or impact of IoT technologies in elderly healthcare. This includes studies discussing the use of sensors, health monitoring systems, disease management, and other IoT-related solutions specifically designed for the elderly population.
- Scientific Quality: Articles were required to meet high scientific quality standards. This includes studies with valid methodologies, reliable results, and thorough data analysis. Only peer-reviewed articles from reputable journals and conferences were considered to ensure the credibility of the findings.

The exclusion criteria for article selection are:

- Survey-based studies: Articles that solely summarized previous research without presenting original findings or new experimental results were excluded. This ensures the review focuses on primary research and avoids redundancy.
- Non-English articles: Articles published in languages other than English were excluded. This criterion ensures that the selected studies are accessible to a global audience, maintaining consistency and enhancing the overall comprehensibility of the review.
- Studies that did not directly address IoT technologies or their application in elderly healthcare were excluded. This ensures that the review remains focused on the specific topic of interest.

Figure 5 shows the research methodology for finding articles.

V. EXAMINING THE MAIN TOPICS AND SECTION OF ELDERLY HEALTHCARE IN IoT

Many advances have been made in IoT technology and the healthcare system in recent years. By connecting to medical systems and smart sensors, IoT has played an effective role in providing medical services, remote disease monitoring, reducing healthcare costs, and improving the quality of life of patients and the elderly [23], [66], [67]. Figure 6 presents a comprehensive taxonomy of various subjects of elderly healthcare studies in the IoT and its main areas. Defined areas for the elderly healthcare systems in IoT include security and privacy, smart home, remote healthcare system, smartphone, wearable devices, and healthcare costs. Then, we defined subsections in the taxonomy considered for the five domains. Studies conducted in the field of elderly care within the Internet of Things (IoT) framework show that this technology has a significant impact on improving medical services, remote disease monitoring, reducing healthcare costs, and enhancing the quality of life for the elderly. However, the reviews conducted in this paper indicate that there are several challenges and issues in implementing IoT in elderly healthcare that require further research. Given the increased use of electronic health records (EHR) and internet-connected medical sensors, the issue of security and privacy

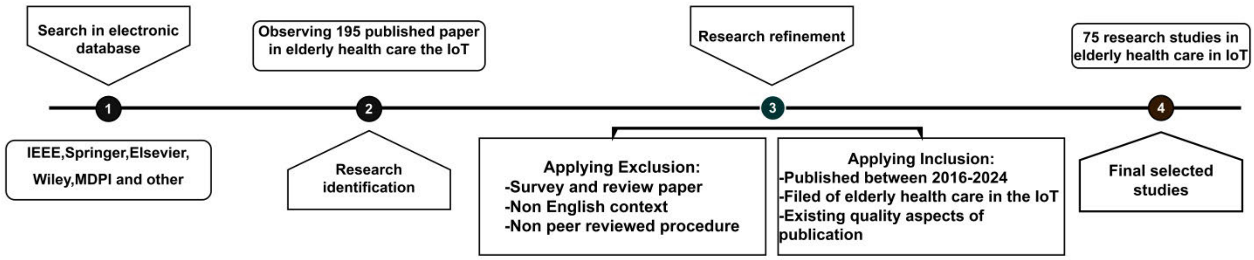

FIGURE 5. Chart of research evaluation and selection criteria.

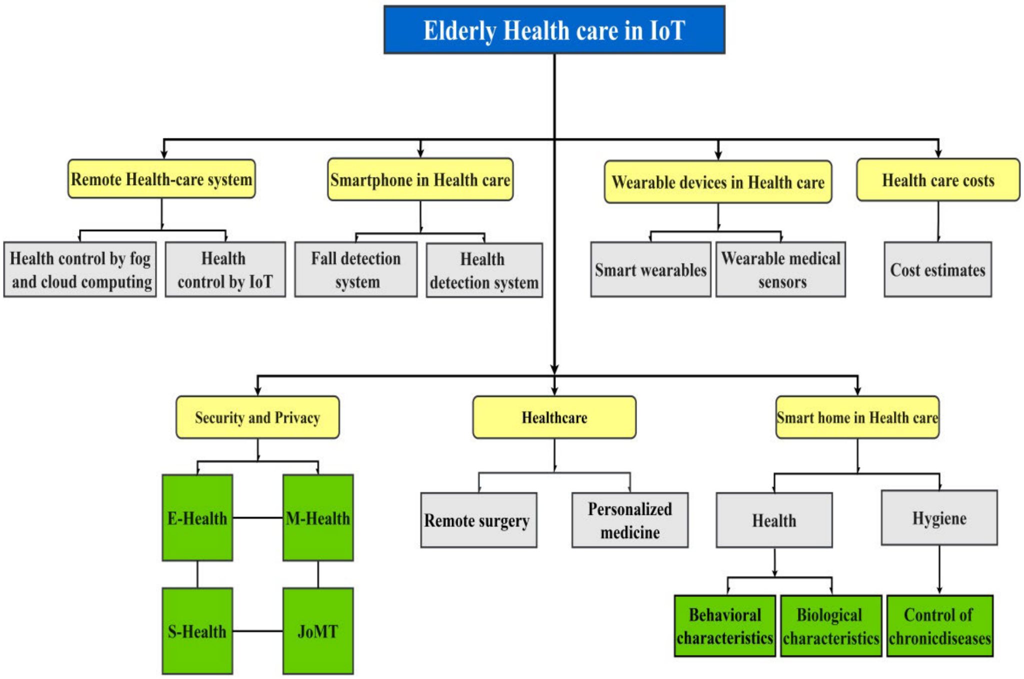

FIGURE 6. The proposed taxonomy of elderly healthcare in the IoT.

of patient information is considered one of the fundamental challenges.

The reviewed articles in this section show that comprehensive security standards for protecting sensitive elderly data are still lacking. Examining and improving encryption algorithms, multi-factor authentication, and key distribution methods in medical IoT systems are proposed as future research directions. In the reviewed studies, chronic disease management through smart homes is one of the most important areas. The main challenge in this domain is the integration of various smart devices, ensuring the accuracy of monitoring data, and interoperability with other health systems. Developing standard communication protocols between different devices and evaluating machine learning algorithms for predicting the health status of the elderly is a solution for future research. Remote monitoring has been one of the key areas of research, but dependence on cloud and fog infrastructures has created challenges such as data processing delays and high energy consumption. Investigating optimized edge computing methods to reduce delays in processing data from medical sensors is a solution for future studies. Fall detection systems and health monitoring through smartphones have been explored in many studies, but challenges related to the accuracy and sensitivity of detection algorithms and reducing false alarms still exist. An approach for future research could involve improving deep learning models for analyzing elderly motion data and reducing false alerts in fall detection. The use of wearable sensors for monitoring vital signs is highlighted as one of the important research areas, but challenges such as low accuracy of some sensors, limited battery life, and ease of use for the elderly are raised. Investigating new materials and technologies for producing wearable sensors with longer battery life and higher accuracy is a potential direction for future research. With the increasing elderly population, the costs associated with medical care and IoT devices have become a major concern. A future research direction could involve analyzing the impact of IoT technologies on reducing healthcare costs and developing economic models for optimal utilization of medical resources.

This study provides a taxonomy based on several domains of healthcare studies for the IoT in elderly healthcare. In this research, according to various challenges and issues, we will first examine the areas and sub-sections of studies on IoT in elderly healthcare. Our research will categorize studies based on keywords, simulation/implementation, and experimental results of each study. We compare the dataset's strengths and weaknesses and the application field.

A. REMOTE HEALTHCARE SYSTEM

According to the fields of the remote healthcare system and the conducted research, one of the main topics for IoT in elderly healthcare is remote health monitoring. Saidi et al. [68] explored remote elderly healthcare using fog-to-cloud computing, focusing on data security, availability, and management. They proposed an architecture combining fog and cloud computing to improve data processing and storage efficiency. The model was simulated using FogWorkflowSim, showing that fog computing enhances system performance. The advantage of this research is its provision of a framework for cloud storage and data management in fog computing, while the drawback is the lack of comprehensive solutions for maintaining privacy and secure access to elderly data. Alexandru et al. [69] investigated remote elderly healthcare using fog and cloud computing to address the challenges posed by an aging population. They proposed an architecture for processing big health data through the IoT, aiming to improve the quality of life by providing accurate health assessments and preventive measures. The study shows that cloud and fog computing are effective in remotely monitoring elderly health. The paper's advantage is offering a fog and cloud-based platform for health monitoring, while the drawback is that traditional architecture is unsuitable for healthcare platforms. Alshammari et al. [70] analyzed health data in IoT using cloud and fog computing. They proposed a framework for healthcare data and addressed data heterogeneity between different sources using the MapReduce Hadoop method. The findings showed that cloud and fog computing improve classification, data storage, and security. The advantage of the paper was presenting various approaches for health data analysis in IoT, while its drawback was the lack of discussion on data processing time in fog computing. Ijaz et al. [71] investigated the use of cloud and fog computing for remotely monitoring the health of the elderly and providing health services. They highlighted the challenges in healthcare costs and hospital visits, especially with the increase in the elderly population and the Covid-19 pandemic. The study found that cloud and fog computing improve healthcare efficiency, safety, cost, and data reliability. As a future solution, integrating cloud, fog, and edge computing could enhance home healthcare. The paper's strength is its focus on remote patient hospitalization using IoT, while its drawback is the lack of video communication in remote health monitoring. Nandankar et al. [72] evaluated a remote elderly healthcare system using cloud and fog computing to address the challenges of large-scale data generation and processing in the context of an aging population. The study presented a system to analyze data and resolve issues related to data heterogeneity. It highlighted the importance of using algorithms, like machine learning, for health data analysis. However, the paper's weakness was the lack of assessment of fog computing offloading challenges. Sun et al. [73] investigated the security of data in remote health monitoring systems based on IoT. To ensure data security during sharing, they utilized advanced encryption access policies, which help reduce security costs. Their proposed scheme demonstrates high efficiency in smart health systems and lightweight decryption. The advantage of the article was presenting various remote health monitoring approaches, while its drawback was the lack of consideration for traceability. Riad et al. [73] examined the use of IoT for remote health monitoring of the elderly. They introduced a data access control mechanism for better management, ensuring the security and privacy of patient data. Patient data was protected with advanced encryption before being sent to the cloud to prevent unauthorized access. The results demonstrated that the proposed mechanism was secure and highly efficient. The advantage of the paper was the analysis of security mechanisms in remote health monitoring, while its drawback was the lack of consideration for privacy issues in cloud and edge computing. Valsalan et al. [74] examined IoT-based remote health monitoring, highlighting its role in healthcare through smartphones and wearable devices. Their study focused on using IoT to analyze patient data via the cloud for disease diagnosis and remote healthcare recommendations. By measuring heart rate and body temperature, preventive health strategies were proposed. The study's advantage was presenting various IoT-based monitoring approaches, while its limitation was the lack of focus on data security and privacy. Acharya et al. [75] evaluated a remote healthcare system based on IoT. Given the increasing elderly population and chronic diseases, health monitoring is essential. Their study showed that remote health monitoring systems measure patients' physiological parameters and send data to the cloud, enabling real-time monitoring and reducing healthcare costs. These systems minimize human error and decrease hospital visits while providing critical real-time data to doctors. The study's advantage was presenting an IoT-based health monitoring system, while its limitation was the inability to detect patient movements in the monitoring kits.

B. EVALUATION OF STUDIES IN THE REMOTE HEALTHCARE SYSTEM CATEGORY

Table 2 shows the categorization of studies in the field of remote healthcare systems, which generally focuses on subfields such as fog computing, cloud computing, and the Internet of Things (IoT). This categorization reflects the diversity of methods and approaches in this area and aims to address the challenges and applications of

TABLE 2. Categorization of studies in the remote healthcare system category.

Study	Keyword	Domain	Simulation / Implementation	Dataset	Application Domain	Case Study	Results	Benefit	Drawback
Saidi et al. [68]	Older adults, Cloud computing, Fog computing, IoT	Elderly monitoring architecture	FogWorkflowSim	-	Fog and Cloud computing	Fog and Cloud computing	- Increase system performance using fog calculations.	- Provide a framework for cloud storage and data management in cloud computing.	In order to access the big data of the elderly, effective and comprehensive privacy solutions have not yet been considered.
Alexandru et al. [69]	IoT, Big Data, fog computing, cloud computing, health	Electrocardiogram (ECG)	C + +	-	Fog and Cloud computing	Fog and Cloud computing	- Effective performance of fog and cloud computing in remote health monitoring.	- Provide a fog and cloud-based platform for monitoring the health of the elderly.	- Traditional architecture is not suitable for healthcare platforms.
Alshammari et al. [70]	Cloud Computing, Fog Computing, Health, IoT	Message queuing telemetry transport (MQTT)	Apache Spark	Medical data	Fog and Cloud computing	Fog and Cloud computing	Ensure data security using fog and cloud computing.	- Provide different approaches to analyzing IoT health data.	- The proposed framework does not address the issue of data processing time by fog calculations.
Ijaz et al. [71]	IoT, fog computing, cloud computing, healthcare	Cloud-based smart home environment (CoSHE)	Java platform	-	Fog and Cloud computing	Fog and Cloud computing	- Reliability, safety, and low cost in fog and cloud computing technology.	- Performance of the inpatient system using the IoT.	- Video communication is not considered in the remote patient health monitoring system.
Nandankar et al. [72]	IoT, Big data, fog computing, cloud computing, health	Map Reduce Hadoop clusters	Apache Spark	Medical data	Fog and Cloud computing	Fog and Cloud computing	- Large-scale data analysis.	- Provide an algorithm for data analysis in the healthcare system.	- The evacuation challenges of fog calculations have not been addressed.
Sun et al. [73]	IoT, Smart Health, Privacy	Electronic health record systems (EHRs)	Encryption Algorithm	-	IoT	IoT	- High-performance and secure solutions in advanced encryption.	- Provide different approaches to IoT-based health monitoring remotely.	- Traceability is not considered in the proposal.
Valsalan et al. [74]	IoT, Health, Sensors	Membership function	MATLAB	Health data	IoT	IoT	- Use of intelligent sensors to control the disease.	- Provide different approaches to IoT-based health monitoring remotely.	- The issue of security and privacy of health data is not addressed.
Acharya et al. [75]	Sensor, IoT, Health	Intensive Care Units (ICU)	MATLAB	-	IoT	IoT	- Reduce human error in the proposed system and distribute data in real-time.	- Provide a patient health monitoring system using IoT technology.	- Patients' movements are not detected in the monitoring kits provided.

these technologies in remote healthcare. Table 3 presents the evaluation criteria for published studies in remote healthcare systems. The evaluation criteria include reliability, cost, sensitivity, performance, safety, and privacy. Among these criteria, performance has received the highest rating, indicating that efficiency remains a primary focus in this area of research. This shows that performance, especially in the context of remote healthcare, continues to be a key priority in the studies. In comparison to performance, other criteria such as sensitivity and cost have also been considered, but significant practical challenges remain in accurately assessing these factors. Meanwhile, privacy and reliability have been addressed in some studies but have not been consistently explored across all articles. Safety, as an important criterion in remote healthcare systems, has been examined in only a limited number of studies, which may reflect differing priorities among researchers in the design of these systems. Table 4 presents the qualitative evaluation criteria of studies in the remote healthcare system. Analyzing these criteria shows that research has primarily focused on performance, with less attention given to issues such as safety, sensitivity, and cost. This analysis suggests that research in this field has not sufficiently addressed aspects like security, sensitivity, safety, and cost in remote healthcare systems. Given the ongoing growth and development of IoT, fog, and cloud computing technologies, it can be expected that greater attention will be paid to criteria such as safety, privacy, sensitivity, and cost in future research. In this regard, innovations and advancements in these technologies could help improve performance and mitigate existing challenges in remote healthcare systems [68]. Ultimately, this analysis indicates that despite technical advancements in various

TABLE 3. Evaluation criteria of published studies in remote healthcare systems.

