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Research Article

WEARABLE IOT SYSTEMS IN HEALTHCARE FOR GERIATRIC PATIENTS – SYSTEMATIC REVIEW

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The authors declare that they have no competing interests.
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Abstract
The rapid increase in the global elderly population has raised the need for innovative, scalable, and patient-focused healthcare solutions. In response, wearable IoT (Internet of Things) technologies have become a key approach for continuous health monitoring, early detection of diseases, and personalized care for seniors. This systematic review examines recent progress in wearable IoT systems tailored for geriatric healthcare, focusing on their technological development, clinical significance, and real-world challenges to implementation. A thorough review of multidisciplinary literature from 2013 to early 2024 was carried out, including studies from healthcare, biomedical engineering, computer science, and public health. The review sorts wearable devices by sensor types, design forms, and communication methods, and assesses their applications in major areas like managing chronic diseases, fall detection and prevention, cardiovascular and metabolic monitoring, mobility evaluation, and cognitive health monitoring. It summarizes evidence on clinical benefits, usability, accuracy, and patient compliance, noting both advantages and current limitations. The review also investigates

factors affecting adoption, such as usability, cost, digital literacy, and caregiver support, as well as obstacles like data privacy concerns, limited interoperability, energy use, and regulatory issues. Based on these findings, it offers specific recommendations for future research, user-focused design, standardization, and policy development to support the sustainable integration of wearable IoT devices into geriatric healthcare systems.

Keywords: Wearable Internet of Things (IoT); Geriatric Healthcare; Remote Health Monitoring; Elderly Care Technologies; Smart Wearable Devices; Chronic Disease Management; Fall Detection; Ambient Assisted Living; Usability and Adoption; Data Privacy and Interoperability

Introduction

The continuous demographic shift toward aging societies is intensifying demands on healthcare infrastructure and resources. Older adults face disproportionate risks of chronic disease, acute medical events (e.g., falls, cardiac episodes), and social isolation, underscoring the necessity of preventive and individualized monitoring strategies. Wearable IoT systems—comprising miniaturized sensor networks, wireless communication modules, and backend analytics platforms—have emerged as key enablers for remote, non-invasive, and real-time health surveillance tailored to geriatric needs [1][2][3][4].

This review systematically analyzes the latest progress in wearable IoT systems for care of the elderly, synthesizing evidence on device typologies, clinical utilities, integration with telemedicine, and unresolved technical-social issues, aiming to inform researchers, practitioners, and policymakers engaged in digital health for aging populations.

Methods

2.1 Search Strategy

Comprehensive searches were executed in PubMed, Scopus, IEEE Xplore, ScienceDirect, and associated biomedical engineering databases, covering literature published from January 2013 to March 2024. The search incorporated keywords and controlled vocabulary terms: (“wearable” OR “smartwatch” OR “sensor” OR “smart garment” OR “patch” OR “IoT”) AND (“healthcare” OR “remote monitoring” OR “chronic disease” OR “geriatric” OR “elderly”).

2.2 Inclusion and Exclusion Criteria

Studies eligible for inclusion met the criteria:

- Focus on wearable IoT systems designed or evaluated for elderly or geriatric populations.
- Empirical studies, technical validations, or review articles published in English.
- Studies evaluating device performance, user experience, security, or integration aspects.

Studies omitted were:

- Not exclusively focused on older adults.
- Devices lacking IoT (network connectivity) functionality.
- Conference abstracts, preprints, and non-peer-reviewed material.

2.3 Data Extraction and Quality Assessment

Two independent reviewers carried out document screening, with discrepancies resolved by a third reviewer. Parameters extracted included study design, device type, clinical application, population characteristics, outcome measures, usability/adoption barriers, security solutions, and interoperability strategies.

