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Article

A Bibliometric Analysis of Digital Twin Technology Applications in Home Health Monitoring

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Abstract: Objective: With population aging and the rising prevalence of chronic diseases and cognitive impairment, the demand for home health monitoring is increasing. This study systematically examines the current status and development trends of digital twin technology in home health monitoring. Methods: Relevant literature published between 2015 and 2025 was retrieved from the Web of Science Core Collection. Following a two-stage screening process, 201 articles were included. Biblioshiny and CiteSpace were employed to conduct bibliometric and visualization analyses, highlighting publication trends, collaboration networks, thematic evolution, and keyword clustering. Results: Findings indicate that research on digital twins in home health monitoring has expanded rapidly since 2016, with major emphases on physiological monitoring, functional assessment, and environmental health interaction. Frequently occurring keywords reflect technological foundations such as “artificial intelligence” and “machine learning”, as well as application hotspots including “rehabilitation” and “virtual reality.” China and the United States emerged as the most productive contributors. Conclusion: Digital twins are driving a paradigm shift in home health monitoring from passive response to proactive intervention. However, challenges remain regarding data standardization, model robustness, and privacy protection. Future work should foster interdisciplinary collaboration and explore integration with traditional Chinese medicine to further enhance the value of digital twins in home health management.

Keywords: digital twin; home health monitoring; bibliometrics; health management

1. Introduction

As global population aging accelerates and the prevalence of chronic diseases and cognitive impairment continues to rise, home health monitoring has become an increasingly critical component of modern health management systems. Digital Twin (DT) [1], a mathematical model equipped with dynamic updating mechanisms, generates virtual representations closely aligned with physical entity data. In recent years, DT has gained momentum in healthcare and shown considerable application potential [2]. By integrating real-time data, streamlining clinical workflows, and enabling predictive interventions, DT facilitates personalized health management and supports early risk screening, thus being recognized as a key element in home-based health management. Nevertheless, its practical applications still face challenges that require further reflection and improvement. Current review studies remain fragmented and lack systematic bibliometric analysis. To address this gap, this study employs bibliometric analysis tools to visualize literature retrieved from the Web of Science Core Collection, aiming to trace the evolution of research in this field, summarize the present state of applications, and further identify the major challenges that hinder its development.

2. Methods

2.1. Data Source and Search Strategy

This study drew upon the Web of Science Core Collection as the primary data source. A tailored search query was designed to systematically capture literature related to “digital twin” and “home health monitoring.” The specific query was:

TS = (“digital twin” OR “digital health twin” OR “virtual patient” OR “healthcare twin*”) AND TS = (“home care” OR “community care” OR “long-term care” OR “health monitoring” OR “patient monitoring” OR “health surveillance” OR “health tracking” OR “older adult*” OR “chronic disease” OR “nursing” OR “rehabilitation”)

Within the time frame of 2015–2025, a total of 774 records were retrieved, forming the foundation for subsequent analyses.

2.2. Inclusion and Exclusion Criteria

To ensure both scientific rigor and analytical focus, the 774 initially retrieved records underwent two stages of screening.

The first stage applied document type and language restrictions. Only “Article” and “Review Article” from the Web of Science Core Collection were retained, while retracted publications were excluded, resulting in 751 valid records.

The second stage focused on thematic relevance. Titles, abstracts, and keywords were manually reviewed by the research team. Studies were included if they involved core technologies such as Digital Twin, Virtual Patient, or Healthcare Twin and were highly relevant to home health monitoring, remote monitoring, or rehabilitation. Publications unrelated to human health (e.g., veterinary science, architecture) were excluded.

After these two stages, 201 publications were finalized as the analytical sample. The detailed screening procedure is illustrated in Figure 1.