Study	Sensitivity	Reliability	Cost	Safety	Privacy	Performance
Saidi et al. [68]	×	×	×	×	×	✓
Alexandru et al. [69]	✓	×	×	×	×	✓
Alshammari et al. [70]	×	×	×	×	×	✓
Ijaz et al. [71]	×	✓	✓	✓	×	✓
Nandankar et al. [72]	×	✓	×	×	×	✓
Sun et al. [73]	×	×	×	×	✓	✓
Valsalan et al. [74]	×	×	×	×	×	✓
Acharya et al. [75]	×	×	✓	×	×	×

TABLE 4. Qualitative evaluation criteria in remote healthcare systems.

Evaluation criteria	Low	Medium	High
Sensitivity	✓	×	×
Reliability	×	✓	×
Cost	×	✓	×
Safety	✓	×	×
Privacy	✓	×	×
Performance	×	×	✓

areas, further research is needed in aspects such as data security, system reliability, sensitivity, and cost. Future research should place greater emphasis on these dimensions to enhance not only the efficiency but also the sustainability and security of remote healthcare systems.

C. SMARTPHONE IN HEALTHCARE

In this section, we review the articles in the field of smartphones in elderly healthcare.

Shahzad et al. [76] investigated a smartphone-based system for automated elderly fall detection using multiple algorithms. Using a system that can automatically detect the fall of older adults and simultaneously be effective and reliable can prevent the risks and injuries of older adults falling. This study used a two-stage algorithm embedded in a smartphone to detect falls. Shahzad et al. [76] investigated a smartphone-based system for automated elderly fall detection using a two-stage algorithm. The system aims to prevent the risks and injuries associated with falls in older adults by accurately detecting falls and reducing false alarms. The algorithm achieved good classification results, with low computational cost and energy consumption, working effectively both online and offline. The paper's strength is its innovation in fall detection and emergency alarm systems, while the drawback is the lack of consideration for feature extraction engineering to improve system performance. Ammar et al. [77] conducted surveys on digital health technology to promote a healthy and active life for older adults. The study emphasized the role of information and communication technology in improving the physical and mental health of the elderly. The use of digital health solutions was found to be a key factor in managing health strategies for the elderly. The paper's strength was its focus on using digital technology for health management, while its drawback was that mental and behavioral disorders of the elderly could not be monitored through this technology. Huq et al. [78] evaluated triaxial accelerometry data in elderly fall detection using smart mobile phones. Reviews show that a six-month trial was conducted through a smartphone. In this experiment, fall data were analyzed, and a fall detection algorithm was designed for the elderly. The authors' studies showed that the elderly are cared for and feel more secure during the research. The survey results showed that the analysis of three-axis accelerometer data to detect the fall of the elderly faces many problems. The benefit of this paper was monitoring the health of the elderly and improving their quality of life. The drawback of the paper was that the data extracted from the triaxial accelerometer was not of high quality. Concepción et al. [79] investigated a fall detection system for the elderly using the Ameva algorithm. The system efficiently monitors elderly physical activity, with low complexity and energy consumption, making it suitable for smart watches and wearable devices. The algorithm focuses on detecting falls and tracking daily activities, with healthcare workers able to monitor the elderly through an alarm system. The paper's strength lies in presenting a new technique for fall detection, while its weakness is the lack of attention to the security of the proposed algorithm. Oh et al. [80] studied the health of Korean elderly using smartphones, focusing on their access to health information. The research found that the elderly in Korea, with lower education levels, face challenges in accessing online medical information and are more likely to use smartphones for health monitoring due to high healthcare costs and limited insurance coverage. The study highlights the importance of literacy in improving access to health information. The paper's benefit is demonstrating the role of smartphones in elderly healthcare, while its drawback is not addressing the duration of smartphone use. Majumder et al. [81] explored the use of smartphone sensors for monitoring health data, especially for elderly individuals. With the growing aging population, smartphones offer an efficient and cost-effective solution for remotely tracking chronic diseases like diabetes and cardiovascular conditions. The study highlighted the benefits of smartphone sensors in enabling independent living and providing early disease diagnosis. However, the paper did not address security and privacy concerns related to smartphone use in healthcare systems. Khan et al. [82] assessed special needs and medication compliance in the elderly using smartphones. The study highlighted the challenges of managing healthcare and monitoring chronic diseases in the aging population. To improve elderly care and independence, the Ambient Assisted Living (AAL) method was proposed, utilizing smartphones for remote monitoring. The system synchronizes medication data with the cloud, providing a comprehensive history to pharmacy vendors. The study's advantage is offering smartphone-based solutions to enhance elderly quality of life, while its drawback is the lack of deep analysis of large-scale data in the proposed system.

Salman et al. [83] conducted an assessment of elderly users using smartphones. The main purpose of this study was to use the SMASH technique (Smartphone's usability heuristics) to explore the problems of older adults using smartphones. The survey results show that the experts could predict 79.17% of the problems experienced by the elderly and provide feedback to the smartphone designers for each problem. In their review, the authors categorized smartphone usage problems and proposed solutions. As a future solution, techniques for designing a prototype of a smartphone launcher can be considered. The article's advantage was presenting a technique for evaluating elderly users' use of smart mobile phones. The weakness of the paper was that the solutions proposed by the authors lacked IOS evaluation.

D. EVALUATION OF STUDIES IN THE SMARTPHONE IN THE HEALTHCARE CATEGORY

Table 5 shows the categorization of studies in the field of smartphone use in healthcare, which is generally divided into two main subcategories: health detection systems and fall detection systems. This categorization highlights the diverse applications of smartphones in healthcare, which assist in diagnosing and monitoring diseases and health conditions. The use of these technologies is particularly important in elderly care, as they enable health status monitoring and early detection of health issues. Table 6 compares the evaluation criteria of reviewed studies in the field of smartphones in healthcare. The evaluation criteria include sensitivity, availability, reliability, security, privacy, usability, performance, cost, and accuracy. Among these, the sensitivity criterion received the highest evaluation scores, indicating that sensitivity is one of the most important factors in assessing smartphone-based technologies in this field. This may be due to the importance of precision in measuring physiological parameters and accurate detection of health problems. Furthermore, criteria such as cost, performance, and accuracy were used moderately in the articles, reflecting the focus on various aspects of the development and implementation of these technologies. However, privacy and usability were less emphasized compared to other criteria, suggesting that these aspects require more attention in future research. Table 7 examines the qualitative evaluation criteria of smartphone analytical articles. The results indicate that the majority of evaluation statistics in the analytical articles pertain to the sensitivity criterion, highlighting the significance of this criterion in evaluating the performance of smartphones in healthcare. Additionally, performance, accuracy, availability, security, and reliability criteria were used moderately in the articles, indicating efforts to improve and stabilize these features in related technologies. However, criteria such as cost, privacy, and usability received very little attention in the articles, suggesting a need for further research in these areas to adequately address various aspects of health and data security in these technologies. Overall, this analysis shows that while smartphones hold great potential in healthcare, especially for elderly care, more focus should be given to aspects such as privacy, data security, and cost in future research. In the article, these evaluation criteria are used to comprehensively assess the performance and capabilities of smartphone-based systems in healthcare. These criteria are particularly important for evaluating the accuracy, reliability, security, and efficiency of these technologies in various areas such as health detection, patient monitoring, and elderly care management. The selection of these criteria is based on the specific needs of healthcare systems and the challenges present in this field, allowing researchers to more accurately analyze the strengths and limitations of these technologies and identify areas for improvement.

E. SECURITY AND PRIVACY IN HEALTHCARE

In this section, we show the areas of security and privacy of healthcare for the elderly in the IoT. Beheshti et al. [84] considered a framework for security in the electronic health of patients. E-health provides many services related to medicine and healthcare. Electronic health, one of the IoT subsets, faces many challenges, including maintaining the security and privacy of patients' health data. In the framework proposed by the authors, an authentication scheme for people's privacy was presented, which meets the security requirements in e-health. The proposed scheme uses lightweight encryption due to its lack of computational complexity. The results obtained from the investigations show the safety of the proposed plan. The benefit of this paper was to present new approaches to maintaining the privacy of patients' health data.

The drawback of the paper was that approaches to security requirements in e-Health had not been explored. Azeez et al. [85] investigated privacy and security in eHealth using the cloud, highlighting the impact of information and communication technology on healthcare. They proposed a cloud-based taxonomy and presented a secure architecture for e-Health, addressing data accessibility, reliability, and efficiency to ensure privacy and security between patients and healthcare workers. The study's benefit was its presentation of policies to maintain patient data security, while its drawback was the lack of focus on the security challenges in cloud computing. Enaizan et al. [86] analyzed the security of electronic medical record systems. The study focused on the security and confidentiality of electronic medical records, which are key components of electronic health. The authors developed frameworks using structural equation modeling and multi-criteria decision-making to evaluate security and privacy. The findings showed that electronic medical records positively impact data integrity, confidentiality, and non-repudiation, while negatively affecting unauthorized use and errors. The paper's benefit was its evaluation and review of electronic medical records in hospitals. Sivan et al. [87] examine the security and privacy challenges in cloud-based e-health systems. The authors identify threats such as data leakage, unauthorized access, and cyberattacks, and propose security-enhancing solutions including encryption, multi-factor authentication, and the use of blockchain

TABLE 5. Categorization of studies in the field of smartphones in the healthcare category.

Study	Keyword	Domain	Simulation / Implementation	Dataset	Application Domain	Case Study	Results	Benefit	Drawback
Shahzad et al. [76]	Fall detection, Smartphone, Healthcare	Classification Algorithm	Simulation by MATLAB	-	Fall detection system	Fall detection system	- Reduce energy and costs.	- Provide a crash detection and emergency alarm program using a smartphone.	- Not considering the feature extraction engineering part in improving the system's overall performance.
Ammar et al. [77]	Digital health, Physical activity, Psychosocial strain Seniors	Information and communications technology	-	-	Fall detection system	Fall detection system	-	- Use of digital technology to control the health of the elderly and provide health solutions.	Elderly mental and behavioral disorders cannot be controlled through digital health technology.
Huq et al. [78]	Algorithm, Elderly, Smart phone,	Tri-axial accelerometry	Java platform	Accelerometer data	Fall detection system	Fall detection system	- Reduce the risk of falls with wearable items.	- Monitoring the health of the elderly through a three-axis accelerometer.	- The data extracted from the three-axis accelerometer is not of high quality.
Concepción et al. [78]	Activity Recognition, Artificial Intelligent, Smart-Energy Computing	Activity recognition systems for elders.	Prototype	Health data	Fall detection system	Fall detection system	Low energy consumption reduced computational cost and high accuracy rate.	- Provide a technique for modern classification and diagnosis of falls in the elderly.	- The security issue of the proposed algorithm has not been investigated.
Oh et al. [80]	Older people; health information, smartphone; self-care	Health Information Seeking	-	-	Health detection system	Heal detection system	-	The role of smartphones in the health of the elderly.	- There is no set time for using the smartphone.
Majumder et al. [81]	Smartphone; remote healthcare; Sensor	Medical device	-	-	Health detection system	Health detection system	-	- Provide different policies for devices and their implications for the healthcare system.	- The security and privacy of smartphones in healthcare systems have not been addressed.
Khan et al. [82]	Elderly, Smart Assist, Smartphone	Clinical Administration Layer	-	-	Health detection system	Health detection system	-	- The article presents smartphone-based solutions to improve the quality of life of the elderly.	- In the proposed system, in-depth large-scale data analysis is not performed.
Salman et al. [83]	Usability, Smartphone, Elderly	Heuristic evaluation	Prototype	Health data	Health detection system	Health detection system	- Predictability of elderly problems in using a smartphone.	- Provide a technique for evaluating older users in the use of smartphones	- The authors' proposed solutions lacked iOS evaluation.

technology. The article concludes that implementing multi-layered security approaches can effectively protect sensitive patient information and increase trust in these systems. Chenthara et al. [88] review the key security and privacy challenges faced by e-health solutions deployed in cloud computing environments. The study highlights major threats such as data breaches, unauthorized access, and weak access control policies. To address these issues, the authors explore several techniques, including attribute-based encryption (ABE), policy-based access control (PBAC), blockchain for secure audit trails, and machine learning for anomaly detection. The article concludes that no single solution can fully ensure data security in cloud-based e-health systems; instead, a combination of advanced security technologies and standardized frameworks is essential to effectively protect sensitive health information. Hatzivasilis et al. [89] present a comprehensive review of security and privacy issues in the Internet of Medical Things (IoMT). The study highlights key challenges such as data leakage, insecure communications, device authentication, and regulatory compliance. It discusses lightweight encryption, secure communication protocols, and blockchain as potential solutions. The authors conclude that ensuring privacy and security in IoMT requires a multi-layered approach tailored to the resource constraints and specific needs of medical devices. Ghubaish et al. [90] provide an overview of recent

TABLE 6. Evaluation factors in the field of smartphones in healthcare.