3. Results

3.1 Types of Wearable IoT Devices in Geriatric Healthcare

Sensor and Device Platforms

Recent advances enumerate a diverse arsenal of wearable IoT devices targeting geriatric populations—including smart watches, smart bands, flexible bio-patches, electronic insoles, chest-mounted ECG recorders, and garments incorporating strain and triboelectric nanogenerator (TENG) sensors [1][5][6][7][8]. Leading-edge devices leverage conformable, biocompatible materials and microfluidic technologies to enable simultaneous monitoring of physiological parameters (e.g., heart rate, respiration, body temperature, glucose or oxygen saturation) as well as movements for fall and gait assessment [5][6][9].

Soft, stretchable devices fabricated from nanomaterials and engineered textiles are highlighted for their comfort and continuous monitoring potential, which is a critical consideration for frail or mobility-impaired seniors [1][8][10].

Multimodal Sensing and Real-Time Analytics

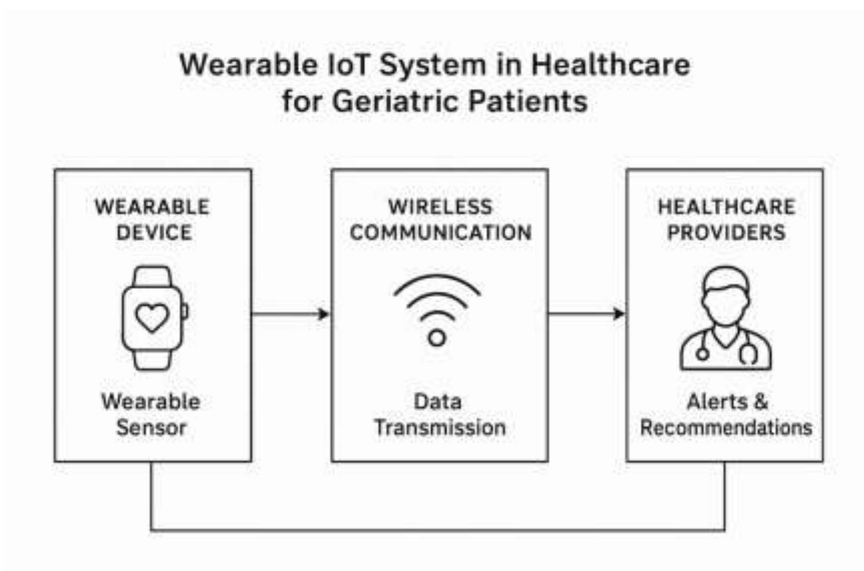
Modern systems are increasingly integrating multimodal sensing (electrical, chemical, biomechanical) with on-body edge computing and wireless networking (BLE, Wi-Fi, LTE) for seamless data streaming to mobile or cloud infrastructure [4][11][12][13]. Real-time health analytics, including AI-driven human activity recognition and anomaly detection algorithms, underpin early warning functions for acute events or deteriorations in chronic disease management [5][11][14].

Table 1. Types of Wearable IoT Devices in Geriatric Healthcare

Device Type	Sensor Modalities	Primary Parameters Monitored	Key Features	References
Smart watches &Smart bands	PPG, accelerometers, gyroscopes	Heart rate, physical activity, sleep, SpO_2	Compact, wrist-worn, multimodal sensing	[1][5][12][13]
Electronic Patches (ECG, Bio-patches)	ECG, biochemical sensors	Arrhythmia, respiration, sweat, glucose	Skin-adhered, flexible microfluidics	[6][9][15]
Smart Insoles	Pressure sensors, inertial sensors	Gait, foot pressure, balance	Gait and fall monitoring	[5][14]
Chest-worn ECG Recorders	ECG	Heart rhythm, cardiac monitoring	High-fidelity data capture	[1][12]
Garments with TENG Sensors	Strain, triboelectric sensors	Movement, posture, respiration	Textile-integrated, stretchable, energy harvesting	[5][8][10]

