



Bridging the Socio-Technical Gap: A 2024–2025 Review of Integrated IoT Solutions for Geriatric Care

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Abstract

Global demographic transitions toward older population structures are placing unprecedented pressure on healthcare systems, long-term care infrastructures, and community support services. As the prevalence of chronic disease, multimorbidity, and functional decline rises among aging populations, healthcare systems are increasingly exploring digital health technologies capable of enabling continuous monitoring and home-based care. The Internet of Things (IoT) has emerged as a critical technological paradigm for supporting aging in place through interconnected wearable devices, environmental sensors, and cloud-based analytics capable of monitoring physiological status and daily activities in real time. Despite significant advances in sensing technologies, artificial intelligence, and smart home infrastructures, the large-scale adoption of IoT-enabled geriatric care remains limited. A key barrier lies in the persistent socio-technical gap between technological capability and real-world healthcare integration. This review synthesizes peer-reviewed research published between 2024 and 2025 examining integrated IoT solutions for geriatric care, focusing on three interconnected dimensions: clinical applications in health monitoring and chronic disease management, human factors influencing acceptance and adoption among older adults and caregivers, and systemic challenges related to interoperability, privacy, and data governance. The review highlights emerging evidence demonstrating that IoT systems can improve early detection of health deterioration, support medication adherence, reduce hospitalizations, and enhance independence among older adults. However, successful implementation requires addressing ethical considerations, usability barriers, and fragmented digital health infrastructures. By integrating recent findings across healthcare, computer science, and public health research, this paper proposes a socio-technical framework for scalable IoT-enabled geriatric care and identifies future research priorities necessary for achieving sustainable and equitable digital health ecosystems.

Keywords

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1. Introduction

Population aging represents one of the most significant demographic transformations of the twenty-first century. Improvements in life expectancy, declining fertility rates, and advances in medical care have resulted in a steadily increasing proportion of older adults across nearly every region of the world. Current demographic projections suggest that by 2030 approximately one in six people globally will be aged 60 years or older, while the population aged 80 years and above is expected to expand dramatically over the coming decades [1]. This demographic shift is accompanied by rising prevalence of chronic diseases, multimorbidity, and functional limitations, which collectively impose significant demands on healthcare systems and long-term care services.

Older adults frequently require continuous monitoring and long-term management of complex health conditions including cardiovascular disease, diabetes, respiratory disorders, neurodegenerative diseases, and frailty. Traditional healthcare delivery models, which rely heavily on hospital-centered care and episodic clinical visits, are increasingly inadequate to address the ongoing monitoring needs of aging populations. As healthcare systems face shortages of clinical personnel and increasing costs associated with institutional care, attention has shifted toward models that enable older adults to remain safely and independently in their own homes for as long as possible [2]. This approach, commonly referred to as aging in place, is associated with improved psychological well-being, reduced healthcare expenditures, and enhanced quality of life among older adults.

Digital health technologies have emerged as a key component in supporting aging-in-place strategies. Among these technologies, the Internet of Things (IoT) has attracted considerable attention due to its ability to integrate wearable sensors, environmental monitoring devices, communication networks, and intelligent analytics into a cohesive system capable of monitoring health status in real time. IoT-enabled healthcare systems can collect continuous streams of physiological and behavioral data, including heart rate, physical activity, sleep patterns, medication adherence, and environmental conditions [3]. These data streams can then be processed using artificial intelligence and machine learning techniques to detect health deterioration, predict medical events, and alert caregivers or clinicians when intervention is required.

Recent technological developments have significantly expanded the range of IoT applications in healthcare. Wearable biosensors are now capable of continuously measuring vital signs such as electrocardiograms, oxygen saturation, blood glucose levels, and gait characteristics. Simultaneously, smart home technologies incorporate ambient sensors, motion detectors, and camera-based monitoring systems capable of identifying behavioral changes associated with cognitive decline, mobility impairment, or fall risk. When integrated with telehealth platforms and

electronic health records, these technologies can support remote clinical decision-making and personalized care management for older adults living at home [4].

Despite the rapid development of IoT technologies for healthcare, widespread adoption in geriatric care remains uneven. A growing body of research suggests that technological innovation alone is insufficient to ensure successful implementation in real-world healthcare environments. Instead, the integration of IoT systems into clinical practice requires careful consideration of socio-technical factors including usability, digital literacy, trust in technology, data privacy concerns, regulatory frameworks, and interoperability between heterogeneous healthcare information systems [5].

Older adults may experience barriers to adopting digital health technologies due to physical limitations, cognitive decline, unfamiliarity with digital interfaces, or concerns about privacy and surveillance. Additionally, healthcare providers often face challenges related to integrating large volumes of sensor data into existing clinical workflows, as well as ensuring the reliability, security, and interpretability of data generated by distributed monitoring systems [6]. These factors collectively contribute to a socio-technical gap between technological capability and practical healthcare deployment.

Bridging this gap requires interdisciplinary approaches that combine technological innovation with human-centered design, ethical governance, and healthcare system integration. Recent research increasingly emphasizes the importance of designing IoT healthcare systems that are not only technologically sophisticated but also accessible, trustworthy, and adaptable to the needs of older adults and their caregivers. Furthermore, advances in edge computing, federated learning, and privacy-preserving analytics offer promising opportunities to address concerns related to data security and scalability while maintaining clinical usefulness.

This review synthesizes recent peer-reviewed research published between 2024 and 2025 on IoT-enabled solutions for geriatric care. The objective is to examine how emerging technologies are being integrated into healthcare systems to support aging populations while identifying the technical, human, and systemic challenges that continue to hinder large-scale adoption. Specifically, the review explores three interconnected dimensions: the clinical applications of IoT technologies for health monitoring and chronic disease management; the human factors influencing acceptance, adoption, and ethical considerations; and the technical and infrastructural barriers related to interoperability, data governance, and cybersecurity.

By integrating insights from healthcare research, digital health studies, and information systems literature, this paper aims to provide a comprehensive understanding of the current state of IoT-enabled geriatric care and to outline future research directions necessary for developing scalable and sustainable digital healthcare ecosystems.

2. Methodology

This review adopts a structured literature review approach to synthesize recent peer-reviewed research on Internet of Things (IoT) applications in geriatric healthcare. The methodology was designed to systematically identify, evaluate, and analyze scientific studies published between 2024 and 2025, focusing specifically on IoT-enabled technologies that support health monitoring, disease management, and aging in place for older adults. The methodological framework follows principles commonly used in systematic and scoping reviews, including transparent search strategies, clearly defined inclusion criteria, and structured data synthesis.

The methodological approach consisted of four major stages: literature search and database selection, study screening and eligibility assessment, data extraction and categorization, and qualitative synthesis of findings. These stages were structured to ensure that the resulting review reflects the most recent and relevant evidence while maintaining methodological rigor and reproducibility.