Study	Performance	Accuracy	Availability	Security	Reliability	Cost	Privacy	Usability	Sensitivity
Shahzad et al. [76]	✓	✓	×	×	×	×	×	×	✓
Ammar et al. [77]	×	×	✓	×	×	×	×	×	×
Huq et al. [78]	×	×	✓	✓	×	×	×	×	✓
Concepción et al. [79]	✓	✓	×	×	✓	×	×	×	×
Oh et al. [80]	×	×	×	×	×	✓	×	×	×
Majumder et al. [81]	✓	×	×	✓	✓	×	✓	×	✓
Khan et al. [82]	×	×	×	×	×	×	×	×	✓
Salman et al. [83]	×	×	×	×	×	×	×	✓	×

TABLE 7. Qualitative evaluation criteria in smartphones in healthcare.

Evaluation criteria	Low	Medium	High
Performance	×	✓	×
Accuracy	×	✓	×
Availability	×	✓	×
Security	×	✓	×
Reliability	×	✓	×
Cost	✓	×	×
Privacy	✓	×	×
Usability	✓	×	×
Sensitivity	×	×	✓

advancements in the security of Internet of Medical Things (IoMT) systems. The paper identifies major security threats such as data breaches, unauthorized access, and attacks on device integrity. It reviews emerging solutions, including blockchain, edge computing, AI-based threat detection, and lightweight encryption. The authors conclude that while progress has been made, securing IoMT requires integrating multiple technologies and designing adaptable, scalable, and energy-efficient security frameworks to protect sensitive medical data effectively. Aman et al. [91] studied the architecture and security of the medical IoT. Medical IoT is an excellent option for assisting patients in controlling and preventing many diseases by monitoring a person's health remotely through the cloud with health monitors or wearable sensors. In this study, the authors examined the security of the medical IoT by integrating blockchain as well as artificial intelligence and presented specific architectural models. The authors' analysis showed that blockchain technology is a suitable option for the security of intelligent systems and for reducing security damages. As a future solution, the security issues of medical IoT can be investigated by integrating data mining and artificial intelligence. The benefit of this paper was a comprehensive review of the security of intelligent systems and the reduction of security risks. The drawback of the paper was that the management solutions for the proposed architectural models were not considered. Vaiyapuri et al. [92] explored security and privacy challenges in medical IoT (IoMT) systems. They highlighted how IoMT, including remote health monitoring and smart drugs, has reduced hospital visits but emphasized the importance of addressing security issues. The study evaluated advanced security solutions, focusing on safe data sharing through blockchain and suggested the use of Elliptic Curve Cryptography (ECC) to meet security requirements. The paper's advantage is proposing a security algorithm for IoMT, while its drawback is the lack of consideration for effective, lightweight systems for maintaining security. Papageorgiou et al. [93] analyzed the privacy and security of mobile health applications, focusing on their use of health-related data to improve patient care. Using the GDPR method, the study evaluated the performance of various apps, revealing that many fail to comply with guidelines, compromising user privacy. While the study highlighted the benefits of free mobile health apps, it also identified significant drawbacks, such as lack of encryption and insecure programming techniques, which pose ongoing challenges without proposed solutions. Nurgalieva et al. [94] conduct a scoping review on the security and privacy aspects of mobile health (mHealth) applications. The study highlights common issues such as inadequate data encryption, insufficient user consent mechanisms, and lack of transparency in data sharing practices. The authors analyze a wide range of mHealth apps and find that many fail to meet essential security and privacy standards. The paper concludes that there is an urgent need for clearer regulatory guidelines, better user awareness, and the integration of privacy-by-design principles to ensure the protection of users' sensitive health data. Attarian et al. [95] proposed a protocol for securing mobile health applications using the IoT. The study focused on using Elliptic Curve Cryptography (ECC) for data security in mobile health apps, addressing key concerns

TABLE 8. Categorization of studies in the field of security and privacy in the healthcare category.

Study	Keyword	Domain	Simulation / Implementation	Dataset	Application Domain	Case Study	Results	Benefit	Drawback
Beheshti et al. [84]	E-Health, IoT, Security, Privacy	The Electronic Health Record	Simulation by ProVerif	-	E-Health	E-Health	- Lightweight encryption. - Simplicity of the proposed scheme calculations.	- Provide new approaches to protecting the health of patient health data.	- Failure to address the challenges of security requirements in e-health.
Azeez et al. [85]	E-Health, Security, Privacy, Cloud	Communication Technology.	-	-	E-Health	E-Health	- High efficiency and reliability of the proposed architecture.	- Provide e-health policies to protect patient data.	- Failure to address security challenges in cloud computing.
Enaizan et al. [86]	Security, Privacy, Electronic Medical	Multi-criteria decision.	Implemented by K-means clustering.	Health data	E-Health	E-Health	- The positive effect of electronic medical records on data integrity and confidentiality.	Evaluation and review of electronic medical records in hospitals.	- Minor impact of electronic medical records on authentication issues and performance of health data.
Sivan et al. [87]	E-Health, Cloud computing, Security, Privacy.	Electronic health records.	Prototype	-	E-Health	E-Health	- Scalability and flexibility of data.	- Provide various solutions in the healthcare system for data security and privacy.	-The security of the approaches presented in e-health is not guaranteed.
Chenthara et al. [88]	Security, Privacy, e-Health, Cloud	Symmetric Encryption	-	-	e-health	E-Health	-	- Provide various solutions for secure data encryption and security.	- Provide no approach to data confidentiality and integrity.
Hatzivasilis et al. [89]	Healthcare, IoT, Security, Privacy	e-health	Java platform	-	IoMT	IoMT	- Use the controller to reduce potential hazards and threats.	- Provide defensive approaches to protect the privacy and security of patient and elderly data.	- The challenges of the proposed approach are not mentioned.
Ghubaish et al. [90]	Healthcare systems, IoT, Security	Machine-to-Machine (M2M)	Prototype	-	IoMT	IoMT	- Provide security frameworks and requirements.	- Investigation of security techniques and requirements in IoT systems.	- Most security frameworks are not intended for different types of attacks.
Aman et al. [91]	IoT, Architecture, Privacy, Security	Wireless Body Area Networks (WBAN)	C+ +	-	IoMT	IoMT	- Reduce intelligent system security vulnerabilities with blockchain technology.	- Comprehensive review of intelligent systems security and mitigation of security risks.	- Management solutions are not considered for the proposed architectural models.
Vaiyapuri et al. [92]	Healthcare, IoT, Security, Privacy	The smart healthcare system (SHS)	ECC Algorithm	-	IoMT	IoMT	- Effective performance of ECC algorithm in smart health system security.	- Provide an algorithm to check the security of the smart health system and the IoT.	- Effective and lightweight systems are not considered in the security and maintenance of smart health systems.
Papageorgiou et al. [93]	Privacy, Security, Mobile Health	Mobile Accessible Personal Health Records	Android	Patient data	Mobile Health	Mobile Health	- Improper execution and poor design of programs in protecting users' privacy.	- Provide free mobile health apps to analyze their privacy and security issues.	- Lack of encryption of programs and insecure programming techniques.
Nurgalieva et al. [94]	Digital health, Data Privacy, Data Protection, Data Security	General Data Protection Regulation	Android	Patient data	Mobile Health	Mobile Health	- Assess security and privacy issues of digital health applications.	- Systematic review of mobile health application analysis.	- Digital health Study solutions and security issues have not been explored.

of security and privacy in medical data. The proposed method offered high security, unforgeability, and reduced key-breaking, with low computational cost. The study highlighted that the protocol protected health data through the IoT, but noted that challenges regarding data anonymity and security in healthcare systems remain unresolved. The paper's advantage was its secure encryption for medical data protection, while its drawback was the ongoing security

TABLE 8. *(Continued.)* **Categorization of studies in the field of security and privacy in the healthcare category.**

Attarian et al. [95]	Mobile health, Smart contracts, Privacy, Security, IoT	Onion encryption	Simulation by Kali Lin	Health data	Mobile Health	Mobile Health	- Low computing cost in the proposed protocol.	- Provide secure encryption to protect medical data in mobile health apps.	-Existence of security challenges and anonymity of data in healthcare.
Cagnazzo et al. [96]	Cybersecurity, IoT, privacy, blockchain	Mobile health systems	-	-	Mobile Health	Mobile Health	- Identifies potential security risks in mobile health systems, Highlights vulnerabilities related to data transmission, authentication, and access control.	- Provides a systematic approach to identifying and mitigating security threats in mobile health systems.	- Lacks empirical validation or real-world case studies to assess the effectiveness of the proposed threat model.
Zhang et al. [97]	Smart health, Privacy, Security,	Attribute-based access control (ABAC)	MATLAB	Health dataset	Mobile Health	Mobile Health	-Proposes a policy-hiding attribute-based access control (ABAC) scheme for smart health systems. - Demonstrates improved security and privacy protection for patient data.	- Enhances security and privacy in smart healthcare environments while maintaining computational efficiency.	- Lacks real-world deployment and empirical validation with actual healthcare data.
Butt et al. [98]	Smart health, cybersecurity, IoT	Policy hiding, encryption.	Python	Health dataset	Mobile Health	Mobile Health	- Proposes a policy-hiding attribute-based access control (ABAC) scheme for smart health systems. -Demonstrates improved security and privacy protection for patient data.	- Enhances security and privacy in smart healthcare environments while maintaining computational efficiency.	- Lacks real-world deployment and empirical validation with actual healthcare data.
Srilakshmi et al. [99]	IoT security, smart healthcare	Software-Defined Networking (SDN)	Simulated by Software-Defined Networking (SDN)	-	Mobile Health	Mobile Health	- Shows improvement in network security through SDN-based monitoring and control. - Evaluates the system's performance in terms of attack detection and response time.	- Integrates SDN with IoT healthcare to enhance security and prevent cyber threats.	- Lacks real-world deployment and validation; primarily focuses on simulation-based analysis.
Ogundoyin et al. [100]	Smart health, Privacy-preserving, IoT	Cryptographic techniques.	Simulated using cryptographic frameworks	-	Mobile Health	Mobile Health	- Demonstrates improved privacy preservation for smart health data in smart cities. - Reduces computational overhead while maintaining security. - Provides resistance against unauthorized access and data breaches.	- Effectively integrates privacy-preserving mechanisms with fine-grained access control for outsourced healthcare data.	- Lacks real-world deployment and empirical validation beyond simulation-based evaluation.

challenges. Cagnazzo et al. [96] reviewed mobile health systems and evaluated threat models, emphasizing how technology has reduced healthcare costs and shifted care from inpatient to outpatient and home settings. They discussed the challenges of security and reliability in these systems and proposed authentication and encryption methods using the DREAD model to assess risks. The paper highlights the potential of mobile health architecture to improve threat modeling, suggesting a standard security protocol for future solutions. The benefit of the paper is its exploration of security techniques, while the weakness is the lack of discussion on systems with high fluctuations in mobile health.

Zhang et al. [97] explored security and privacy in smart health, leveraging IoT and advanced technologies to enhance healthcare quality. They introduced the PASH method, which uses SHR decryption and adheres to secure, standardized policies to ensure data privacy and access control. The study demonstrated that PASH offers high security and effective performance. While the research highlighted a robust system for protecting user health data, it acknowledged that policy concealment issues in smart health remain underexplored. Butt et al. [98] examined security in smart health systems using IoT, focusing on health monitoring, emergency diagnosis, and remote medical services. They highlighted the risks posed by various attacks and threats to these systems. The study proposed that meeting security requirements can enhance system safety and suggested designing intelligent health systems with robust security strategies to prevent data theft and attacks. While the research provided valuable security guidelines, it did not address the challenges of implementing these security requirements in health systems. Ogundoyin et al. [99] explored data privacy and security in smart health systems using IoT advancements. They proposed the PAASH scheme, which employs Elliptic Curve Cryptography (ECC) for authentication and data security. The study demonstrated that PAASH effectively meets security requirements for smart health systems. However, the research identified a drawback: direct data uploads to the medical cloud cause performance delays. As a future solution, the authors suggested implementing a fog computing-based architecture to address this issue.

F. EVALUATION OF STUDIES IN SECURITY AND PRIVACY IN THE HEALTHCARE CATEGORY

Table 8 categorizes various studies in the field of healthcare security and privacy, with subsections that include smart health, electronic health, mobile health, and the Internet of Medical Things (IoMT). These categories reflect the diverse applications of smart technologies in healthcare and their importance in improving the quality of medical services and elderly care. Smart health and IoMT, in particular, play a critical role in creating intelligent systems and using data for disease prevention, diagnosis, and care for patients and the elderly. Table 9 examines the evaluation criteria for security and privacy in healthcare. The evaluation criteria include security, privacy, availability, reliability, cost, scalability, performance, and accuracy. In this context, security and privacy standards received the highest evaluation statistics, indicating the crucial importance of safeguarding sensitive data in healthcare smart systems. Given the increasing threats and cyberattacks on smart systems, security and privacy, especially in healthcare, should be given more serious attention [98]. Table 10 presents a comparison of the qualitative evaluation factors for analytical articles on security and privacy. Security and privacy, which received the highest evaluation statistics, clearly reflect the focus on these aspects in healthcare studies. Smart health systems and IoMT require strong security measures to prevent data theft and cyberattacks. Performance and cost were evaluated at a moderate level, indicating that researchers are focusing on improving system efficiency and reducing costs, though more attention is still needed in these areas. Scalability, accuracy, and reliability were less frequently addressed in the reviewed articles, which may be due to a stronger focus on security and privacy challenges. However, scalability and reliability are crucial for the development of sustainable healthcare systems. The analysis indicates that future research in healthcare security and privacy should focus more on the scalability, accuracy, and reliability of systems. Additionally, future studies should give more attention to the economic and performance-related challenges of these technologies to provide smart and secure healthcare systems for societies.

G. SMART HOME IN HEALTHCARE

We divided the areas of the smart home in healthcare for the elderly into two subsections: hygiene and health. The articles of each subsection have been reviewed separately.