Entities & Flow

1. **Wearable Devices**
   - **Smartwatches & Smartbands** → *Heart rate, activity, sleep, SpO_2*
   - **Electronic Patches (ECG, Bio-patches)** → *Arrhythmia, respiration, sweat, glucose*
   - **Smart Insoles** → *Gait, foot pressure, balance*
   - **Chest-worn ECG Recorders** → *Cardiac rhythm data*
   - **Garments with TENG Sensors** → *Movement, posture, respiration*
2. **Data Acquisition Layer**
   - Collects raw signals from **sensors** (PPG, ECG, accelerometers, gyroscopes, biochemical sensors, etc.)
3. **Processing & Cloud Layer**
   - Pre-processing (filtering, noise reduction)
   - Feature extraction (heart rate, gait metrics, respiration pattern)
   - Cloud storage & analytics (AI/ML for anomaly detection, trend analysis)
4. **Healthcare Service System**
   - Patient monitoring dashboard
   - Alerts & emergency notifications
   - Long-term record storage
   - Doctor/clinician access



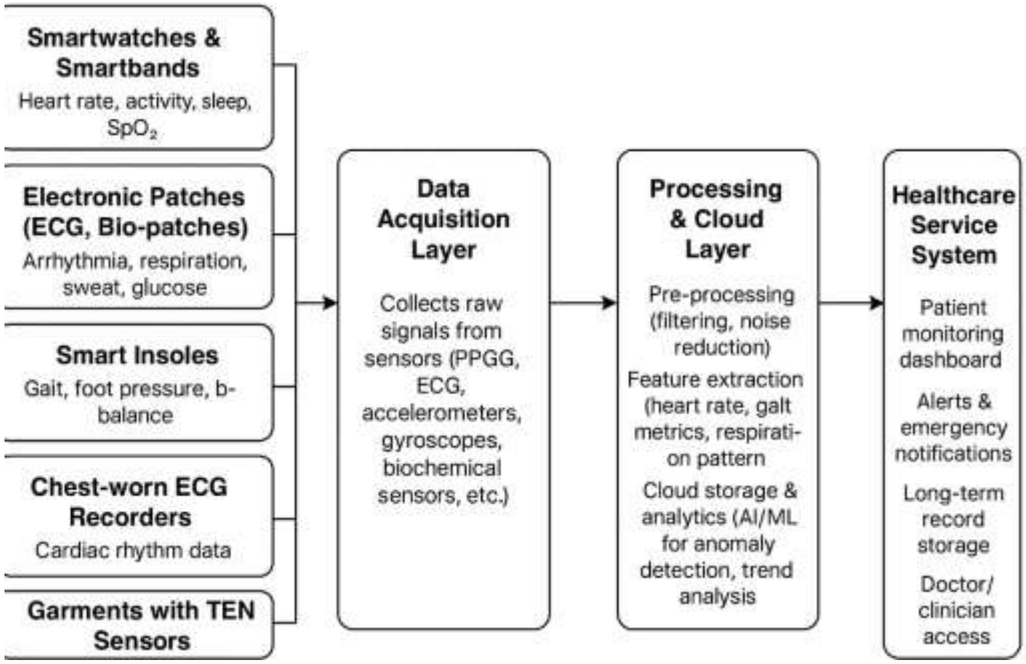


Figure 2: Entities & Flow

3.2 Clinical Applications in Geriatrics

Chronic Disease and Acute Event Monitoring

- **Cardiovascular Monitoring:** Pervasive use of ECG-enabled patches, PPG (photoplethysmography) sensors, and smartwatches has yielded tangible benefits in arrhythmia detection, heart failure risk assessment, and post-discharge monitoring for seniors [1][12][13].
- **Metabolic and Respiratory Disease:** Devices with integrated microfluidics and biochemical sensors facilitate non-invasive glucose, sweat, and respiratory analysis, enabling diabetes and pulmonary disease management outside clinical settings [1][6][9][15].
- **Neurodegenerative Disorders:** Wearable inertial sensors and motion trackers are applied in real-time gait, tremor, and movement disorders, notably improving the assessment and rehabilitation of patients with Parkinson's Disease and fall-prone elderly [5][14].