2.1 Literature Search Strategy

A comprehensive literature search was conducted across major academic databases widely used in healthcare, computer science, and interdisciplinary technology research. The primary databases included **Scopus**, **Web of Science**, **PubMed**, **IEEE Xplore**, and **ScienceDirect**, which collectively cover the majority of peer-reviewed publications related to digital health technologies and IoT systems.

Search queries were designed to capture publications addressing IoT technologies in the context of geriatric healthcare, remote monitoring, and aging-in-place solutions. Boolean operators and keyword combinations were used to expand coverage while maintaining relevance. The core search expression included variations of the following terms:

- Internet of Things OR IoT
- geriatric care OR elderly care OR aging in place
- remote health monitoring OR digital health OR telehealth
- wearable sensors OR smart homes OR ambient assisted living

An example search query used across several databases was structured as follows:

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("Internet of Things" OR IoT) AND  
("elderly" OR "older adults" OR "geriatric care" OR "aging in place") AND  
("health monitoring" OR "digital health" OR "smart home" OR "wearable sensors")
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The search process initially identified a large pool of articles across the selected databases. Duplicate records were removed using reference management software before proceeding to the screening stage.

2.2 Inclusion and Exclusion Criteria

To ensure consistency and relevance, explicit inclusion and exclusion criteria were applied during the screening process. These criteria were developed to prioritize studies that directly address IoT technologies within geriatric healthcare contexts while excluding unrelated technological or demographic research.

Inclusion criteria

Studies were included in the review if they satisfied the following conditions:

1. Published in peer-reviewed academic journals or conference proceedings.
2. Published between 2024 and 2025.
3. Focused on IoT-enabled healthcare technologies, including wearable devices, smart home systems, remote patient monitoring platforms, or ambient assisted living systems.
4. Addressed applications relevant to older adults or geriatric healthcare.
5. Provided empirical findings, system evaluations, or comprehensive reviews related to IoT-based healthcare solutions.

Exclusion criteria

Studies were excluded if they met any of the following conditions:

1. Publications released before 2024.
2. Studies not specifically related to healthcare or geriatric applications.
3. Articles lacking peer review, such as editorials, opinion pieces, or non-academic reports.
4. Studies focusing solely on theoretical networking technologies without healthcare application.

These criteria ensured that the final dataset focused on recent, high-quality scientific contributions directly relevant to IoT-enabled geriatric care.

2.3 Study Screening and Selection Process

The article selection process followed a multi-stage screening procedure consistent with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. The

screening process involved three sequential steps: title screening, abstract screening, and full-text evaluation.

During the initial title screening, articles were reviewed to remove clearly irrelevant publications unrelated to healthcare, aging populations, or IoT technologies. The remaining articles were then subjected to abstract screening, during which studies were evaluated based on their stated objectives, methodology, and relevance to IoT-enabled geriatric care.

Articles that passed the abstract screening stage were subsequently assessed through full-text review, where eligibility was determined according to the inclusion and exclusion criteria described earlier. Studies meeting all criteria were included in the final dataset used for analysis.

The final set of selected publications formed the evidence base for the thematic synthesis presented in later sections of this review.

2.4 Data Extraction and Thematic Analysis

After the final set of studies was selected, relevant information from each article was extracted and organized into a structured database. Key information extracted from each study included:

- Authors and publication year
- Study type (empirical study, review, system design, clinical evaluation)
- IoT technologies used (wearable sensors, smart home devices, monitoring platforms)
- Target healthcare application (chronic disease monitoring, fall detection, medication management, etc.)
- Reported outcomes and benefits
- Identified technical or human-centered challenges

The extracted data were subsequently categorized into thematic groups reflecting the primary research dimensions addressed in this review. These themes include IoT-enabled health monitoring systems, user adoption and ethical considerations, and technical infrastructure challenges. Thematic analysis allowed the identification of common trends, recurring barriers, and emerging innovations across the selected literature.

The following conceptual diagram illustrates the literature selection process used in this review.

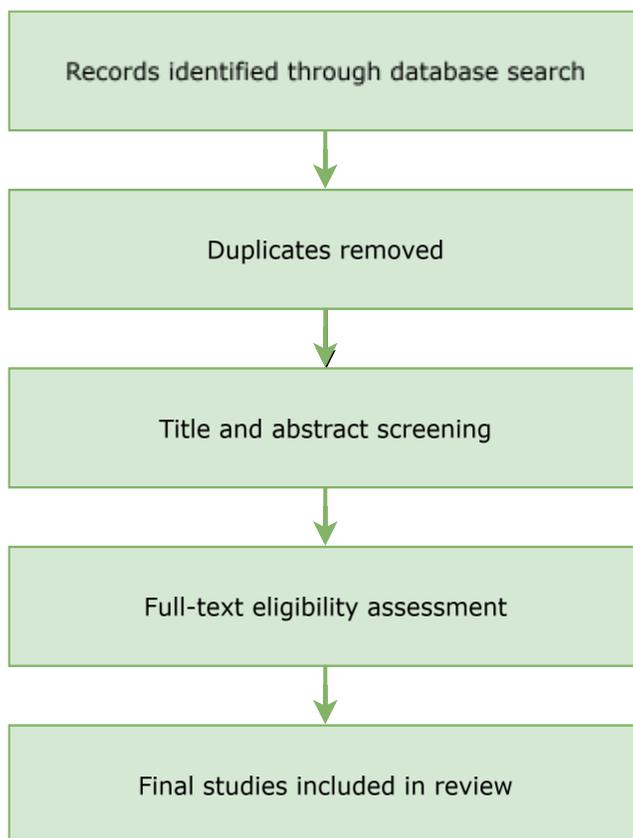


Figure 1 PRISMA Literature Selection Process

This structured screening process ensured transparency and reproducibility while maintaining a focused dataset of recent high-quality studies.

3. IoT-Enabled Health Monitoring and Management

The Internet of Things (IoT) has emerged as a foundational technological paradigm for enabling continuous health monitoring and personalized care for aging populations. IoT-enabled healthcare systems integrate interconnected sensors, wearable devices, communication networks, and cloud-based analytical platforms to collect and analyze physiological and behavioral data in real time. These systems allow healthcare providers to monitor patients remotely, detect early signs of health deterioration, and implement timely interventions before conditions escalate into acute medical emergencies. As healthcare systems worldwide face increasing pressure from aging populations and rising chronic disease prevalence, IoT-based monitoring technologies offer promising solutions for improving healthcare efficiency and supporting independent living among older adults [1][7].