H. HYGIENE

Monitoring chronic diseases in the elderly is one of the parts of the smart home in the IoT that relates to the healthcare of the elderly. This sub-section will examine analytical articles in this field. Bennett et al. [101] explored healthcare in smart homes, focusing on how sensors and actuators improve the quality of life for the elderly, particularly those with conditions like Alzheimer's and Parkinson's. They emphasized the potential of smart homes to enhance remote disease prevention and treatment. The authors suggested that smart solutions could reduce pressure on healthcare providers and offer more affordable services. While the paper highlights the benefits of smart homes in elderly healthcare, it lacks a solution for reducing healthcare costs in these settings. Pham et al. [102] explored using cloud technology for healthcare in smart homes, particularly for the elderly. By utilizing wearable sensors, the smart home environment collects data on the elderly's movement and sound, providing insights into their daily activities and behavioral changes. This data is then sent to the cloud for remote access by caregivers. The authors implemented complex algorithms to integrate health data, although this led to high energy consumption. The paper's advantage was the proposed algorithm for elderly healthcare in smart homes, but it lacked a system for automatically alerting caregivers in emergencies. Chatrati et al. [103] investigated smart home systems for predicting and controlling diseases like diabetes and hypertension. Their system analyzes patients' blood to monitor health remotely, alerting healthcare providers about abnormalities. The system aids in early disease detection, reducing hospitalization costs and patient stress. The paper's advantage is the development of a remote-control system for managing diabetes and hypertension. However, the drawback is that it did not comprehensively address the challenges of health monitoring from various aspects. Maresova et al. [104] investigated chronic diseases in the elderly, noting

TABLE 9. Evaluation factors in the healthcare field of security and privacy.

Study	Privacy	Security	Reliability	Availability	Scalability	Cost	Accuracy	Performance
Beheshti et al. [84]	✓	✓	×	×	×	×	×	×
Azeez et al. [85]	✓	✓	✓	✓	×	×	×	✓
Enaizan et al. [86]	✓	✓	×	×	×	×	×	×
Sivan et al. [87]	✓	✓	×	×	✓	×	×	×
Chenthara et al. [88]	✓	✓	×	✓	×	×	×	×
Hatzivasilis et al. [89]	✓	✓	×	×	×	✓	×	×
Ghubaish et al. [90]	×	✓	×	×	×	×	×	×
Aman et al. [91]	✓	✓	×	×	×	×	×	×
Vaiyapuri et al. [92]	×	✓	✓	×	×	×	✓	×
Papageorgiou et al. [93]	✓	✓	×	×	×	✓	×	×
Nurgalieva et al. [94]	✓	✓	✓	×	×	×	×	×
Attarian et al. [95]	✓	✓	×	×	×	✓	×	×
Cagnazzo et al. [96]	✓	✓	×	×	×	×	×	×
Zhang et al. [97]	✓	✓	×	✓	×	×	×	×
Diaz et al. [98]	×	✓	×	×	×	×	×	×
Srilakshmi et al. [99]	×	✓	×	✓	×	×	×	✓
Ogundoyin et al. [100]	✓	✓	×	×	×	×	×	✓

TABLE 10. Qualitative evaluation criteria in security and privacy in healthcare.

Evaluation criteria	Low	Medium	High
Privacy	×	×	✓
Security	×	×	✓
Reliability	✓	×	×
Availability	×	✓	×
Scalability	✓	×	×
Cost	×	✓	×
Accuracy	✓	×	×
Performance	×	✓	×

that nearly 60% of older adults in the U.S. suffer from conditions like high blood pressure, diabetes, and heart disease. They provided solutions to improve the quality of life for the elderly, focusing on physical and mental needs. Encouraging daily activities and social participation can positively impact their well-being. The benefit of this paper was its focus on approaches to managing chronic diseases in the elderly, while the drawback was the refusal of some elderly individuals to engage in daily activities, which negatively affects their health. Atella et al. [105] studied the rise in chronic diseases among the elderly, linking it to increased healthcare and economic costs, especially in developed countries. They predicted that by 2050, costs for those over 80 would triple. Focusing on Italy, the study found that most elderly individuals over 60 suffer from multiple chronic diseases, leading to high long-term care expenses and reduced physical performance. The authors proposed approaches to lower healthcare costs by monitoring chronic conditions and preventing severe issues. While the research highlighted the importance of managing chronic diseases to improve the elderly's quality of life, it did not address specific illnesses or movement disorders. Battineni et al. [106] presented machine learning models for chronic disease monitoring in the elderly, highlighting that AI can accurately predict and manage chronic diseases. The study emphasized the effectiveness of integrating machine learning with AI for disease control and long-term prediction models. The benefit of the paper was its comprehensive evaluation of chronic disease management, while the drawback was that the proposed model did not address the issue of reducing medical expenses. Rizzuto et al. [107] studied the impact of chronic diseases on the elderly, highlighting an increase in diseases like diabetes, cardiovascular issues, Alzheimer's, and mental disorders with aging. They found that elderly over 80 suffer from multiple chronic diseases and have the highest death rates, particularly from heart diseases and neurological disorders. Cardiovascular disease reduces lifespan by nearly five years, while chronic neurological and mental conditions shorten it by over six years. The paper's benefit was in

TABLE 11. Categorization of studies in the field of smart homes in the healthcare category.

Study	Keyword	Domain	Simulation / Implementation	Dataset	Application Domain	Case Study	Results	Benefit	Drawback
Bennett et al. [101]	Healthcare; Smart home; Sensors; IoT	Implantable Medical Devices	-	-	Chronic diseases	Chronic diseases	-	- The role of smart homes in controlling and monitoring the health of the elderly.	- There is no solution to reduce the cost of healthcare for the elderly in the smart home.
Pham et al. [102]	E-Health, Security, Privacy, Cloud	IoT, Smart home, Healthcare	Algorithm SVM	Health data	Chronic diseases	Chronic diseases	- High energy consumption and high processing capability.	- Provide an algorithm for a smart home environment in elderly healthcare.	- An elderly illness warning system that can automatically alert caregivers to an emergency has not been designed.
Chatrati et al. [103]	E-Health, Healthcare, Type 2 Diabetes, Hypertension	remote Healthcare	Machine learning	Blood data	Chronic diseases	Chronic diseases	- Predict the onset of diabetes and blood pressure using a machine learning algorithm.	-provide a remote control system to measure patients' diabetes and hypertension.	- It has not comprehensively examined the challenges of health monitoring from various perspectives.
Maresova et al. [104]	Chronic diseases, Elderly, IoT	Activities of daily living (ADL)	C++	-	Chronic diseases	Chronic diseases	- Positive performance in the physical and mental condition of the elderly by performing daily activities.	- Provide different approaches to improve the lives of the elderly and control chronic diseases.	- Some seniors refuse to perform daily activities of life, and this affects the mental and physical functioning of the elderly.
Atella et al. [105]	Elderly, Chronic disease, Healthcare, IoT	Anatomical Therapeutic Chemical (ATC)	C / C++	Patient data	Chronic diseases	Chronic diseases	- Provide effective approaches to controlling or delaying chronic disease.	- Chronic diseases in the elderly and their control to improve their quality of life.	- Approaches intended for specific diseases or movement disorders are ineffective in the elderly.
Battineni et al. [106]	Chronic diseases, Accuracy, Machine Learning	Logistic regression (LR)	Support vector machines (SVM)	Patient data	Chronic diseases	Chronic diseases	- Accurate function of machine learning in predicting chronic diseases.	- Evaluate extensive studies to control chronic diseases in the elderly.	- The model proposed and designed by the authors does not mention the issue of reducing medical costs.
Rizzuto et al. [107]	Chronic diseases, disability, Elderly	Population attributable risk (PAR)	-	-	Chronic diseases	Chronic diseases	- The highest mortality rate is in patients with cardiovascular and mental disorders.	- Evaluation of chronic diseases in the lives of the elderly.	Elderly healthcare costs have not been reviewed.
Palmer et al. [108]	Chronic Diseases, Healthcare, elderly	Multimorbidity	Java platform	-	Chronic diseases	Chronic diseases	- Provide care models to control chronic disease.	- Provide frameworks to control chronic illness in the elderly and help improve their lives.	- Provide frameworks to control chronic illness in the elderly and help improve their lives.
Raghupathi et al. [109]	Chronic disease, Health, Elderly	Pulmonary disease	MATLAB	Health data	Chronic diseases	Chronic diseases	- Complete disease information with behavioral and psychological analysis.	- Evaluation of different approaches to controlling chronic disease and reducing disease-related mortality.	- Disease prevention or reduction policies are not discussed.
Zhou et al. [110]	Chronic disease, Elderly, Rural	Medical benefit	Prototype	-	Chronic diseases	Chronic diseases	- Provide healthcare policies to reduce medical costs.	- Investigation of chronic diseases and a solution to reduce healthcare costs for the elderly.	- No attention has been paid to promoting the physical health of the elderly and improving their quality of life.
Kim et al. [111]	Healthcare, Elderly, Chronic diseases	Self-Efficacy	ANOVA	Elderly data	Chronic diseases	Chronic diseases	- Reducing depression in the elderly through healthy living and continuous learning and exercise.	- Providing an approach for the self-efficacy of the elderly.	- Variables such as economic level and social support did not affect the evaluation.
Alanazi et al. [112]	Chronic diseases, Elderly, algorithms, Machine learning	Convolutional Neural Network	CCN and KNN Algorithm	Patient data	Chronic diseases	Chronic diseases	-High accuracy of the proposed system in early disease diagnosis.	-Investigating chronic diseases using the proposed algorithms.	-The details related to chronic disease prediction in the regression algorithm and decision tree have not been investigated.
Gentile et al. [113]	Healthcare, hypertension, Risk, Blood	Chronic kidney disease	-	-	Chronic diseases	Chronic diseases	- Using a combination therapy to prolong	- Evaluation of high blood pressure and its	- The approaches presented by doctors and the

TABLE 11. ***(Continued.)*** **Categorization of studies in the field of smart homes in the healthcare category.**

							the life of the elderly.	impact on the life of the elderly.	heart and kidney disease association are different from each other.
Keshary et al. [114]	IoT, Elderly, Patient, Healthcare	Remote Health Monitoring	Android	-	Chronic diseases	Chronic diseases	- Examining vital signs of patients remotely to control the disease.	- Investigating diabetes in the elderly using the IoT.	- The issue of health data security in mobile applications has not been addressed.
Jo et al. [115]	Remote Monitoring, Integrated Smart-Home System	Health and Well-being of the Elderly	Android	-	Chronic diseases	Chronic diseases	-the use of smart-home systems for health monitoring and managing daily activities.	- Empirical evaluation of elderly perceptions on the use of IoT technologies in daily life.	- Lack of technical simulation or implementation of smart-home systems to analyze their performance more precisely.
Miori et al. [116]	Elderly Care, Smart Environments	IoT-enabled Social Systems	-	-	Chronic diseases	Chronic diseases	- Enhance social connectivity for the elderly through IoT.	- It presents a framework for integrating IoT technologies to enhance the elderly's quality of life.	- The paper lacks specific experimental results or a demonstration of real-world implementation.
Philip et al. [117]	IoT, Smart Homes, Healthcare, Wearable Sensors	In-Home Health Monitoring Systems	MATLAB	Patient dataset	Chronic diseases	Chronic diseases	- The integration of various IoT devices and sensors for seamless health monitoring remains a challenge.	- A thorough review of current advancements and challenges in IoT-based in-home health monitoring systems.	- Limited focus on the technical challenges, such as system interoperability and scalability, in real-life scenarios.
Mostafa et al. [118]	Elderly Smart Home IoT,	Adjustable Autonomous Multi-Agent System	MATLAB	Patient dataset	Chronic diseases	Chronic diseases	- Autonomy in Task Management:, Improved Efficiency.	- User Autonomy, Independent Living, User Comfort:	- Limited discussion on the technical and practical challenges of implementing the system in real-life smart homes
Butt et al. [119]	Elderly Care, Smart Home	Healthcare Technology	Python	Health dataset	Chronic diseases	Chronic diseases	- Health Monitoring, Emergency Assistance, Efficiency of Systems.	- The paper addresses the rising need for elderly care solutions in China driven by an aging population.	- There is limited discussion on the challenges of cost, scalability, and user acceptance of these smart home technologies.
Ghasemi et al. [120]	Elderly Health Care, IoT, Smart Homes	Structural and Behavioral Reference Model	Python	Health dataset	Chronic diseases	Chronic diseases	- Behavioral Response, Autonomy and Safety, System Integration:	- Comprehensive Reference Model,	- Unverified Effectiveness
Do et al. [121]	Smart Home, Elderly Care, IoT	Robot-Integrated Smart Home	Simulated by RISH	-	Chronic diseases	Chronic diseases	- Real-Time Assistance, Improved Autonomy	- Innovative Integration, Comprehensive Assistance	- Limited Scalability, Lack of Long-Term Evaluation
Hosseinzadeh et al. [122]	Elderly Health Monitoring, IoT	Humanized Computing	-	-	Chronic diseases	Chronic diseases	- No specific experimental results or case studies are provided.	- Comprehensive Framework, Potential for Real-Time Monitoring.	- Lack of Empirical Data, Limited Practical Application.
Pal et al. [123]	Smart-home, IoT, elderly	TAM (Technology Acceptance Model),	Simulated by SEM	-	Chronic diseases	Chronic diseases	- Social influence and facilitating conditions also play a crucial role in adoption.	- Provides a comprehensive analysis of factors affecting elderly users' adoption of smart-home services.	- Limited to self-reported data, which may introduce biases in responses.

examining the effects of chronic diseases on the elderly, while its drawback was the lack of analysis on healthcare costs. Palmer et al. [108] presented several patient care models to promote a healthy life and monitor chronic diseases of the elderly. In addition to high healthcare costs, older people with multiple chronic diseases also have a higher mortality rate. This Study aims to investigate chronic diseases and provide solutions for disease control and treatments. The study showed that care models provided recommendations for older adults with multiple chronic conditions and advised them of effective methods of self-care. The benefit of this paper was that it provided frameworks for chronic disease control in the elderly and helped improve their lives. The drawback of the paper was that the challenges and solutions related to medical and healthcare costs for the elderly had not been considered. Raghupathi et al. [109] conducted an empirical study on chronic diseases in the elderly in the United States, highlighting that nearly half of the elderly suffer from chronic conditions like cancer, heart disease, and diabetes. The study emphasized that behavioral and psychological analysis can provide valuable insights into the progression of these diseases and assist in health-related decision-making. The benefit of the paper was its examination of different approaches to controlling chronic diseases and lowering mortality rates, while the drawback was the lack of discussion on policies for disease prevention or reduction. Zhou et al. [110] reviewed chronic diseases among the elderly in rural China, identifying conditions like cancer, diabetes, and cardiovascular diseases as leading causes of death. The study highlighted challenges such as low income, limited medical resources, and high healthcare costs in rural areas. It proposed that improved healthcare policies and government support could reduce costs and enhance elderly health. While the paper focused on lowering healthcare expenses, it overlooked strategies to improve physical health and quality of life for the elderly. Kim et al. [111] studied chronic diseases and health conditions among the elderly, focusing on mental health, depression, and lifestyle. With the aging population becoming a social issue, the research aimed to improve elderly life quality and address chronic diseases. A comprehensive survey of individuals over 60 was conducted, and data were analyzed using ANOVA. Results showed that continuous exercise and learning can reduce depression and chronic diseases, promoting independence and better quality of life. While the study highlighted approaches to enhance self-efficacy in the elderly, it overlooked variables like economic status and social support. Alanazi et al. [112] explored the use of machine learning to identify chronic diseases in the elderly, noting that over 70% of their income is spent on medical expenses. Using KNN and CNN algorithms, they predicted diseases and analyzed disease symptoms based on structured and unstructured data. Their proposed model outperformed logistic regression and decision tree algorithms with an accuracy of over 95%. This model allows for early disease detection and reduces diagnostic and treatment costs. The benefit of the paper was its focus on using machine learning for chronic disease prediction, while the drawback was the lack of detailed analysis on disease prediction with other algorithms. Gentile et al. [113] investigated the impact of high blood pressure on kidney disease in the elderly, highlighting its role in cardiovascular and kidney diseases. The study found that blood pressure above 14 increases mortality by at least three years in seniors over 65. Controlling blood pressure below 120 mmHg was suggested to improve life expectancy and reduce disease risks. The benefit of the paper was its focus on blood pressure management for elderly patients, while the drawback was the conflicting approaches between doctors and the Heart and Kidney Association.