Mobility and Fall Detection/Prevention

Falls are a leading cause of morbidity and mortality in geriatric populations. Sensor-based fall detection systems—using accelerometers, gyroscopes, and advanced machine learning algorithms—have achieved high sensitivity and specificity, underpinning timely alerts and intervention [5][14]. Context-aware actuation with connected robots or gaming interfaces is enabling personalized rehabilitation and reducing risks [5][14].

Medication Adherence and Behavior Monitoring

Wearables with reminder and compliance-tracking functionalities (via app notifications, vibrations) improve medication intake regularity—critical for polypharmacy prevalent in older adults [1][4][16]. Behavior monitoring extends to sleep, activity, and mood assessment, with data relayed for telemedicine review or automated feedback [2][3].

Public Health and Infectious Disease Surveillance

The COVID-19 pandemic prompted rapid advances in systems for remote patient localization, symptom monitoring, and infection tracking, validating wearables as essential for outbreak containment and continuity of geriatric care [1][12][17].

Table 2. Clinical Applications of Wearable IoT Devices in Geriatrics

Application Domain	Use Cases	Device Types Involved	Outcomes /Impact	References
Cardiovascular Monitoring	Arrhythmia detection, heart failure assessment, post-discharge monitoring	Smartwatches, ECG patches	Early intervention, reduced readmissions	[1][12][13]
Metabolic & Respiratory	Diabetes and pulmonary disease management via biochemical monitoring	Bio-patches, microfluidic devices	Non-invasive monitoring, home-based care	[1][6][9][15]
Neurodegenerative Disorders	Tremor, gait analysis, Parkinson's rehab	Motion sensors, inertial devices	Functional assessment and real-time rehab support	[5][14]
Fall Detection/Prevention	Real-time fall alerts, gait monitoring, rehab using AI and robotics	Accelerometers, gyroscopes, wearable robots	Reduced fall-related morbidity, timely alert	[5][14]
Medication Adherence	Reminders and tracking for polypharmacy	Smartbands, mobile-connected wearables	Improved compliance, reduced medication	[1][4][16]

			errors	
Behavioral Monitoring	Sleep, activity, mood surveillance	Wristbands, smart rings, mobile apps	Continuous behavioral tracking, remote feedback	[2][3]
Infectious Disease Control	COVID-19 tracking, remote symptom monitoring, quarantine adherence	Location-enabled bands, vitals monitors	Public health surveillance, outbreak response	[1][12][17]

3.3 Effectiveness and Impact

Multiple studies confirm the clinical effectiveness of wearable IoT systems in:
- Reducing hospital admissions and emergency healthcare utilization by enabling early anomaly detection and remote triage [1][12][18].
- Empowering patient autonomy and quality of life by continuous, unobtrusive monitoring and timely feedback [1][2][3].
- Enhancing chronic disease management with objective, longitudinal data streams interpreted through machine learning for risk stratification [4][11][14][19].

Quantitatively, systems such as the “HOT Watch” delivered up to 2.47% higher measurement accuracy on vital signs, compared to conventional devices [13]. TENG-sensor based wearables achieved up to 98.4% identification accuracy for tailored rehabilitation plans [5].