Recent research demonstrates that IoT-enabled health monitoring systems can significantly enhance the management of chronic diseases, reduce hospital readmissions, and improve

medication adherence in older adults [8][9]. These systems combine wearable biosensors, ambient environmental monitoring, and intelligent analytics to create integrated digital health ecosystems capable of supporting continuous patient care outside traditional clinical settings. By enabling remote health monitoring, IoT technologies facilitate a transition from reactive healthcare models toward preventive and personalized healthcare approaches.

IoT healthcare infrastructures typically operate through multi-layer architectures consisting of perception, network, and application layers. The perception layer includes physical sensing devices such as wearable sensors and environmental monitoring units that collect raw physiological and contextual data. The network layer transmits this information through wireless communication technologies including Bluetooth, Wi-Fi, and 5G networks, while the application layer processes and analyzes the data using artificial intelligence and cloud computing services [10]. These interconnected layers enable the continuous monitoring of health indicators and support clinical decision-making through real-time data analytics.

Within geriatric healthcare, IoT applications can be broadly categorized into four primary domains: wearable health monitoring systems, smart home and ambient assisted living technologies, chronic disease management platforms, and artificial intelligence–driven predictive monitoring systems.

3.1 Wearable Health Monitoring Systems

Wearable health monitoring devices represent one of the most widely adopted forms of IoT technology in modern healthcare systems. These devices incorporate miniature sensors capable of continuously measuring physiological signals such as heart rate, electrocardiography (ECG), blood oxygen saturation, body temperature, and physical activity levels. Advances in sensor miniaturization, wireless communication protocols, and energy-efficient hardware have enabled wearable devices to provide continuous physiological monitoring with minimal user intervention [11].

Wearable monitoring technologies are particularly beneficial for older adults who require continuous observation of health indicators due to chronic conditions or mobility limitations. Smartwatches, fitness trackers, wearable patches, and sensor-embedded garments can collect physiological data throughout daily activities and transmit the information to mobile devices or cloud-based health monitoring platforms. These data streams can then be analyzed using machine learning algorithms to detect abnormal health patterns and generate alerts for caregivers or healthcare professionals.

Recent studies highlight the growing importance of wearable biosensors in monitoring cardiovascular health among elderly populations. Continuous electrocardiographic monitoring through wearable devices can enable early detection of arrhythmias, atrial fibrillation, and other cardiac abnormalities, allowing healthcare providers to initiate timely interventions and prevent

severe complications [11][4]. Additionally, wearable accelerometers and gyroscopes can track mobility patterns and physical activity levels, which are important indicators of overall health status and functional independence in older adults.

Another critical application of wearable technologies involves fall detection and fall risk monitoring. Falls remain one of the leading causes of injury and hospitalization among older adults, making early detection systems an essential component of geriatric healthcare technologies. Wearable sensors equipped with accelerometers and gyroscopic motion detectors can identify rapid changes in body orientation or sudden impacts that indicate a fall event [12]. These systems can automatically trigger emergency alerts to caregivers or healthcare services, thereby reducing response times and improving patient outcomes.

Recent research has also explored the integration of wearable sensors with advanced machine learning algorithms for improving fall detection accuracy. Deep learning models such as convolutional neural networks and transfer learning frameworks have demonstrated improved detection performance compared to traditional rule-based methods [13]. These technological developments highlight the potential of wearable IoT devices to enhance safety and health monitoring capabilities for aging populations.

3.2 Smart Home and Ambient Assisted Living Technologies

Smart home technologies represent another critical domain of IoT-enabled healthcare systems designed to support aging in place. These systems incorporate networks of environmental sensors, motion detectors, smart appliances, and connected communication platforms that monitor daily activities and environmental conditions within residential environments. Smart home monitoring systems are often implemented within the broader framework of Ambient Assisted Living (AAL), which aims to create intelligent living environments capable of supporting the independence and well-being of older adults.

Smart home monitoring technologies can analyze patterns of daily activity such as movement within the home, sleep behavior, cooking habits, and medication routines. Deviations from established behavioral patterns may indicate potential health issues, including cognitive decline, depression, or physical mobility impairments. By detecting such changes early, smart home monitoring systems enable proactive interventions that can prevent health deterioration or accidents.

Environmental sensors integrated within smart homes can also monitor safety conditions such as smoke detection, gas leaks, temperature changes, and water usage. These monitoring capabilities are particularly important for older adults who may face increased risks associated with household hazards. Automated alerts and communication systems can notify caregivers or emergency services when abnormal environmental conditions are detected.

Recent studies have demonstrated that smart home technologies can significantly improve quality of life among older adults by supporting independent living and reducing caregiver burden [5]. Smart home systems can also integrate voice assistants and conversational interfaces that allow elderly users to interact with digital systems using natural language commands. Such interfaces improve usability and accessibility, particularly for individuals with limited technological experience or physical limitations.

In addition, emerging research explores the integration of artificial intelligence and digital twin technologies into smart home monitoring environments. Digital twins can create virtual representations of physical environments and human activities, allowing predictive modeling of health risks and environmental interactions within smart homes [14]. These advancements illustrate the growing sophistication of IoT-enabled home healthcare ecosystems.

3.3 IoT Applications in Chronic Disease Management

Chronic diseases are among the primary contributors to healthcare utilization and mortality in aging populations. Conditions such as diabetes, cardiovascular disease, hypertension, and chronic respiratory disorders require long-term monitoring and consistent management in order to prevent complications. IoT-enabled healthcare systems provide valuable tools for managing chronic diseases through continuous remote monitoring and personalized care management.

Remote patient monitoring systems utilize interconnected medical devices and biosensors to track key physiological indicators relevant to specific chronic conditions. For example, continuous glucose monitoring devices allow individuals with diabetes to monitor blood glucose levels in real time, enabling early detection of dangerous fluctuations in blood sugar levels. Similarly, wearable blood pressure monitors and electrocardiographic sensors allow clinicians to track cardiovascular health indicators outside clinical environments.

IoT-based monitoring systems also support medication adherence management, which is a major challenge among older adults with multiple chronic conditions. Studies have shown that medication non-adherence contributes significantly to poor treatment outcomes and increased healthcare costs among elderly populations. Smart medication management systems that incorporate IoT sensors can track medication intake and provide reminders through mobile applications or automated alerts.

Recent research indicates that digital health platforms integrating IoT monitoring with telehealth services can significantly improve chronic disease management outcomes. These platforms allow healthcare providers to remotely monitor patient health data, adjust treatment plans, and provide timely interventions without requiring frequent hospital visits [8]. As healthcare systems

increasingly adopt remote monitoring technologies, IoT-based chronic disease management platforms are expected to play an essential role in supporting sustainable healthcare delivery models for aging populations.

3.4 AI-Driven Predictive Health Monitoring

Artificial intelligence (AI) and machine learning technologies have become integral components of advanced IoT healthcare systems. The continuous data streams generated by wearable sensors, smart home devices, and remote monitoring systems provide large datasets that can be analyzed using machine learning algorithms to identify patterns, detect anomalies, and predict potential health events.