Keshary et al. [114] explored diabetes management in the elderly using IoT technology. With the rise in elderly populations, chronic diseases like diabetes have increased significantly. The study focused on monitoring vital signs, such as blood oxygen levels and heart rate, using pulse oximeters and transmitting data to cloud and mobile servers via sensors. This allowed healthcare providers to remotely assess patients' health. The research highlighted the potential of IoT for personalized healthcare but did not address security concerns related to health data in mobile applications.

I. HEALTH

Another field of smart homes in elderly healthcare is the health field, which examines the behavioral and biological characteristics of the elderly. Below, we will discuss analytical articles related to this field. Jo et al. [115] studied smart homes using the IoT, focusing on the elderly's perception of integrated smart home systems. They found that older adults were initially dissatisfied with using wearable sensors, citing interruptions to their daily activities and difficulty using the devices. However, after reassurance from healthcare providers about continuous health monitoring and safe living conditions, many elderly users were open to adopting independent smart homes. The benefit of the paper was its exploration of elderly users' experiences with smart homes and the provision of policies to protect their data privacy. Miori et al. [116] investigated social IoT to improve the quality of life of older adults. In their research, the authors designed a system to collect user data under the control of healthcare providers and medical staff. They also provided frameworks for integrating social networks with IoT technology. This integration has led to new solutions to develop and improve the quality of life of the elderly. The article's benefit was providing a model for the comfortable life of the elderly through the IoT. The disadvantage of the paper was that the role of IoT in the lives of the elderly had not been investigated from various angles. Philip et al. [117] studied IoT-based systems for home healthcare, highlighting their potential to transform healthcare services by improving quality of life, reducing costs, and enhancing safety. The system enables remote patient monitoring and encourages adherence to health plans, empowering patients to manage their health. The research emphasized the growing role of e-health in healthcare but noted challenges, such as technological barriers and the need for acceptance by patients and policymakers.

Mostafa et al. [118] presented multi-agent modeling for the smart home of the elderly through the IoT. With the advancement of technology, the IoT plays a vital role in intelligent applications and human life. Considering the importance of the IoT in the smart home and healthcare environment, the needs and behaviors of a young person and an older adult are entirely different. Therefore, providing a smart home for independently monitoring and controlling such differences in the IoT is necessary. In their study, the authors investigated and analyzed the challenges related to the management and control of the IoT using the simulation of an automatic multi-agent system. The results of the tests showed that the detection of the daily activity of the elderly in the simulated system has very high accuracy. The advantage of the paper was the simulation of autonomous functions in a smart home environment for the elderly. The healthcare system settings are such that the elderly usually follow a certain daily routine. If this routine is changed, the healthcare system's performance will decrease, which is considered the drawback of the paper. Hang et al. [119] studied smart homes for elderly care in China, focusing on the impact of medical technology on improving the quality of life and life expectancy. The demand for elderly care services has risen, and smart homes offer solutions for the elderly's independence, safety, health, and cost efficiency. However, challenges like inconsistencies in product and service provision remain. The study found that smart homes positively impact the physical and mental health of the elderly, improving their quality of life. The paper's benefit was highlighting smart home development, while its drawback was the unresolved issues, including high costs and low demand. Ghasemi et al. [120] analyzed smart home models using IoT for elderly care, focusing on low-cost, long-term healthcare solutions, early diagnosis, and independent living. The system integrates wearable and environmental sensors to monitor elderly activities, vital signs, and physical conditions, improving security and efficiency. The benefit of this study was applying IoT to manage elderly behavior, while its drawback was not identifying all threats to the elderly's quality of life. Do et al. [121] developed a robot-integrated smart home (RiSH) for elderly healthcare. The system uses sound signals and inertia to recognize the environment, enabling human tracking, activity detection, and fall detection. Test results showed that RiSH accurately tracked human location and activity, with moderate accuracy in detecting falls. The benefit of the study was introducing RiSH as a platform for elderly care, while its drawback was the limited testing of RiSH in real-world environments. Hosseinzadeh et al. [122] investigated the health of the elderly using humans' behavioral and biological characteristics. The health issues of the elderly have become a serious problem because of the growing elderly population and the rising cost of healthcare. For this purpose, network technologies and sensors provide a basis for the IoT. The authors' proposed system creates an elderly health monitoring system, which provides the medical team to evaluate essential behavioral and biological activity data using IoT systems. Data collection and pre-processing also take place in the smart system. They performed the evaluation process with different classification methods and presented an algorithm. The results demonstrated the precision and effectiveness of the authors' proposed design. The article's advantage was presenting a monitoring plan for the health system of the elderly based on their behavioral characteristics. The drawback of the paper was that it did not address the solutions and challenges of the health of the elderly in the real physical world. Pal et al. [123] analyzed the use of smart homes by elderly users, considering the growing elderly population and their concerns. The study examined the positive (compatibility, satisfaction) and negative (security, privacy, cost) aspects of smart homes for the elderly through an online questionnaire and modeling. The authors proposed two models: ESHTAM (Elderly Smart Home Technology Acceptance Model) and TAM (Technology Acceptance Model), finding that ESHTAM showed 85.4% better capability in smart home adoption compared to SAM. The study highlights the potential of smart homes to improve the quality of life for the elderly through technology and services.

J. EVALUATION OF STUDIES IN SMART HOMES IN HEALTHCARE

Table 11 emphasizes the two main domains of smart homes in healthcare: chronic disease control and the biological and behavioral characteristics of the elderly. The evaluation considers hygiene and health aspects, focusing on the healthcare needs of the elderly within the IoT environment. This highlights the multifaceted role of smart homes in promoting both the well-being and medical care of elderly individuals through IoT-based solutions. Table 12 presents the evaluation criteria used in studies about smart homes. These include: Performance: The most commonly used criterion, which evaluates how effectively smart homes function to improve the lives of the elderly and manage chronic diseases. Cost: Frequently assessed, reflecting the focus on making smart homes affordable and cost-effective. Accuracy: This is also assessed, indicating an interest in ensuring that smart homes provide precise health monitoring and interventions. Mobility, scalability, availability, reliability, security, and privacy: These criteria are used to a much lesser extent, suggesting that while they are important, more research is needed to evaluate these aspects thoroughly. This distribution shows a clear focus on performance in smart home studies, with an emphasis on how well these systems can address chronic health issues and enhance the elderly's quality of life. Table 13 provides a qualitative evaluation of smart home studies, confirming that performance is the most prominently assessed criterion. In contrast, the cost and accuracy criteria are moderately assessed, while mobility, scalability, availability, reliability, security, and privacy are evaluated the least. This imbalance indicates a gap in the research, particularly in addressing concerns around the scalability and privacy of smart home systems, which are crucial for ensuring widespread adoption and secure use. In summary, while there is strong emphasis on performance in the development and evaluation of smart homes for elderly healthcare, more attention is needed to evaluate aspects like scalability, security, and privacy. Furthermore, reducing healthcare costs through the use of smart homes is a significant area of focus, but challenges related to affordability and comprehensive service integration remain [101].

K. WEARABLE DEVICES IN HEALTHCARE

In this section, we examine the fields of wearable healthcare devices for the elderly in the IoT. Wearable devices include medical sensors and smart wearables. Li et al. [124] studied the use of smart wearable sensors for elderly health monitoring. With the rising elderly population, these devices provide quick feedback on vital signs and transmit data wirelessly to healthcare providers. They are cost-effective, user-friendly, and comfortable, with over 90% of users finding them convenient and socially acceptable. The study emphasized that wearable systems enhance privacy, security, accuracy, and quality of life while reducing health risks, underscoring their importance in elderly healthcare. An et al. [125] studied smart medical devices for the elderly, proposing a hybrid algorithm to improve remote control functionality. Using gyroscope sensors, the research enhanced muscle strength estimation accuracy during isometric contractions, aiding individuals with nervous system disorders. The algorithm measured joint angular velocity via an accelerometer. While the study demonstrated adaptability to wearable devices, it did not explore the therapeutic implications of the design.

Hyndavi et al. [126] investigated a smart wearable device using different sensors (temperature, pressure, etc.) for women's safety. The primary purpose of designing wearable devices is to prevent any damage and possible risks in patients, especially women. Studies show that by using alarm sensors, an emergency message is sent to relatives or the police, and the person's location is informed to them so that they can prevent any unfortunate incident. These warning sensors are placed in necklaces, smart bracelets, smart watches, etc. The results of the authors' review show the convenience of use, the cost-effectiveness of the proposed design, and the ability to implement it manually and automatically. The benefit of this paper was the review of smart wearable devices using the IoT. The drawback of the paper was that the challenges of using smart wearable devices and their solutions had not been evaluated. Majumder et al. [127] used IoT-enabled smart wearable devices to predict cardiac arrest in patients. The research aimed to design a system that monitors heart rate and body temperature, using machine learning and sensor data processing to predict cardiac arrests. The study showed reliable results in classifying normal and abnormal electrocardiogram patterns. The benefit of the paper was its integrated approach to controlling cardiac abnormalities, while its weakness was the lack of measurement of patients' physiological parameters during daily activities. Yang et al. [128] investigated a rehabilitation system for patients using IoT and smart wearables, specifically focusing on smart armbands with low-power, small sensors. The study showed that machine learning algorithms could effectively evaluate and classify hand movements. However, placing surface electrodes reduced the accuracy of movement classification. The system proposed can help save time in rehabilitation. The advantage of the paper was the algorithm for evaluating arm movements using wearable sensors, while the weakness was the sensors' inability to detect all hand movements due to their high computational load. Ba et al. [129] investigated wearable medical sensors for elderly care. In this research, using machine learning, a framework for the personalization of the elderly is provided to develop a function of measuring models. The MLA-IDDF framework (Machine Learning assisted Integrated Data-driven framework) describes the patient's condition and provides detailed information about them. The proposed model reconstructs the raw signals with high accuracy so that this framework can improve the performance of machine learning. In the simulation analysis of the MLA-IDDF model, it was shown that the signal compression increases and the recovery error decrease. The article's benefit is presenting an integrated data-driven approach using machine learning. The weakness of the paper is that the challenges of signals in sensors have not been investigated. Makhadmeh et al. [58] studied the diagnosis of heart diseases using wearable medical sensors and IoT. Their research used deep learning neural networks and data analysis for performance evaluation. The system accurately predicted heart disease by classifying data with regression and detected abnormal heart pulses efficiently. The advantage of the paper was the high-precision algorithm for predicting heart disease, while the disadvantage was the lack of investigation into optimal methods for diagnosing medical conditions and tracking disease progression. Fouad et al. [130] proposed a scalable framework for data processing using medical wearable sensors in IoT. The framework integrates computing systems with wearable sensors for improved decision-making, enhanced communication rates, and low response time. Experimental results showed high compatibility with the criteria, offering improved storage space and minimal response time. The advantage of the paper was the distributed computing approach to enhancing smart medical sensor performance, while the weakness was the lack of evaluation for supporting heterogeneous applications. Sodhro et al. [131] investigated healthcare using wearable sensors for patients and older adults. Wearable sensors technology has brought about a huge revolution in healthcare and has greatly helped assist the elderly healthcare remotely. Body sensor networks are developing and evolving rapidly, creating a comfortable and easy life for elderly patients. The authors investigated an energy-efficient algorithm that was presented for the reliability and cost-effectiveness of wearable sensors. The results of the experiments showed that this proposed algorithm increases the presented model's reliability, energy efficiency, and stability. The article's advantage was providing a healthcare platform for ill older adults. The weakness of the paper was that the proposed algorithm was not implemented in hardware. Muthu et al. [57] used smart medical sensors based on IoT to predict disease. IoT technology uses artificial intelligence to assess patients' conditions and collect and share health information. Considering the health system's challenges, smart medical sensors have been used for data analysis in this study. The authors collected and analyzed patient data using regression rules. Experimental results showed a high percentage of sensors' accuracy and prediction rate. The advantage of the paper was to present a machine learning algorithm in healthcare. The drawback of the paper is that no solution has been considered for the health system's challenges.

L. ANALYSIS OF REVIEWED ARTICLES IN THE FIELD OF WEARABLE DEVICES IN THE HEALTHCARE CATEGORY

Table 20 outlines the various aspects for evaluating studies on wearable devices in healthcare. The two key categories for wearable devices are smart wearables and smart medical sensors. These devices play a significant role in elderly healthcare, offering services like real-time vital sign monitoring and recommendations. As the elderly population increases, the adoption of these devices can help reduce healthcare costs by offering home-based care and improving health outcomes. Table 15, This table lists the evaluation criteria used in studies on wearable devices in healthcare. These criteria include: Performance: The most commonly

TABLE 12. Evaluation factors in the field of smart homes in healthcare.