Table 3. Effectiveness and Impact of Wearable IoT Devices

Metric/Outcome	Reported Results	Reference
Hospital Readmission Reduction	Reduced emergency visits via early alerts	[1][12][18]
Patient Autonomy & Quality of Life	Improved independence, reduced caregiver burden	[1][2][3]
Chronic Disease Management	Longitudinal trend analysis and personalized care	[4][11][14]
Vital Sign Accuracy – HOT Watch	Up to 2.47% higher accuracy vs. traditional monitors	[13]
Rehab Accuracy – TENG-based Wearables	Up to 98.4% accuracy in activity recognition	[5]

3.4 Determinants of Adoption in the Elderly

Despite technological promise, real-world adoption of these technologies in geriatric populations remains variable and, in some domains, disappointingly low (less than 20% in large US cohorts) [2]. Key determinants include:

- **Technology Self-Efficacy& Digital Literacy**: Older adults with higher confidence in using technology and prior exposure are significantly more likely to accept and adhere to wearable IoT devices [2][3][20].
- **Perceived Health Value & Social Norms**: Health consciousness and perceived utility, reinforced by encouragement from peers and medical providers, are robust predictors of device uptake [3][20].
- **Demographic and Socioeconomic Factors**: Education, gender, income, and cultural context mediate adoption rates; targeted intervention is needed to reduce digital divides [2][3].

Table 4. Determinants of Wearable IoT Adoption in the Elderly

Determinant	Description	Effect on Adoption	References
Technology Self-Efficacy	Confidence in handling devices	Higher self-efficacy → Higher adoption	[2][3][20]
Perceived Health Value	Belief in usefulness of the device	Strong positive predictor	[3][20]
Social Influence	Encouragement from healthcare providers or family	Facilitates uptake	[3]
Demographic/Socioeconomic Factors	Education, income, gender, digital literacy	Key barriers and stratifiers	[2][3]
Prior Experience with Technology	Familiarity with smartphones or apps	Strong influence on usability perception	[2][3]

3.5 Technical, Security, and Ethical Challenges

Data Security and Privacy

The ubiquity of wearable IoT devices amplifies risks of unauthorized data access, leakage, or tampering. End-to-end encryption, robust access control (e.g., blockchain-integrated attribute-based encryption [21]), and compliance with healthcare data regulations (HIPAA, GDPR) are vital needs [21][22][23]. Technological gaps persist in device authentication, secure wireless transfer, and transparent user consent management, particularly when cognitive decline is present [21][22].

Interoperability and Integration

Inconsistent data formats and proprietary platforms hinder seamless interoperability with electronic health records (EHRs), limiting clinical utility and data-driven insights [4][16][19]. Standards-based network architectures and unified protocols (e.g., HL7 FHIR, open APIs) are recommended but not yet universally implemented [4][20].

Usability and Long-Term Wearability

Device form factors must accommodate the sensory, motor, and cognitive impairments common in aging—requiring soft, skin-conforming materials, straightforward interfaces, minimal maintenance (battery life), and fail-safes against misplacement or misuse [7][8][10]. User-centered co-design approaches are essential to minimize abandonment [2][3][20].

Analytical Performance and Longitudinal Validation

Wearable sensors and associated algorithms must maintain measurement accuracy, signal stability, and resilience to environmental noise over extended periods [9][14][24]. There is a need for more robust, large-scale, and multi-center validation studies—particularly for molecular/biochemical monitoring and AI-driven event detection [6][11][14][19][24].

Table 5. Technical, Security, and Ethical Challenges in Wearable IoT Systems

Challenge Category	Issues Identified	Proposed Solutions/Needs	References
Data Security & Privacy	Unauthorized access, data tampering, and consent complexity	End-to-end encryption, blockchain, regulatory compliance (HIPAA/GDPR)	[21][22][23]
Interoperability & Integration	Proprietary formats, lack of EHR integration	Open APIs, HL7 FHIR, standardized protocols	[4][16][19][20]
Usability & Wearability	Difficult interfaces, discomfort, and maintenance needs	Soft materials, intuitive design, user-centered co-design	[2][3][7][8][10][20]

Analytical Performance	Signal noise, lack of long-term validation	Larger multi-center trials, robust testing of AI algorithms	[6][9][11][14][24]

4. Discussion

Wearable Internet of Things (IoT) systems are fundamentally transforming the landscape of geriatric healthcare by shifting the emphasis from traditional, reactive, hospital-based interventions to more proactive, personalized, and distributed models of care delivery [4][18]. These systems enable continuous physiological monitoring, early anomaly detection, real-time feedback, and tailored rehabilitation—capabilities that are particularly critical for older adults who often experience multiple comorbidities, functional decline, and barriers to frequent in-person clinical visits.