Predictive health monitoring systems utilize AI algorithms to analyze physiological signals and behavioral patterns collected through IoT devices. These algorithms can detect subtle deviations from normal health patterns that may indicate early stages of disease progression or functional decline. For example, machine learning models analyzing gait patterns and movement data can identify early indicators of neurological disorders or increased fall risk.

Recent research highlights the potential of hybrid deep learning models to improve predictive accuracy in IoT-based health monitoring systems. These models combine multiple sensor inputs and advanced neural network architectures to analyze complex datasets and generate more reliable health predictions [15]. Such approaches enable healthcare providers to transition from reactive treatment strategies toward proactive preventive care models.

Emerging technological developments also explore the use of edge computing and federated learning in IoT healthcare environments. Edge computing enables data processing to occur directly on local devices or edge servers, reducing latency and improving system responsiveness. Federated learning allows machine learning models to be trained across decentralized datasets while preserving data privacy, which is particularly important for sensitive healthcare information [16].

Although AI-driven monitoring technologies offer significant potential benefits, their implementation raises important challenges related to algorithm transparency, clinical validation, and ethical governance. Ensuring that predictive models remain interpretable and trustworthy is essential for gaining acceptance among healthcare professionals and patients.

Technology	Sensors / Components	Healthcare Applications	Key Benefits
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Wearable Biosensors	ECG sensors, accelerometers, gyroscopes	Cardiovascular monitoring, activity tracking	Continuous physiological monitoring
Smart Home Sensors	Motion detectors, environmental sensors	Behavior monitoring, safety detection	Supports aging in place
Remote Monitoring Devices	Glucose monitors, blood pressure sensors	Chronic disease management	Reduces hospital visits
AI Monitoring Systems	Multi-sensor analytics, machine learning	Predictive health analysis	Early detection of health risks

Table 1 Major IoT Technologies Used in Geriatric Health Monitoring

IoT technologies have significantly expanded the possibilities for continuous health monitoring and personalized care for aging populations. Wearable devices, smart home monitoring systems, remote patient monitoring platforms, and AI-driven predictive analytics collectively enable healthcare systems to transition toward proactive and preventive care models. These technologies can improve chronic disease management, enhance safety through fall detection systems, and support independent living for older adults. However, despite these technological advancements, widespread implementation remains constrained by several human, ethical, and systemic challenges [17]. These challenges highlight the importance of examining the social and behavioral dimensions of IoT healthcare adoption, which are discussed in the following section.

4. The Human Dimension: Acceptance, Adoption, and Ethics

While IoT-enabled healthcare technologies offer significant potential for improving geriatric health monitoring and supporting independent living, their successful implementation depends not only on technological capabilities but also on human factors such as user acceptance, accessibility, trust, and ethical governance. The adoption of Internet of Medical Things (IoMT) systems among older adults is influenced by complex socio-technical interactions involving individual attitudes, technological usability, healthcare infrastructure, and cultural perceptions of digital health technologies.

4.1 Technology Acceptance Among Older Adults

Technology acceptance remains one of the most critical determinants of successful IoT healthcare implementation. Older adults often face barriers when interacting with digital technologies due to factors such as limited digital literacy, physical impairments, or concerns regarding privacy and security. Studies examining the adoption of Internet of Medical Things technologies have

identified several key determinants influencing user acceptance, including perceived usefulness, ease of use, trust in technology, and perceived health benefits [18].

Research on assistive smart home systems indicates that perceived improvements in quality of life significantly increase willingness among older adults to adopt IoT-based healthcare technologies. When users believe that technology can support independence, reduce caregiver dependence, and improve safety within home environments, adoption rates increase substantially. Conversely, complex user interfaces, technical malfunctions, or lack of adequate training may discourage older individuals from engaging with digital healthcare platforms.

Another important determinant of technology acceptance involves device usability and accessibility. Age-related physical changes, including reduced vision, limited mobility, and declining cognitive function, require IoT healthcare devices to be designed with inclusive usability principles. Interfaces incorporating large displays, voice interaction, simplified navigation structures, and automated data collection can significantly improve usability among elderly populations. Research on wearable interfaces and assistive technologies demonstrates that user-centered design approaches can substantially increase the effectiveness and adoption of digital health monitoring tools among older adults [19].

Factor	Description	Impact on Adoption
Perceived usefulness	Belief that technology improves health outcomes	Strong positive influence
Ease of use	Simplicity of device interfaces and interaction	High impact on adoption
Trust in technology	Confidence in system reliability and accuracy	Critical for long-term use
Privacy and security	Concerns about data protection	May discourage adoption
Accessibility	Design suitable for age-related impairments	Improves usability
Social support	Encouragement from caregivers and family	Facilitates adoption

Table 2 Key Factors Influencing IoT Healthcare Adoption Among Older Adults

4.2 Ethical Considerations and Privacy Challenges

The widespread deployment of IoT-based healthcare systems introduces important ethical challenges related to data privacy, consent, and autonomy. IoT devices continuously collect large volumes of sensitive personal health information, including physiological data, behavioral patterns, and environmental context. Protecting this data from unauthorized access or misuse is

essential for maintaining patient trust and ensuring ethical compliance in digital healthcare environments.

Privacy concerns are particularly significant for older adults who may be uncomfortable with continuous monitoring technologies within their homes. Although remote monitoring systems can improve safety and healthcare outcomes, some individuals perceive these technologies as intrusive or potentially violating personal autonomy. Ethical frameworks for IoT healthcare systems therefore emphasize the importance of transparent data governance policies, informed consent mechanisms, and secure data management infrastructures.

Data protection challenges are further complicated by the distributed architecture of IoT ecosystems. Health data collected by wearable sensors and home monitoring devices often pass through multiple communication layers, including mobile devices, cloud platforms, and healthcare provider networks. Each layer introduces potential vulnerabilities that must be addressed through encryption protocols, authentication mechanisms, and secure system architectures.

Emerging research also highlights the importance of ethical AI governance in IoT healthcare systems. Machine learning algorithms used for predictive health monitoring must be designed to ensure fairness, transparency, and accountability in decision-making processes. Biased training datasets or opaque algorithmic models may lead to inaccurate predictions or unequal healthcare outcomes. Consequently, the development of trustworthy AI frameworks is increasingly recognized as an essential component of responsible IoT healthcare deployment [20].