Study	Cost	Performance	Mobility	Availability	Privacy	Accuracy	Interoperability	Scalability	Reliability	Security
Bennett et al. [101]	✓	×	×	×	×	×	×	×	×	×
Pham et al. [102]	×	✓	×	×	×	✓	×	×	×	×
Chatrati et al. [103]	×	✓	×	×	×	✓	×	×	×	×
Maresova et al. [104]	×	✓	×	×	×	×	×	×	×	×
Atella et al. [105]	✓	✓	×	×	×	×	×	×	×	×
Battineni et al. [106]	✓	✓	×	×	×	✓	×	×	×	×
Rizzuto et al. [107]	×	✓	✓	×	×	×	×	×	×	×
Palmer et al. [108]	✓	×	×	×	×	×	×	×	×	×
Raghupathi et al. [109]	×	✓	×	✓	×	×	×	×	×	×
Zhou et al. [110]	✓	×	×	×	×	×	×	×	×	×
Kim et al.[111]	×	✓	×	×	×	×	×	×	×	×
Alanazi et al. [112]	×	✓	×	×	×	✓	×	×	×	×
Gentile et al. [113]	×	×	×	×	×	✓	×	×	✓	×
Keshary et al. [114]	×	✓	×	×	×	×	×	×	×	✓
Jo et al. [115]	×	×	×	×	✓	×	×	×	×	×
Miori et al. [116]	✓	×	×	×	×	×	✓	×	×	×
Philip et al. [117]	×	✓	×	×	×	×	✓	✓	✓	×
Mostafa et al. [118]	×	×	×	×	×	✓	×	×	×	×
Butt et al. [119]	✓	×	×	×	×	×	×	×	×	×
Ghasemi et al. [120]	✓	✓	×	✓	×	×	✓	×	×	✓
Do et al. [121]	×	✓	×	×	×	✓	×	×	×	×
Hosseinzadeh et al. [122]	×	×	×	×	✓	×	×	×	✓	✓
Pal et al. [123]	×	×	×	×	✓	×	×	×	✓	✓

used criterion, evaluating how well the device functions to assist in healthcare management. Cost: The affordability of devices, which is crucial for their widespread adoption, especially among elderly individuals. Validity: Ensures the device measures what it is supposed to measure. Sensitivity: Evaluates the device's ability to detect even small changes in health conditions. Reliability: The consistency of the device's performance over time. Scalability: The ability to adapt and scale up the system as the user base grows. Response time: How quickly the device responds to changes in the user's health status. Precision and Accuracy: These are both key factors for wearable devices to provide accurate health data for reliable diagnosis and monitoring. Table 16, This table compares the evaluation criteria from the studies in terms of their usage frequency in analytical articles. The findings show that: Performance was the most frequently used criterion, indicating its importance in evaluating the effectiveness of wearable devices in healthcare. Accuracy

TABLE 13. Qualitative evaluation criteria in smart homes in healthcare.

Evaluation criteria	Low	Medium	High
Cost	×	✓	×
Performance	×	×	✓
Mobility	✓	×	×
Availability	✓	×	×
Privacy	✓	×	×
Accuracy	×	✓	×
Interoperability	✓	×	×
Scalability	✓	×	×
Reliability	✓	×	×
Security	✓	×	×

was the second most frequently used criterion, reflecting its role in ensuring precise health monitoring. Cost, sensitivity, reliability, scalability, validity, response time, and precision were used much less frequently in studies. This suggests that while these aspects are crucial, they are often overlooked or less emphasized in the research. The analysis of these tables reveals a significant focus on the performance and accuracy of wearable devices in healthcare, particularly in managing elderly care. However, other factors like cost, sensitivity, and reliability are less frequently evaluated, indicating a gap in comprehensive evaluation. To fully assess the potential of wearable devices, more research should explore these other criteria, particularly for enhancing scalability, sensitivity, and precision in real-world applications [124].

M. HEALTHCARE COSTS

In this section, we examine the healthcare costs of the elderly in the IoT. Wodchis et al. [132] examined high-cost healthcare for the elderly. For each senior, the cost of healthcare varies each year. Many seniors have chronic diseases requiring special healthcare, which often requires expensive treatments. This research mainly aims to evaluate the healthcare costs for each older adult and identify the high cost of elderly healthcare. This study showed that the needs vary based on the elderly suffering from a wide range of health issues. The benefit of this paper was the assessment of the high healthcare costs for the elderly. Improving healthcare systems for the elderly requires better management in this study, but different techniques have not been provided for the cost of elderly healthcare, which was considered a drawback of the paper. McPhail et al. [133] analyzed the impact of healthcare costs for chronic diseases in the elderly. Rising healthcare expenses are linked to drug prices, hospital admissions, and primary care. The lack of economic studies poses challenges for multi-disease decision-making. The findings indicate that healthcare techniques can cost-effectively reduce the burden of several diseases. The study's strength lies in estimating healthcare costs for elderly diseases, while its limitation is the lack of investigation into care models for elderly individuals with multiple diseases requiring special healthcare. Pinedo et al. [134] examined healthcare costs associated with muscle weakness in the elderly in England, estimating an additional £2.5 billion annual expense. The study highlighted that rising elderly populations will lead to increased healthcare costs, with the government bearing most of the burden if family care is lacking. The authors suggested that improving elderly lifestyles to reduce muscle weakness could lower costs. The paper's strength was analyzing the financial impact of muscle weakness, while its limitation was the low elderly participation in healthcare services due to high costs.

N. ANALYSIS OF REVIEWED ARTICLES IN THE FIELD OF HEALTHCARE COSTS CATEGORY

Table 17 categorizes various studies in the field of healthcare costs for the elderly. It clearly demonstrates that although numerous studies have been conducted on the costs of elderly healthcare, many of them lack practical solutions for managing these costs. This highlights the need for further research into developing cost-effective and efficient care models. Additionally, reducing costs and improving access to healthcare services for the elderly, particularly those with special needs, remains a significant challenge that requires more attention. Table 18 presents the quantitative evaluation criteria of published studies in the field of healthcare. In this study, the cost evaluation criterion in the elderly healthcare system has the highest statistics due to its significant importance in the reviewed studies. Table 19 examines the qualitative evaluation criteria of studies at three levels: low, medium, and high. Elderly individuals, due to their specific health conditions and need for long-term care, impose high costs on healthcare systems. These costs include medical care, medications, medical equipment, and home care services or residential care facilities. Evaluating costs helps policymakers and planners allocate resources more effectively and provide optimal healthcare services for the elderly. This has led to costs being regarded as a key criterion in studies. Researchers' studies showed that the needs of the elderly are in a wide range of healthcare [132]. On the other hand, elderly healthcare costs may be calculated by primary care visits, medications, or elderly counseling. Therefore, as a future strategy, more research on the lifestyle of the elderly should be provided to reduce healthcare costs [134].

O. HEALTHCARE

Bajenaru et al. [135] analyzed the healthcare and caregiving needs of the elderly and proposed solutions for designing personalized healthcare systems. These systems include sensors and electronic tools for monitoring the health status of the elderly. Identified needs include monitoring daily activities, diseases, special conditions, and rapid communication with doctors and caregivers. The study focuses on determining the essential features for systems that must be adaptable to the different conditions of users. The results showed that healthcare systems should have features such as adjustability, effective communication with doctors, and data processing capabilities. Furthermore, the experiences suggest that the high sensitivity of systems to input data and the need for precision in user interface design are key issues in this field.

TABLE 14. Categorization of studies in the field of wearable devices in the healthcare category.

Study	Keyword	Domain	Simulation / Implementation	Dataset	Application Domain	Case Study	Results	Benefit	Drawback
Li et al. [124]	Smart wearable systems, Health monitoring, older adults	Telehealth	-	-	Smart wearables	Smart wearables	-	- The role of smart wearable systems and their function on the health of the elderly.	-When reporting health data self-assessment, the assessment results may be incorrect.
An et al. [125]	Smart wearable, elderly	Estimation Hybridized Computer Algorithm	Simulated by the evolved musculoskeletal model	-	Smart wearables	Smart wearables	- High estimation accuracy.	- Provide a method for the locomotor system and its adaptation to smart wearable devices.	- Traditional Therapeutic implications of the proposed scheme have not been proposed.
Hyndavi et al. [126]	IoT, Smart Devices, Women's Safety	Temperature Sensor	Prototype	Health data	Smart wearables	Smart wearables	-Ability to run automatically and manually, easy to carry, lightweight, and affordable.	- Check smart wearables using the IoT.	- The challenges of using smart wearables have not been explored.
Majumder et al. [127]	IoT, Energy Efficient, Smartphone	Body Area Sensor	MATLAB	ECG data	Smart wearables	Smart wearables	- High-precision sensor data analysis.	- Provide an integrated approach to controlling cardiac abnormalities in patients.	-Physiological parameters of patients were not measured during their daily activities.
Yang et al. [128]	Stroke rehabilitation, IoT, wearable devices, machine	Machine learning	Prototype	Training data	Smart wearables	Smart wearables	- Ability of the proposed system to facilitate the rehabilitation process of patients.	- Provide an algorithm to evaluate arm movements using wearable sensors.	- Wearable sensors cannot detect all hand movements because they have a high computational load.
Ba et al. [129]	Elderly, Machine learning, Medical wearable sensors	Integrated data-driven framework	MLA-IDDF Method	-	Wearable Medical Sensor	Wearable Medical Sensor	- Increase signal compression, and reduce recovery error.	- Provide an integrated data-driven approach using machine learning.	-Signal challenges in sensors have not been investigated.
Makhadmeh et al. [58]	IoT, Heart Disease, Wearable Medical Sensors	Boltzmann deep belief in neural network	MATLAB	Patient data	Wearable Medical Sensor	Wearable Medical Sensor	- High accuracy of the proposed scheme in reducing cardiac mortality.	- Provide a high-precision algorithm for predicting heart disease.	- Optimized approaches to diagnosing medical conditions and details of disease progression have not been reviewed.
Fouad et al. [130]	IoT, Medical Sensors, Response Time	Pervasive Computing Systems	MATLAB	-	Wearable Medical Sensor	Wearable Medical Sensor	- Low response time and high compatibility of the proposed framework.	- Provide a distributive computational approach to improve the performance of intelligent medical sensors.	- The proposed framework for supporting heterogeneous programs has not been evaluated.
Sodhro et al. [131]	Wearable Sensing, Smart, Elderly healthcare	Elderly Patients	MATLAB	-	Wearable Medical Sensor	Wearable Medical Sensor	- Cost-effectiveness and reliability of wearable sensors.	- Provide a healthcare platform for the sick elderly.	- The proposed algorithm is not implemented in the hardware.
Muthu et al. [57]	Artificial Intelligent, IoT, Disease	Electroencephalogram (EEG)	MATLAB	-	Wearable Medical Sensor	Wearable Medical Sensor	- Prediction rate and high accuracy of the proposed design.	- Provide a machine learning algorithm for data analysis in healthcare.	- There is no solution to the challenges of the health system.

The strength of the article lies in its focus on creating a healthcare system with high adaptability and flexibility. The weakness of the article is the need for further validation of the systems under different conditions and on a larger scale. Paul et al. [136] explored the integration of Machine Learning (ML) and the Internet of Things (IoT) in Precision Healthcare. The study highlighted how IoT and ML can enhance disease diagnosis, prediction, and treatment by analyzing patient data collected through sensors, such as vital signs and daily activities. Machine learning models were used to predict health risks, showing improved diagnostic accuracy and faster emergency response times. The system also proved effective in managing chronic conditions. While the research demonstrated the potential of IoT and ML for precise healthcare, it was limited by a small sample size and the need for broader testing across diverse populations and conditions. Saikali et al. [137] explore the benefits of telesurgery (remote surgery) in humanitarian and surgical settings. The study highlights its advantages in challenging conditions, such as remote areas or healthcare crises, while addressing technical and administrative challenges like the need for stable communication infrastructure and surgeon training. Telesurgery,

TABLE 15. Evaluation factors in the field of wearable devices in healthcare.

Study	Reliability	Accuracy	Performance	Cost	Sensitivity	Precision	Response time	Scalability	Validity
Li et al. [124]	✓	✓	×	×	×	×	×	×	×
An et al. [125]	×	✓	✓	×	×	×	×	×	×
Hyndavi et al. [126]	×	×	✓	✓	×	×	×	×	×
Majumder et al. [127]	×	✓	✓	×	×	×	×	×	×
Yang et al. [128]	×	✓	✓	✓	×	×	×	×	✓
Ba et al. [129]	×	✓	✓	×	×	×	×	×	×
Makhadmeh et al. [58]	×	✓	✓	×	✓	✓	×	×	×
Fouad et al. [130]	×	×	✓	×	×	×	✓	✓	×
Sodhro et al. [131]	✓	×	✓	×	×	×	×	×	×
Muthu et al. [57]	×	✓	✓	×	✓	✓	×	×	×

TABLE 16. Qualitative evaluation criteria in wearable devices in healthcare.

Evaluation criteria	Low	Medium	High
Reliability	✓	×	×
Accuracy	×	✓	×
Performance	×	×	✓
Cost	✓	×	×
Sensitivity	✓	×	×
Precision	✓	×	×
Real-time	✓	×	×
Scalability	✓	×	×
Validity	✓	×	×

utilizing advanced technologies like robotic surgery and internet communication, allows surgeons to perform or guide surgeries remotely. The findings indicate that telesurgery can improve access to complex surgeries in underserved areas, reduce patient wait times, and enhance medical service delivery during crises such as natural disasters or pandemics. The article's strength lies in leveraging advanced technology to expand surgical access, though it acknowledges weaknesses, including technical hurdles and the difficulty of training medical teams to effectively use these technologies. Demnati et al. [138] studied telesurgery in hand surgery, highlighting its potential to improve surgical precision and access to specialized care, especially in underserved areas. Using robotic and communication technologies, surgeons can perform or guide surgeries remotely, benefiting remote regions and crisis situations. The study found that telesurgery increased precision and reduced patient wait times compared to traditional methods. While the research demonstrated its value in expanding access to surgical services, it also noted technical challenges and limitations in diverse geographic and medical conditions.

P. ANALYSIS OF REVIEWED ARTICLES IN THE FIELD OF HEALTHCARE CATEGORY

Table 20 outlines various aspects for evaluating studies related to healthcare systems. This table clearly demonstrates that although numerous studies have been conducted in the field of healthcare, many of them lack empirical validation or real-world implementation. This highlights the need for further research in testing and implementing these concepts in real-world conditions. Additionally, a greater focus on important criteria such as cost, safety, and privacy could enhance the quality and applicability of these studies. Ultimately, this table helps researchers identify the strengths and weaknesses of existing studies and better define future research directions. In Table 21, the quantitative evaluation criteria of published studies in the field of healthcare are presented. In this study, the performance evaluation criterion has the highest frequency among the studies reviewed in this domain.