The integration of wearable IoT devices in geriatrics has demonstrated considerable potential across various clinical domains. Their utility extends from cardiovascular and metabolic monitoring to fall detection, neurodegenerative disorder assessment, medication adherence, and even public health responses such as infection tracking during the COVID-19 pandemic. Importantly, the real-time, high-frequency data captured by these systems allow for dynamic health profiling, risk stratification, and remote management of chronic diseases, thereby reducing the need for emergency interventions and hospital readmissions [1][12][18].

Despite these advancements, the translation of wearable IoT innovations into mainstream geriatric care remains hampered by several critical challenges. Adoption rates among older adults are frequently suboptimal, driven in part by low levels of digital literacy, cognitive or sensory impairments, and skepticism about the usefulness or trustworthiness of new technologies [2][3][20]. Usability issues such as complex interfaces, uncomfortable form factors, and device maintenance requirements (e.g., charging, data syncing) further impede long-term adherence [7][8][10]. Furthermore, privacy concerns, particularly around sensitive health data, deter usage, especially when consent processes are opaque or when devices lack robust encryption and access control mechanisms [21][22].

A pressing concern is the digital divide—the disparity in access and capability between technology-proficient and technology-marginalized older adults. Addressing this divide requires a multifaceted approach, including age-sensitive educational initiatives, simplified and inclusive design principles, and support systems that facilitate onboarding and sustained use [3][20]. Co-design approaches that actively involve older adults in the development and evaluation of wearable technologies can significantly improve alignment with user expectations and capacities, reducing abandonment rates.

From a systems perspective, the lack of interoperability between wearable devices and electronic health record (EHR) systems remains a substantial bottleneck. Most commercial wearables operate on proprietary platforms, limiting seamless data sharing and integration into clinical workflows [4][16][19]. The adoption of standards-based frameworks—such as HL7 FHIR and open APIs—is necessary to enable interoperability, enhance clinical decision-making, and support population-level analytics. Equally important is the development of secure, privacy-preserving architectures for data storage and transmission. Techniques such as blockchain-based encryption, differential privacy, and decentralized data governance are emerging as viable strategies to maintain trust while ensuring data fidelity [21][22][23].

Additionally, the analytical performance and clinical validation of wearable systems warrant further investigation. While pilot studies have demonstrated feasibility and diagnostic accuracy in controlled environments, large-scale, longitudinal, and multi-center trials are essential to establish the generalizability, cost-effectiveness, and clinical impact of these technologies—particularly in frail, multi-morbid, or socioeconomically disadvantaged populations [6][11][14][24].

In summary, while wearable IoT devices offer promising avenues for reimagining geriatric care, their widespread and equitable adoption depends on overcoming complex barriers at the user, system, and policy levels. Future research must prioritize interdisciplinary collaborations—bridging gerontology, engineering, informatics, and social sciences—to co-create scalable solutions. Furthermore, policy interventions that incentivize usability, data protection, and integration will be critical in ensuring that these technologies benefit the aging populations most in need.

5. Conclusion

Wearable IoT systems hold transformative potential for enhancing autonomy, safety, and chronic disease outcomes in geriatric populations. Their successful adoption necessitates not only ongoing technological refinement—including soft, high-precision, AI-enabled devices—but also resolution of social, ethical, and integration challenges unique to older adults. Multi-stakeholder collaboration spanning engineering, clinical science, policy, and end-users will be key to scaling safe, accessible, and person-centered wearable IoT healthcare for future aging societies.

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