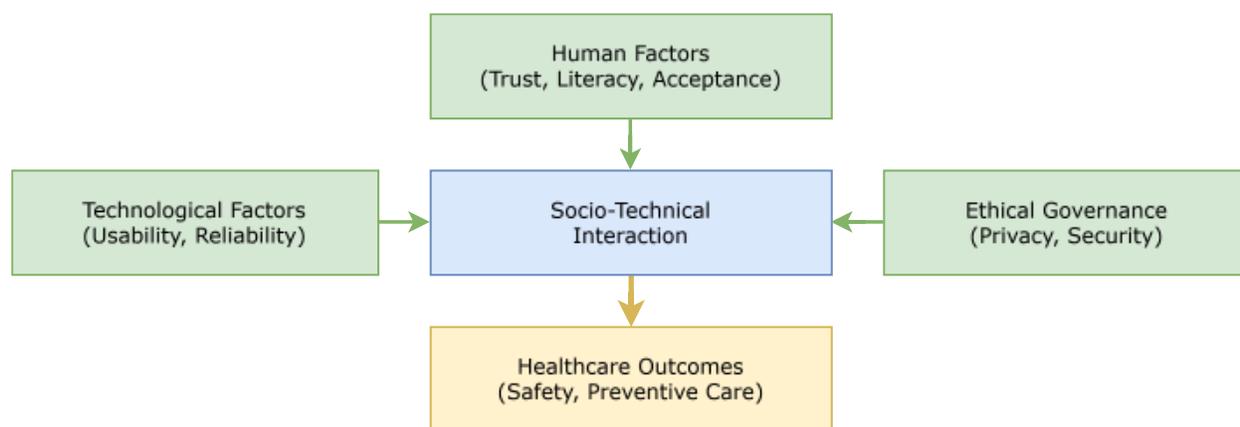


Figure 2 Socio-technical framework illustrating how human factors, technological design, and ethical governance collectively influence the adoption and outcomes of IoT-enabled healthcare systems

4.3 Social and Caregiver Perspectives

The adoption of IoT healthcare technologies also involves broader social dynamics, particularly the role of caregivers and healthcare professionals in supporting older adults. Family members often play a crucial role in encouraging or facilitating technology adoption by assisting with device setup, troubleshooting, and data interpretation.

Healthcare providers also influence adoption by integrating IoT monitoring systems into clinical workflows and recommending appropriate technologies to patients. When clinicians actively engage with remote monitoring platforms and incorporate patient-generated data into treatment decisions, patients are more likely to perceive these systems as valuable components of their healthcare management.

In addition, caregiver acceptance is closely linked to perceived reductions in caregiving burden. Remote monitoring systems can provide caregivers with real-time health updates and automated alerts, enabling them to respond quickly to emergencies while reducing the need for constant physical supervision. These benefits contribute to improved caregiver well-being and may enhance the overall sustainability of home-based care models.

5. Technical and Systemic Challenges

Despite the rapid advancement of Internet of Things technologies in healthcare environments, several technical and systemic challenges continue to limit the large-scale deployment of IoT-based geriatric healthcare systems. These challenges extend beyond hardware development and include issues related to interoperability, data security, system scalability, infrastructure reliability, and regulatory compliance. Addressing these limitations is essential for ensuring the safe and sustainable integration of IoT technologies into healthcare systems.

IoT-enabled healthcare infrastructures typically involve complex networks of interconnected sensors, cloud platforms, and data analytics services. These distributed systems generate large volumes of physiological and behavioral data that must be transmitted, stored, and processed securely. As the number of connected devices increases, managing these data flows while maintaining system performance and security becomes increasingly challenging [\[21\]](#).

Furthermore, healthcare IoT systems must operate within highly regulated environments where patient safety, data privacy, and clinical reliability are paramount. The integration of IoT technologies into clinical workflows therefore requires robust technical frameworks and regulatory standards capable of ensuring system reliability and ethical governance.

The most significant technical and systemic challenges associated with IoT-enabled healthcare systems include interoperability limitations, cybersecurity risks, data management constraints, infrastructure scalability issues, and regulatory compliance barriers.

5.1 Interoperability and System Integration

One of the most widely discussed technical challenges in IoT healthcare ecosystems is the lack of interoperability between devices, platforms, and healthcare information systems. IoT devices used in healthcare environments are often produced by different manufacturers and operate using proprietary communication protocols. As a result, integrating these devices into unified healthcare monitoring systems can be difficult.

Healthcare providers frequently rely on multiple digital platforms, including electronic health record (EHR) systems, telemedicine platforms, and hospital information systems. Integrating IoT-generated health data into these existing infrastructures requires standardized communication protocols and data formats. Without such standards, data generated by wearable devices or smart home sensors may remain isolated within vendor-specific platforms, limiting their clinical usefulness [22].

Several international initiatives have attempted to address interoperability issues by promoting standardized data frameworks. Standards such as Fast Healthcare Interoperability Resources (FHIR) and Health Level Seven (HL7) have been increasingly adopted to facilitate secure data exchange between healthcare systems and IoT platforms. However, widespread adoption remains uneven across healthcare organizations and device manufacturers.

Interoperability challenges are particularly important in geriatric healthcare environments where patients may simultaneously use multiple monitoring technologies, including wearable sensors, medication management systems, and smart home monitoring platforms. Achieving seamless communication among these systems is essential for creating comprehensive patient monitoring ecosystems.

5.2 Cybersecurity and Data Privacy

Security and privacy concerns represent some of the most critical barriers to the adoption of IoT healthcare technologies. IoT healthcare devices collect highly sensitive personal health data, including physiological signals, behavioral patterns, and medical histories. Protecting this information from unauthorized access is essential for maintaining patient trust and complying with healthcare privacy regulations.

IoT healthcare networks are particularly vulnerable to cybersecurity threats due to the large number of connected devices and communication interfaces involved. Many IoT devices have limited computational capacity, which restricts their ability to implement advanced security protocols. As a result, vulnerabilities in device firmware or communication channels may expose healthcare systems to cyberattacks [23].

Potential security threats include unauthorized data access, device hijacking, data manipulation, and distributed denial-of-service attacks. Such threats may compromise patient privacy, disrupt healthcare monitoring services, or even endanger patient safety if clinical decisions are based on manipulated data.

Recent research emphasizes the importance of implementing multi-layer security frameworks within IoT healthcare architectures. These frameworks typically combine encryption mechanisms, secure authentication protocols, intrusion detection systems, and blockchain-based data integrity solutions to enhance the resilience of healthcare networks.

In addition to technical security measures, effective governance frameworks and regulatory oversight are required to ensure responsible data management. Regulations such as the General Data Protection Regulation (GDPR) and various national health data protection policies impose strict requirements for the handling and storage of medical information.

5.3 Data Management and Scalability

IoT healthcare systems generate vast quantities of data from continuous sensor monitoring. Wearable biosensors, smart home devices, and remote patient monitoring platforms collectively produce high-frequency physiological and environmental data streams. Managing this data efficiently presents significant technical challenges for healthcare systems.