This indicates that devices and systems perform at a high level in terms of functionality. Table 22 examines qualitative evaluation criteria across three levels: low, medium, and high. This table reveals that although the performance of devices and systems is rated highly, important criteria such as safety and privacy are evaluated at a low level. This may suggest that security and privacy aspects have not been sufficiently addressed in the design and development of these systems.

VI. DISCUSSION

Figure 7 provides a general overview of the key topics in elderly care within the domain of the Internet of Things (IoT). The three most frequently occurring words "IoT,"

TABLE 17. Categorization of studies in the field of healthcare costs category.

Study	Keyword	Domain	Simulation / Implementation	Dataset	Application Domain	Case Study	Results	Benefit	Drawback
Wodchis et al. [132]	Cost, Healthcare, Management data	Cost distribution	Java platform	-	Healthcare cost	Healthcare cost	- Identify costly seniors in a wide range of healthcare.	- Assess the high cost of elderly healthcare.	Because improving the healthcare systems of the elderly requires better management, different techniques are not presented in this study for the costly elderly.
McPhail et al. [133]	Chronic disease, Cost, Burden	Economic evaluations	Java platform	-	Healthcare cost	Healthcare cost	- Correction of multiple diseases in cost-effective ways.	- Examine the diseases of the elderly to estimate healthcare costs and make decisions about them.	- For the elderly with multiple illnesses and needing special healthcare, care models for these individuals have not been studied.
Pinedo et al. [134]	Healthcare, cost, Ageing	Muscle Weakness	Prototype	Patient data	Healthcare costs	Healthcare costs	-Increase healthcare costs.	- Assessing the muscle weakness of the elderly and the costs associated with health and social care for them.	- Due to the high cost of providing healthcare services, the elderly did not show much interest in using these services.

TABLE 18. Evaluation factors in the field of healthcare costs.

Study	Cost	Security	Performance	Accuracy	Mobility	Availability
Wodchis et al. [132]	✓	×	×	×	×	×
McPhail et al. [133]	✓	✓	✓	×	✓	×
Pinedo et al. [134]	✓	×	✓	×	×	✓

TABLE 19. Qualitative evaluation criteria in healthcare costs.

Evaluation criteria	Low	Medium	High
Cost	×	×	✓
Security	✓	×	×
Performance	×	✓	×
Accuracy	✓	×	×
Mobility	✓	×	×
Availability	✓	×	×

"Health Care," and "Elderly" indicate the primary focus of research on utilizing IoT technology in elderly healthcare. Additionally, "Chronic Diseases" is another significant topic in elderly care, highlighting the need for advanced monitoring and diagnostic systems to manage long-term illnesses. One of the most critical challenges in IoT-based elderly care is data security and privacy. The keywords "Security," "Elderly Safety and Security," and "Blockchain for Healthcare Data Security" suggest that cyber-security and the protection of sensitive patient data are major concerns in this field. Technologies such as Blockchain have been proposed as an innovative solution to safeguard health data and prevent unauthorized access. Keywords like "AI in IoT Healthcare," "Fog Computing," and "Cloud Computing" indicate the widespread use of artificial intelligence, federated learning, cloud computing, and fog computing in enhancing the performance and efficiency of IoT systems. These technologies enable big data analysis, optimization of decision-making algorithms, and data processing in distributed environments. "Wearable Sensors" and "Smart Phone" are essential tools for monitoring the health of the elderly. Wearable sensors can continuously record vital signs and transmit the data to cloud-based databases, while smartphones are used for communication, remote control, and health alert notifica-

TABLE 20. Categorization of studies in the healthcare.

Study	Keyword	Domain	Simulation / Implementation	Dataset	Application Domain	Case Study	Results	Benefit	Drawback
Bajenaru et al [135]	Elderly care, IoT, healthcare	Smart health monitoring	Prototype.	-	Healthcare	Healthcare	- Identifies key user needs for a personalized healthcare system. - Highlights challenges in integrating IoT, AI, and real-time monitoring for elderly healthcare.	- Provides a structured methodology for defining system specifications tailored to elderly needs.	-Lacks experimental validation or real-world implementation.
Paul et al [136]	IoT, healthcare, Smart healthcare	Machine learning	Prototype	-	Healthcare	Healthcare	- Explores the integration of IoT and machine learning in healthcare.	- Discusses various ML techniques and their applications in healthcare.	- Lacks empirical validation or case studies demonstrating real-world implementation.
Saikali et al [137]	Healthcare, Elderly, robotic surgery	Telesurgery	Python	Patient data	Healthcare	Healthcare	-Highlights the potential benefits of telesurgery in humanitarian contexts, such as providing access to high-quality surgical care in remote areas.	- Provides an insightful overview of the humanitarian and surgical benefits of telesurgery.	- Focuses primarily on challenges without proposing concrete solutions or strategies for overcoming them.
Demnati et al [138]	Tele-surgery, IoT, healthcare	Remote technology	-	-	Healthcare	Healthcare	- The paper suggests that tele-surgery has the potential to improve surgical precision in hand surgeries by providing real-time remote assistance.	- Focuses on a specific surgical field (hand surgery), making the application of tele-surgery more tangible and relevant.	- Lacks detailed experimental data or case studies to validate the benefits of tele-surgery in hand surgeries.

tions. The presence of the keyword "Cost" indicates that the implementation and usage costs of IoT in elderly care remain a significant challenge. This includes hardware, software, maintenance, and data security expenses. Developing cost-effective economic models could facilitate the widespread adoption of this technology. Phrases such as "Cloud-based Health Monitoring" and "Health Detection" highlight that continuous health monitoring and early disease detection through IoT are among the key research areas. The use of artificial intelligence algorithms and cloud-based systems contributes to improving the accuracy of monitoring and the automated diagnosis of diseases.

AQ1: How are the main areas of elderly healthcare categorized in the IoT?

The data presented in Figure 8 shows that "Electronic Health" with 34% receives the highest level of attention in the field of security and privacy in elderly healthcare. This indicates that protecting patients' electronic data is one of the primary priorities in IoT-based healthcare systems. Additionally, "smart health, mobile health, and medical IoT" with 22% are among the key areas of security and privacy in this field. These findings highlight the need for developing advanced security protocols and ensuring compliance with privacy requirements in digital healthcare systems to enhance user trust. The data presented in Figure 9 shows that "health detection systems and fall detection systems" with 50% hold the largest share in the field of smartphones. This underscores the importance of smart technologies in monitoring the physical condition of the elderly and preventing potential risks such as falls. Given that falls are one of the most significant causes of injury among the elderly, focusing on the development of more accurate and faster detection systems can help reduce complications and improve patient safety. According to Figure 10, "chronic disease control" with 61% receives the highest level of attention in the smart home sector. This suggests that smart home systems can play a crucial role in monitoring and managing chronic diseases such as diabetes, hypertension, and cardiovascular conditions. Additionally, "behavioral characteristics" with 26% and "biological characteristics" with 13% indicate the importance of analyzing the behavioral and biological data of the elderly in these systems. This emphasizes the necessity of using artificial intelligence and machine learning to analyze behaviors and provide preventive alerts. The findings presented in these three figures indicate that information security, smart health detection systems, and chronic disease control are three key areas in improving elderly healthcare through IoT. The development of secure, efficient, and accurate technologies in these areas can lead to an enhanced quality of life for the elderly and a reduction in healthcare costs.

AQ2: Which assessment tools have been used for elderly healthcare in the IoT?

Based on Figure 11, a review of the articles shows that various tools have been used for evaluation, including MATLAB, Java, C/C++, and Android, each of which accounts for a different share of the studies. Specifically, MATLAB (12%) and physical prototypes (13%) highlight the importance of combining simulation methods and physical implementation in evaluating IoT systems for elderly care. Java (8%) and C/C++ (6%) indicate that the development of caregiving systems often relies on classic programming environments as well. Miscellaneous tools (39%) reflect the wide variety and diversity of tools used, suggesting the absence of a standard framework for evaluating these systems. 16% of the articles did not specify their evaluation tools, which may indicate a lack of documentation in some studies. This analysis reveals that in the field of elderly care in IoT, there is still no standard framework for system evaluation, and researchers use a variety of tools based on their research needs. Furthermore, the unspecified evaluation tools in some articles could pose challenges for reproducing research results.

AQ3: What evaluation criteria have been used in elderly healthcare studies on the IoT?

In Figure 14, studies on smart homes in healthcare showed that performance (29%) received the most attention, underscoring the importance of fast data processing and execution in smart home systems. Other criteria included cost (18%), accuracy (16%), security and reliability (9%), interoperability (7%), accessibility and privacy (4%), and scalability and mobility (2%). Overall, reducing costs and increasing interoperability in smart home systems can enhance healthcare services for patients. In Figure 15, research on remote healthcare systems indicated that performance (53%) was the most evaluated criterion, highlighting the critical role of speed and efficiency in delivering remote healthcare services. Other key factors included cost and reliability (13%), sensitivity, safety, and privacy (7%). These findings underscore the necessity of optimizing performance, reducing costs, and improving reliability in remote healthcare systems. In Figure 16, studies assessing healthcare costs in IoT applications revealed that cost (50%) was the most critical evaluation criterion, reflecting the significant impact of healthcare expenses on the development of digital systems. Performance (22%), along with accuracy, accessibility, mobility, security, and reliability (each at 7%), were also assessed. These results indicate that future research should focus not only on cost reduction but also on improving accessibility and data security in healthcare systems. In Figure 17, an overall comparison of evaluation criteria in healthcare studies showed that performance (45%) was the most studied factor, highlighting the importance of processing speed, accuracy, and efficiency in smart healthcare systems. Other evaluation criteria included reliability (22%), privacy, safety, and cost (each at 11%), emphasizing the need for security and cost optimization in these systems. In Figure 18, studies on wearable devices in healthcare indicated that accuracy (33%) received the highest level of attention, emphasizing the importance of precise physiological parameter measurements. Other criteria included performance (27%), precision (26%), reliability (8%), cost, sensitivity, and accuracy (each at 7%), and validity, scalability, and response time (each at 4%). These results suggest that future research should prioritize improving accuracy and reducing costs in wearable healthcare devices. In Figure 19, an overall evaluation of healthcare assessment criteria for elderly care demonstrated that security (36%) was the most reviewed factor in privacy and security-related studies. Additionally, sensitivity (22%) in smartphones, performance (29%) in smart homes, performance (53%) in remote healthcare systems, performance (33%) in wearable devices, and cost (50%) in healthcare expenses were the highest-rated evaluation criteria. This analysis highlights that performance and cost are the two most crucial factors for future research. With the increasing elderly population and the prevalence of chronic diseases, healthcare costs have become a major challenge. Therefore, future studies should investigate the impact of chronic diseases on healthcare expenses and propose effective solutions to deliver high-quality medical services at minimal costs.

A. OPEN ISSUES, CHALLENS, AND FUTURE WORK

The increase in the elderly population and the high healthcare system costs have irreparable effects on patients and society. The IoT can be a suitable solution to reduce these effects and provide effective healthcare services. IoT can improve the quality of life of the elderly by reducing operating costs. Therefore, new open issues and related challenges need to be solved as future work for developing elderly healthcare systems in the IoT. In this section, using the SLR method on studies related to the healthcare of the elderly in the IoT, open issues and their main challenges are discussed, and future works related to them are presented as an answer to AQ4.

TABLE 21. Evaluation criteria of published studies in healthcare.

Study	Reliability	Cost	Safety	Privacy	Performance
Bajenaru et al [135]	×		×	×	✓
Paul et al [136]	×		×	×	✓
Saikali et al [137]	✓		×	×	✓
Demnati et al [138]	✓		✓	✓	✓

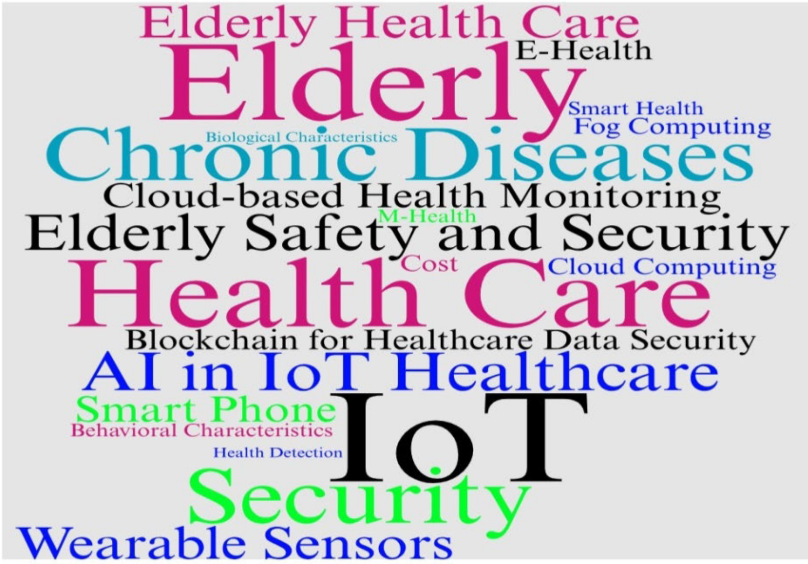

FIGURE 7. Word cloud of elderly healthcare system in the internet of things.

TABLE 22. Qualitative evaluation criteria in healthcare.

Evaluation criteria	Low	Medium	High
Reliability	×	✓	×
Cost	×	✓	×
Safety	✓	×	×
Privacy	✓	×	×
Performance	×	×	✓

AQ4: What are the open issues, challenges, and future work of elderly healthcare studies in IoT?

The evaluation of 75 research articles in this study shows that each study in the field of elderly healthcare in the IoT emphasizes one or more open issues and related challenges. Elderly healthcare in the IoT encompasses numerous open topics, including standardization and interoperability, security and privacy, performance and reliability, Big Data Management, scalability and cost, trust, as well as Federal and Edge Computing. With the rapid growth of the elderly population and the rising costs of healthcare systems, the Internet of Things (IoT) has emerged as an innovative solution to improve quality of life and reduce operational costs. However, implementing IoT-based systems in elderly healthcare presents several challenges. In this section, the most critical challenges in this field are examined from both technical and operational perspectives, with proposed solutions to address them. Given the rapid advancements in the field, future research should focus on exploring newer applications and improvements in IoT technologies for elderly healthcare, particularly on the integration of emerging technologies and their potential impact on healthcare delivery. By addressing these challenges, the integration of IoT in elderly healthcare can be optimized, providing better, more efficient, and accessible care solutions for the aging population.