Traditional healthcare data infrastructures were not originally designed to process continuous real-time data streams. As IoT devices become more widely deployed, healthcare organizations must adopt scalable cloud-based data management architectures capable of storing and processing large datasets [24]. Cloud computing platforms provide flexible storage resources and advanced analytical capabilities, enabling healthcare providers to analyze large volumes of patient data for predictive insights.

However, reliance on centralized cloud infrastructures may introduce latency issues and increase network bandwidth requirements. To address these limitations, many researchers have explored the use of edge computing technologies within IoT healthcare environments. Edge computing allows data processing tasks to occur closer to the source of data generation, reducing transmission delays and improving system responsiveness.

Hybrid architectures combining edge computing and cloud analytics have been proposed as promising solutions for managing large-scale IoT healthcare systems. These architectures enable real-time processing of critical health data at the edge while allowing more complex analytics to be performed in cloud environments.

5.4 Infrastructure Reliability and Network Limitations

The reliability of IoT healthcare systems is highly dependent on the stability of underlying communication infrastructures. Continuous health monitoring systems require reliable network connectivity to transmit sensor data between devices, cloud platforms, and healthcare providers.

In many regions, particularly rural or underserved areas, network infrastructure may not be sufficiently robust to support continuous remote health monitoring. Limited internet connectivity or unstable wireless networks can disrupt data transmission and compromise the reliability of monitoring systems.

Emerging communication technologies such as 5G networks offer promising solutions for addressing these challenges by providing higher data transmission speeds and lower latency. The deployment of 5G infrastructure may significantly enhance the performance of IoT healthcare systems by enabling faster data transmission and improved connectivity between devices.

Nevertheless, large-scale deployment of such infrastructure requires substantial investment and coordinated policy initiatives. Healthcare institutions must therefore consider infrastructure availability when designing and implementing IoT-based monitoring systems.

5.5 Regulatory and Ethical Governance Challenges

The integration of IoT technologies into healthcare systems introduces complex regulatory and ethical considerations. Healthcare technologies must undergo rigorous evaluation processes to ensure that they meet safety and effectiveness standards before being deployed in clinical environments.

Regulatory approval processes for digital health technologies can be lengthy and complex, particularly when devices incorporate artificial intelligence algorithms capable of evolving over time. Regulatory agencies must evaluate not only the safety of hardware devices but also the reliability and transparency of underlying algorithms.

Ethical concerns related to data ownership, algorithmic bias, and patient autonomy also require careful consideration. For example, predictive healthcare algorithms trained on incomplete or biased datasets may produce inaccurate health predictions for certain populations. Ensuring fairness and transparency in AI-driven healthcare systems is therefore essential.

Addressing these regulatory and ethical challenges requires collaboration among technology developers, healthcare providers, policymakers, and patient advocacy groups. Establishing clear governance frameworks will be critical for ensuring that IoT healthcare systems operate responsibly while delivering meaningful benefits to aging populations.

Challenge	Description	Potential Solutions
Interoperability	Lack of standardized communication protocols across IoT devices	Adoption of HL7/FHIR standards
Cybersecurity	Vulnerabilities in connected healthcare devices	Multi-layer encryption and authentication
Data Management	Large volumes of continuous sensor data	Cloud and edge computing architectures
Infrastructure Reliability	Dependence on stable network connectivity	Deployment of 5G and edge networks
Regulatory Compliance	Complex approval processes for digital health technologies	Development of adaptive regulatory frameworks

Table 3 Major Technical Challenges in IoT Healthcare Systems

6. Discussion and Future Directions

The preceding sections of this review have examined the rapid evolution of Internet of Things technologies in the context of geriatric healthcare systems. Collectively, the literature demonstrates that IoT-enabled monitoring platforms have the potential to significantly transform healthcare delivery by enabling continuous physiological monitoring, remote disease management, and predictive health analytics. These technologies support a transition from traditional episodic healthcare models toward continuous, data-driven care environments that emphasize prevention, early intervention, and personalized treatment strategies.

A central observation emerging from this review is that IoT-based healthcare systems operate at the intersection of technological capability and human adoption. While substantial progress has been made in the development of wearable biosensors, smart home monitoring systems, and artificial intelligence–driven health analytics, the long-term success of these technologies depends

on their integration into real-world healthcare environments and their acceptance by patients, caregivers, and healthcare professionals.

The technological ecosystem supporting IoT healthcare systems is inherently multidisciplinary, incorporating elements of biomedical engineering, computer science, health informatics, and clinical medicine. Wearable monitoring devices provide continuous streams of physiological data that can be analyzed to detect subtle changes in patient health conditions. Smart home monitoring systems extend these capabilities by observing behavioral patterns and environmental conditions within residential environments. When integrated with advanced analytics platforms, these systems create comprehensive monitoring ecosystems capable of identifying potential health risks before they escalate into severe medical events.

Despite these technological advances, the deployment of IoT healthcare systems remains uneven across healthcare systems worldwide. Implementation challenges often arise from limitations in infrastructure, system interoperability, and data governance frameworks. Healthcare institutions must ensure that digital monitoring systems integrate seamlessly with existing clinical workflows and electronic health record systems. Without effective integration strategies, the clinical value of IoT-generated data may remain underutilized.

Another important observation concerns the role of human-centered design in the development of healthcare technologies for aging populations. Older adults represent a highly heterogeneous demographic group with diverse health conditions, cognitive abilities, and levels of technological familiarity. As a result, IoT healthcare devices must be designed with accessibility, simplicity, and usability in mind. Technologies that are difficult to operate or that require complex interactions may discourage adoption and reduce long-term engagement.

User trust also plays a crucial role in determining the acceptance of digital health technologies. Continuous health monitoring systems collect sensitive personal data related to physiological status, daily behaviors, and medical conditions. Ensuring that users understand how their data are collected, stored, and used is essential for establishing trust in digital healthcare platforms. Transparent communication, clear data governance policies, and robust privacy protections can help build confidence among patients and caregivers.

The integration of artificial intelligence into IoT healthcare ecosystems represents another major development shaping the future of digital health monitoring. AI-driven analytics enable healthcare systems to process large volumes of sensor-generated data and extract clinically meaningful insights. Predictive algorithms can identify patterns that may indicate the early onset of disease or functional decline, enabling proactive healthcare interventions. These capabilities have the potential to reduce hospitalizations, improve treatment outcomes, and support aging populations in maintaining independence for longer periods.

However, the increasing reliance on algorithmic decision-making introduces new considerations related to transparency, accountability, and fairness. Healthcare professionals must be able to understand and interpret the outputs generated by predictive models in order to make informed clinical decisions. Ensuring that artificial intelligence systems remain interpretable and clinically validated is therefore essential for responsible implementation.

Future research in IoT-enabled geriatric healthcare is likely to focus on several emerging technological directions. One such direction involves the integration of digital twin technologies into healthcare monitoring systems. Digital twins create virtual representations of individuals or physical environments, allowing healthcare providers to simulate health scenarios and predict potential outcomes based on real-time sensor data. These virtual models may eventually support highly personalized healthcare strategies tailored to individual patient profiles.

Another promising research direction involves the expansion of edge computing architectures within IoT healthcare environments. By processing data closer to the source of collection, edge computing systems can reduce latency and enable real-time decision-making. This capability is particularly important for applications such as fall detection systems and emergency health monitoring, where rapid response times are critical.

Advancements in communication technologies are also expected to enhance the performance of IoT healthcare systems. Next-generation wireless networks offer higher data transmission speeds and improved connectivity, enabling large-scale deployments of sensor networks and remote monitoring platforms. These developments may expand the reach of IoT healthcare technologies to rural and underserved regions where access to traditional healthcare services is limited.

In addition to technological innovation, policy development will play a crucial role in shaping the future of digital healthcare ecosystems. Governments and healthcare organizations must establish regulatory frameworks that ensure patient safety while encouraging innovation in digital health technologies. Such frameworks must address issues related to device certification, algorithm validation, and cross-border data sharing.

Another important future direction involves improving interdisciplinary collaboration between technology developers, healthcare providers, and social scientists. The socio-technical nature of IoT healthcare systems requires expertise from multiple disciplines to ensure that technologies are both technically effective and socially acceptable. Collaborative research initiatives can help bridge the gap between technological innovation and real-world healthcare implementation.

The continued expansion of IoT healthcare ecosystems will also generate large-scale datasets that can support population-level health research. Aggregated sensor data may provide valuable insights into aging patterns, disease progression, and the effectiveness of preventive healthcare strategies. When managed responsibly, such data resources could contribute to the development of more efficient healthcare systems capable of responding to demographic changes.

Ultimately, the future success of IoT-enabled healthcare systems will depend on the ability of researchers, policymakers, and healthcare institutions to balance technological innovation with ethical responsibility and human-centered design. The development of integrated healthcare ecosystems that prioritize patient well-being, data security, and system reliability will be essential for realizing the full potential of digital health technologies.

7. Conclusion

The rapid evolution of Internet of Things technologies has introduced new possibilities for addressing the growing healthcare demands associated with global population aging. As healthcare systems face increasing pressure from rising chronic disease prevalence, workforce limitations, and expanding elderly populations, IoT-enabled healthcare platforms offer a promising pathway toward more sustainable and patient-centered models of care. By integrating wearable biosensors, smart home monitoring technologies, remote patient monitoring platforms, and artificial intelligence-driven analytics, IoT systems enable continuous observation of patient health conditions beyond traditional clinical environments.

This review examined recent developments in IoT-enabled geriatric healthcare systems, with particular emphasis on health monitoring technologies, adoption dynamics, and the socio-technical challenges associated with large-scale implementation. The analysis highlights how IoT technologies can significantly enhance healthcare delivery by supporting early disease detection, improving chronic disease management, and enabling older adults to maintain independence while aging in place. Continuous health monitoring systems provide clinicians with valuable real-time physiological and behavioral data, allowing healthcare providers to detect subtle changes in patient conditions and intervene before health issues escalate into serious medical events.

Wearable health monitoring devices have emerged as one of the most widely adopted IoT applications in geriatric healthcare. Advances in biosensor miniaturization and wireless communication technologies have enabled continuous measurement of physiological indicators such as heart rate, physical activity, and sleep patterns. These technologies allow healthcare providers to monitor patient health remotely while reducing the need for frequent clinical visits. In parallel, smart home monitoring systems and ambient assisted living environments extend these monitoring capabilities into residential spaces, allowing the detection of behavioral patterns and environmental conditions that may signal emerging health risks.

The integration of artificial intelligence within IoT healthcare ecosystems further enhances the capabilities of digital health monitoring systems. Machine learning algorithms can analyze large volumes of sensor-generated data to identify patterns associated with disease progression, mobility decline, or increased fall risk. Such predictive analytics enable healthcare systems to transition from reactive treatment strategies toward proactive and preventive care models.

Despite these technological advancements, the widespread adoption of IoT healthcare systems remains influenced by a complex set of human, technical, and regulatory factors. The successful implementation of digital health monitoring technologies requires more than technological innovation alone. Human-centered design principles must guide the development of healthcare devices to ensure that systems remain accessible and usable for older adults with varying levels of technological literacy and physical ability.

Trust and data privacy also represent essential considerations for the long-term acceptance of IoT healthcare technologies. Continuous monitoring systems collect sensitive personal health information, and users must feel confident that their data are handled responsibly and securely. Transparent data governance frameworks, strong cybersecurity protections, and clear communication regarding data usage policies are critical for maintaining patient trust in digital health ecosystems.

Technical challenges related to interoperability, system scalability, and infrastructure reliability also influence the effectiveness of IoT healthcare deployments. Healthcare institutions must ensure that IoT platforms integrate seamlessly with existing clinical information systems while maintaining reliable data transmission and secure communication networks. Addressing these challenges will require coordinated collaboration among technology developers, healthcare providers, policymakers, and regulatory authorities.

Looking ahead, future research and development efforts will likely focus on improving the integration of IoT technologies with emerging digital health innovations such as edge computing, digital twin modeling, and advanced predictive analytics. These technologies may enable more sophisticated healthcare monitoring environments capable of supporting personalized healthcare strategies and real-time clinical decision support.

Equally important is the need for interdisciplinary collaboration in the development of IoT healthcare systems. Because these technologies operate at the intersection of engineering, healthcare, and social sciences, successful implementation requires coordinated efforts across multiple domains of expertise. Researchers must continue to explore not only the technical performance of IoT healthcare systems but also the social and behavioral factors that influence user acceptance and long-term engagement.

In summary, IoT-enabled healthcare technologies hold substantial potential to transform geriatric care by enabling continuous health monitoring, supporting preventive healthcare strategies, and promoting independent living among older adults. However, realizing this potential requires careful consideration of the socio-technical dynamics that shape technology adoption in healthcare environments. By integrating technological innovation with human-centered design, ethical governance, and robust healthcare infrastructures, IoT-based healthcare systems can play a crucial role in addressing the healthcare challenges associated with aging societies.

8: Declaration

8.1 Availability of data and material

Not applicable.

8.2 Funding

Not applicable.