1) STANDARDIZATION AND INTEROPERABILITY

One of the fundamental challenges in IoT-based healthcare systems is the lack of unified standards and poor interoperability between devices, platforms, and communication protocols. Different companies manufacture medical devices and sensors that follow varied standards, leading to incompatibility issues due to the absence of unified validation and certification. Lack of interoperability prevents health data generated from multiple sources (e.g., blood glucose monitors, blood pressure monitors, and heart rate sensors) from being processed on a single platform. As future solutions, the following approaches can be considered: Develop open standards to integrate health data and create common communication protocols for seamless data exchange between IoT devices, Utilize Edge Computing to enable faster processing of health data and reduce dependency on cloud servers [64], [65].

2) SECURITY AND PRIVACY

Security and privacy are among the most critical challenges in IoT-based healthcare. Patient data contains sensitive medical information, and any breach, leak, or manipulation can lead to serious consequences. Many remote healthcare systems are designed without proper security measures, making them vulnerable to cyber-attacks. Man-in-the-Middle (MiTM) attacks pose a significant risk, as they can alter critical patient data during transmission. Weak user authentication can lead to unauthorized access to patient information. As future solutions, the following approaches can be considered:

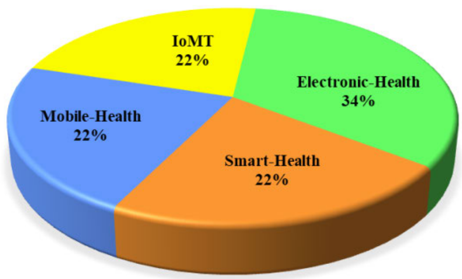

FIGURE 8. The main context percentage of security and privacy in healthcare.

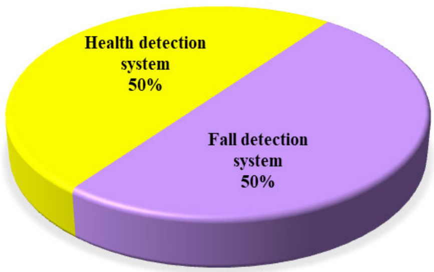

FIGURE 9. The main context percentage of smartphones in healthcare.

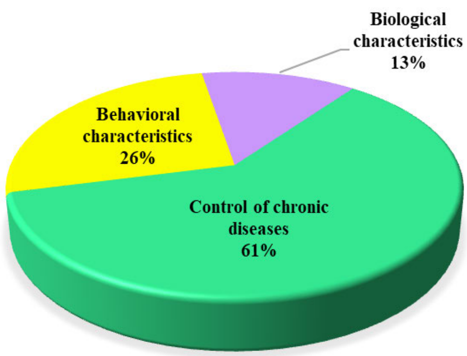

FIGURE 10. The main context percentage of smar thome in healthcare.

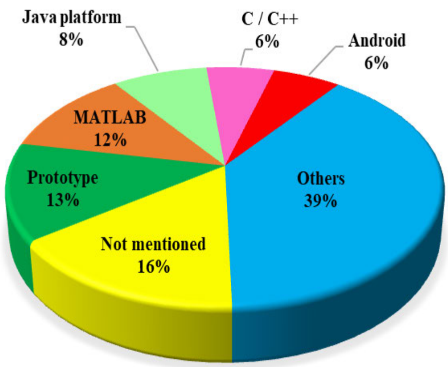

FIGURE 11. Evaluation tools percentage in selected articles.

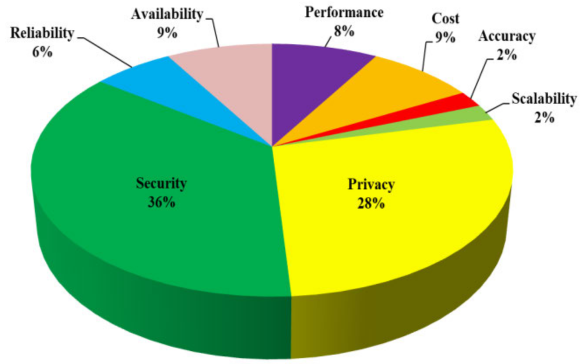

FIGURE 12. Evaluation criteria percentage of security and privacy in healthcare.

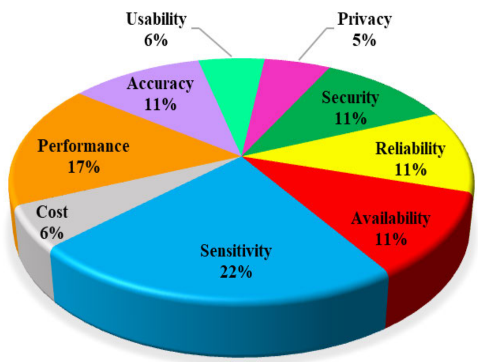

FIGURE 13. Evaluation criteria percentage of smartphones in healthcare.

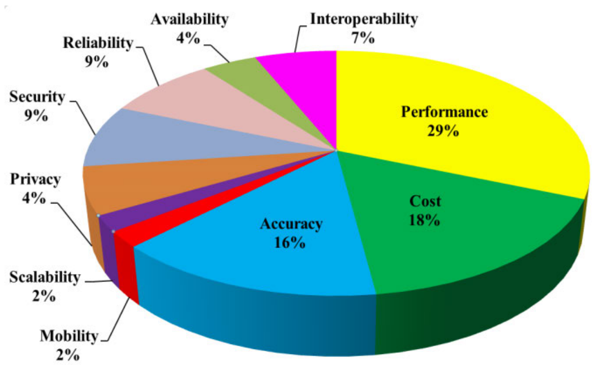

FIGURE 14. Evaluation criteria percentage of smart homes in healthcare.

Implement advanced encryption mechanisms (e.g., AES-256 and ECC) to protect health data during storage and transmission. Deploy Multi-factor Authentication (MFA) to prevent unauthorized access. Utilize blockchain technology in healthcare systems to track data modifications and prevent medical record tampering [84], [85], [86], [87], [88].

3) PERFORMANCE AND RELIABILITY

Reliability and performance of remote healthcare systems directly impact the quality of patient care. Unstable wireless network connections that can result in the loss of critical patient data. High energy consumption of IoT sensors, which shortens the battery life of wearable devices. Lack of cloud processing integration, leading to delays in processing critical

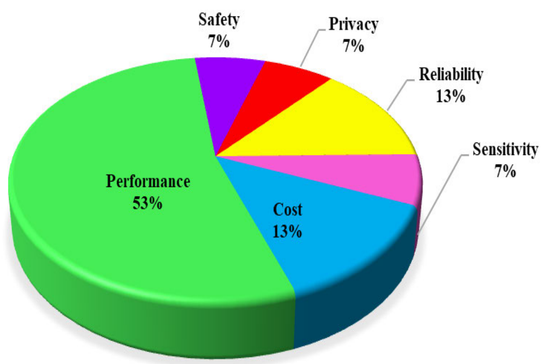

FIGURE 15. Evaluation criteria percentage of the remote healthcare system.

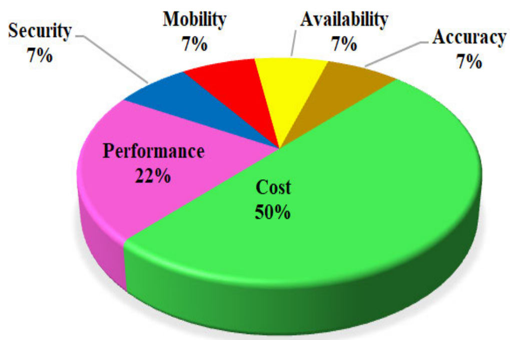

FIGURE 16. Evaluation criteria percentage in healthcare costs.

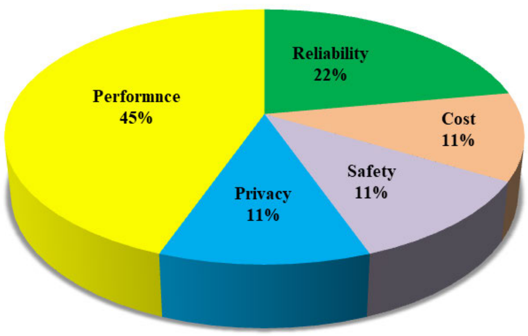

FIGURE 17. Evaluation criteria percentage in healthcare.

data. As future solutions, the following approaches can be considered: Design optimized processing algorithms to reduce data processing delay and decrease network load. Use 5G networks and edge computing to improve data transfer speed. Develop energy management systems to optimize battery consumption in wearable devices [61], [103], [117].

4) BIG DATA MANAGEMENT

The data generated by wearable sensors, remote detection systems, and medical databases are continuously increasing, requiring optimal management and real-time analysis. The high speed of data production in IoT-based healthcare systems creates challenges for real-time storage and processing. Mismatch between structured and unstructured data requires more complex algorithms to process them. As future solutions, the following approaches can be considered: Use machine learning algorithms and big data analytics for optimal data processing, implement hybrid cloud computing to combine the computational capabilities of both cloud and edge, and design data compression algorithms to reduce storage volume [139], [140].

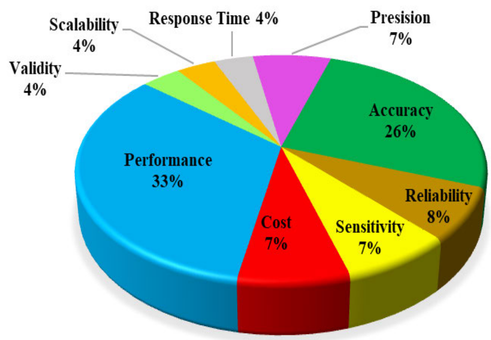

FIGURE 18. Evaluation criteria percentage in wearable devices in healthcare.

5) SCALABILITY AND COST

One of the major challenges to the widespread adoption of IoT technology in healthcare is high costs and the need for system scalability. Limited financial resources in public hospitals and healthcare centers prevent investment in new technologies. As future solutions, the following approaches can be considered: Develop low-cost and energy-efficient sensors that require less maintenance and replacement. Implement pay-as-you-go models for delivering digital healthcare services. Invest in economic models based on health insurance and public-private partnerships to reduce patient costs [20], [23], [25], [28].

6) TRUST

One of the essential issues for data storage and access in IoT healthcare systems is the issue of trust. Trust can be defined as the management of credentials and control of access to confidential data by healthcare providers for security and privacy purposes. With the increase in the number of systems connected to the IoT, the possibility of data vulnerability during transmission or storage increases. Therefore, data protection and reducing the risk of data hacking is one of the important and key issues of healthcare systems in the IoT. As a future solution, healthcare systems should consider mechanisms to guarantee trust and preserve user privacy. The combination of federated learning with Edge AI and the use of blockchain-based access control systems can help improve security and data protection [140], [141], [142].

7) FEDERAL LEARNING

Federated Learning (FL), as an innovative approach in the field of elderly care, faces several challenges despite

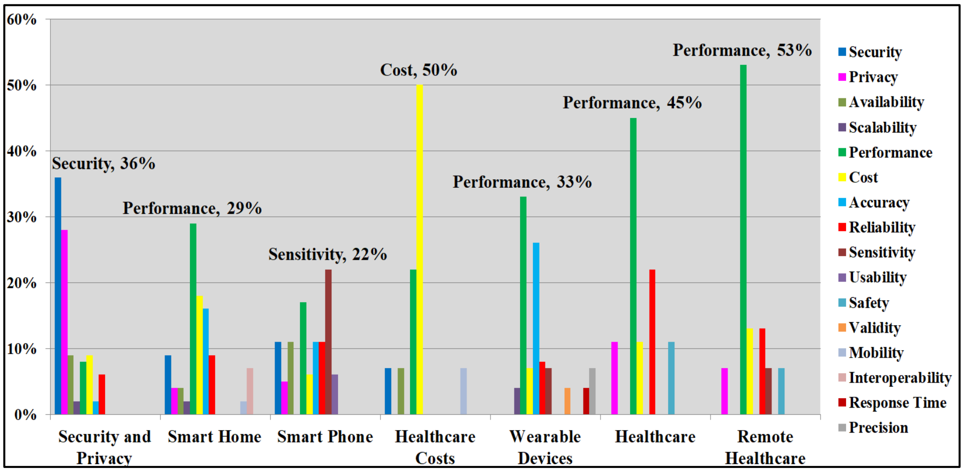

FIGURE 19. A general comparison of evaluation factors of elderly healthcare in IoT.

its high potential. These challenges include issues related to data privacy and security, data heterogeneity, resource limitations in edge devices, communication latency, and scalability. To address these challenges, technical solutions such as homomorphic encryption, data normalization, model compression, and communication optimization have been proposed. In the future, integrating federated learning with emerging technologies like federated reinforcement learning and blockchain, along with the development of security and privacy standards, can enhance the efficiency and reliability of elderly care systems. These advancements not only address current challenges but also pave the way for future research and the development of smarter solutions in the digital health domain [143], [144], [145].

8) EDGE COMPUTING

Edge Computing in elderly healthcare faces challenges due to limited processing power, storage, and energy in edge devices, leading to data processing delays, reduced AI accuracy, and security concerns. Integrating Edge Computing with AI is a promising solution to enhance real-time decision-making, ensuring a stable and scalable healthcare monitoring system [146], [147].

VII. CONCLUSION

Elderly healthcare studies in the IoT were reviewed and analyzed using the SLR method in this research, and a complete understanding of the healthcare of the elderly in the IoT, evaluation of various aspects of the healthcare system, challenges, and future work was obtained. This paper presents the SLR method on published studies between 2016 and 2024. We reviewed 75 articles concentrating on healthcare in the IoT. The evaluation of research studies shows that the keywords "elderly", "healthcare", and "IoT" have the highest study statistics in this article. Also, the evaluation of the applied fields of healthcare for the elderly in the IoT shows that the field of "chronic diseases" has the highest frequency in the reviewed articles. Due to the SLR-based process, we may not have reviewed all available research studies. Due to the extensive review of research articles in healthcare for the elderly in the IoT, it remains impossible to ensure that all research studies have been covered.

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