8.3 Acknowledgements

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References

1. Guillemot, J. R., Zhang, X., & Warner, M. E. (2024). Population aging and decline will happen sooner than we think. *Social Sciences*, 13(4), 190. <https://doi.org/10.3390/socsci13040190>
2. Haferkamp, T., Ing, S., Weyer, G., Gleason, L. J., et al. (2025). Home-Based Primary Care (HBPC): Aging in place in 2025. *Current Geriatrics Reports*, 14. <https://doi.org/10.1007/s13670-025-00429-y>
3. Chu, R. Y. K., Cheng, C. H. G., Leung, K. M. C., Ezulike, J. C. D., & Montayre, J. (2025). Technology-enabled interventions promoting healthy ageing: An umbrella review. *Discover Public Health*, 22, 661. <https://doi.org/10.1186/s12982-025-01066-8>
4. Zhi, H., & Zolotova, M. (2025). Wearable devices and elderly health monitoring: A bibliometric analysis of research trends from 2014 to 2024. *Healthcare*, 13(16), 2066. <https://doi.org/10.3390/healthcare13162066>

5. Qiao, Y., Wang, L., Liu, Y., & Chen, W. (2025). Adoption of assistive smart home technology and health-related quality of life among older adults. *Frontiers in Public Health*, 13. <https://doi.org/10.3389/fpubh.2025.1726983>
6. The Lancet Healthy Longevity. (2024). Restoring cancer care for our ageing populations. *The Lancet Healthy Longevity*, 5(3), e163. [https://doi.org/10.1016/S2666-7568\(24\)00031-X](https://doi.org/10.1016/S2666-7568(24)00031-X)
7. Andrade, A., Cabral, A. T., Bellini, B., Rodrigues, V. F., Da Rosa Righi, R., Da Costa, C. A., & Barbosa, J. L. V. (2024). IoT-based vital sign monitoring: A literature review. *Smart Health*, 32, 100462. <https://doi.org/10.1016/j.smhl.2024.100462>
8. Smith, L., Simpson, G., Holt, S., & Dambha-Miller, H. (2025). Digital applications to support self-management of multimorbidity: A scoping review. *International Journal of Medical Informatics*, 202, 105988. <https://doi.org/10.1016/j.ijmedinf.2025.105988>
9. Hossain, M., Rahman, M., & Ahmed, S. (2025). IoT-based remote monitoring system: A new era for patient healthcare management. *Health Science Reports*, 8(2), e70498. <https://doi.org/10.1002/hsr2.70498>
10. Torres, M., & Delgado, A. (2024). Internet of Things: A comprehensive overview, architectures and applications. *Journal of Ambient Intelligence and Humanized Computing*. <https://doi.org/10.1007/s43926-024-00084-3>
11. Lee, H., Kim, J., & Park, S. (2025). Interactive interfaces and wearable technologies for enhancing elderly health monitoring. *Frontiers in Medicine*, 12, 1724828. <https://doi.org/10.3389/fmed.2025.1724828>
12. Akram, A., Khan, M. B., Ali, N. a. A., Zhang, Q., Ahmad, A., Iqbal, M. S., & Moqurrab, S. A. (2024). Intelligent non-invasive elderly fall monitoring by designing software defined radio frequency sensing system. *Digital Communications and Networks*, 11(3), 634–641. <https://doi.org/10.1016/j.dcan.2024.07.009>
13. Huang, K., Li, P., & Zhao, Y. (2026). Fall detection among elderly persons using FallCNN and transfer learning. *Frontiers in Artificial Intelligence*, 9, 1734096. <https://doi.org/10.3389/frai.2026.1734096>
14. Momand, Z., Mongkolnam, P., Chan, J. H., Charoenkitkarn, N., & Pal, D. (2025). Building Digital Twins for Elderly Care: An End-to-End Framework From Data acquisition to Modeling. *IEEE Access*, 13, 169415–169445. <https://doi.org/10.1109/access.2025.3607603>
15. Vallabhuni, S., & Debasis, K. (2025). Hybrid deep learning for IoT-based health monitoring with physiological event extraction. *Digital Health*, 11, 20552076251337848. <https://doi.org/10.1177/20552076251337848>
16. Alsabah, M., Naser, M.A., Albahri, A.S. et al. A comprehensive review on key technologies toward smart healthcare systems based IoT: technical aspects, challenges and future directions. *Artif Intell Rev* 58, 343 (2025). <https://doi.org/10.1007/s10462-025-11342-3>

17. Habibzadeh, H., Dinesh, K., Shishvan, O. R., Boggio-Dandry, A., Sharma, G., & Soyata, T. (2019). A survey of Healthcare Internet of Things (HIOT): A Clinical perspective. *IEEE Internet of Things Journal*, 7(1), 53–71. <https://doi.org/10.1109/jiot.2019.2946359>
18. Elhoseny, M., Thilakarathne, N. N., Alghamdi, M. I., Mahendran, R. K., Gardezi, A. A., Weerasinghe, H., & Welhenge, A. (2021). Security and privacy issues in Medical Internet of Things: Overview, countermeasures, challenges and future directions. *Sustainability*, 13(21), 11645. <https://doi.org/10.3390/su132111645>
19. Adegoke, K., Adegoke, A., Dawodu, D., Adekoya, A., Bayowa, A., Kayode, T., & Singh, M. (2025). Interoperability as a Catalyst for digital health and therapeutics: A Scoping Review of Emerging Technologies and Standards (2015–2025). *International Journal of Environmental Research and Public Health*, 22(10), 1535. <https://doi.org/10.3390/ijerph22101535>
20. Wandwi, G. (2025). Privacy-Preserving health data transmission in IoT-Enabled mobile health systems. *Journal of Computer Allied Intelligence (JCAI)*, 3(4), 1–11. <https://doi.org/10.69996/jcai.2025018>
21. Naresh, V. S., Pericherla, S. S., Murty, P. S. R., & Reddi, S. (2020). Internet of Things in healthcare: architecture, applications, challenges, and solutions. *Computer Systems Science and Engineering*, 35(6), 411–421. <https://doi.org/10.32604/csse.2020.35.411>
22. Rubí, J. N. S., & De Lira Gondim, P. R. (2020). Interoperable Internet of Medical Things platform for e-Health applications. *International Journal of Distributed Sensor Networks*, 16(1), 155014771988959. <https://doi.org/10.1177/1550147719889591>
23. Padmaja, T., & Chandar, M. (2025). A comprehensive survey on lightweight cryptography algorithms to enhance quality of service in medical internet of things. *International Journal of Safety and Security Engineering*, 15(11), 2403–2417. <https://doi.org/10.18280/ijssse.151120>
24. Refaee, E., Parveen, S., Begum, K. M. J., Parveen, F., Raja, M. C., Gupta, S. K., & Krishnan, S. (2022). Secure and scalable healthcare data transmission in IoT based on optimized routing protocols for mobile computing applications. *Wireless Communications and Mobile Computing*, 2022(1). <https://doi.org/10.1155/2022/5665408>