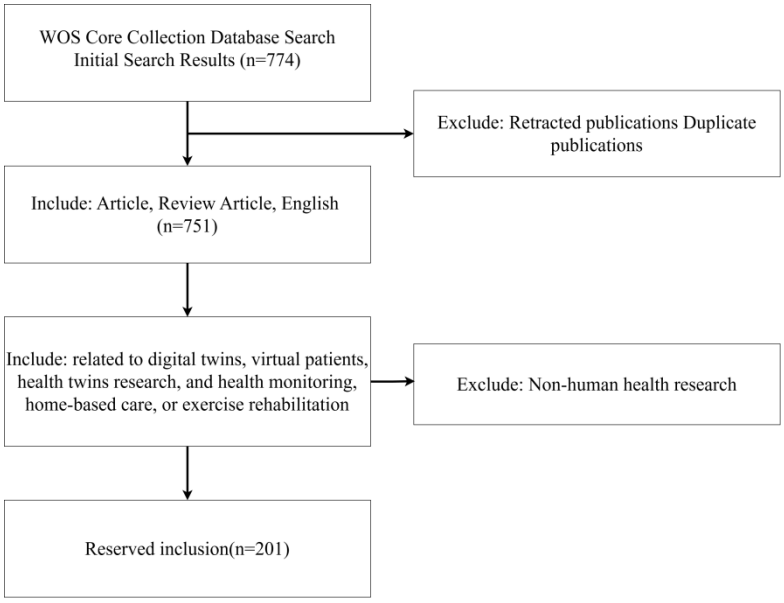

Figure 1. Literature screening flowchart.

2.3. Data Visualization and Analysis

To map the development and research hotspots of digital twin technology in home health monitoring, Bibliometrix [3] and CiteSpace [4] were applied to the 201 core publications. The analyses encompassed publication trends, collaboration networks, thematic clustering, and keyword evolution.

(1) Publication trends and journals: Annual publication outputs were quantified and plotted over time to identify shifts in research activity and growth points. Journal distribution was analyzed to highlight prolific outlets and disciplinary domains, reflecting the concentration and dissemination of research.

(2) Authors and collaboration: Authorand institution-level networks were constructed to examine contributions and collaboration patterns, identify leading scholars and institutions, and, at the national level, illustrate international cooperation structures and geopolitical characteristics.

(3) Thematic evolution: Research themes were identified through co-citation clustering and examined along temporal trajectories, revealing the emergence and migration of hotspots and the progression from theory to application.

(4) Keyword clustering: High-frequency keywords were extracted to construct co-occurrence networks. Combined with word clouds and clustering maps, these analyses highlighted thematic intersections and potential areas of growth.

In sum, this study provides a systematic portrayal of the research landscape and developmental trajectory in this domain, offering both theoretical insights and data support for future studies.

3. Results

3.1. Publication Trends and Journal Distribution

As shown in Figure 2, between 2015 and 2025, research on digital twin technology in home health monitoring has shown a clear upward trajectory, with publication output exhibiting a strong linear growth trend ($R^2 = 0.820$). No related articles were published in 2015, while 2016–2018 marked an early stage with only 5–8 papers annually. From 2019 onward, output began to rise modestly, and after 2020 the field entered a period of rapid expansion. The number of publications increased from 25 in 2020 to 72 in 2024, representing an impressive average annual growth rate of 58.18%. This trend underscores the growing academic interest driven by advances in digital twin technology and the increasing demand for home health monitoring.

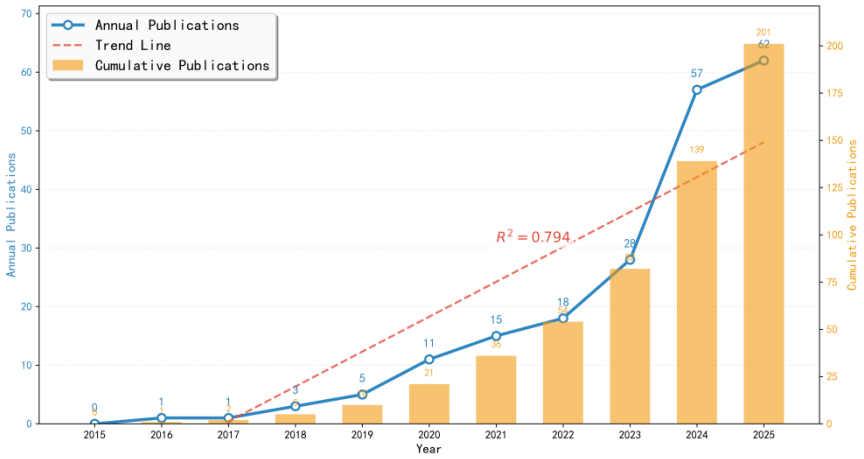

Figure 2. Annual publication trends.

As depicted in Figure 3, publications are concentrated in a small number of core journals. The top five, including IEEE ACCESS, SENSORS, and APPLIED SCIENCES-BASEL, account for 25.9% of the total output in the field, highlighting a concentration of scholarly contributions. These outlets focus on domains such as the Internet of Things, sensors, computer science, and interdisciplinary applications, further confirming the technical orientation of digital twin research.

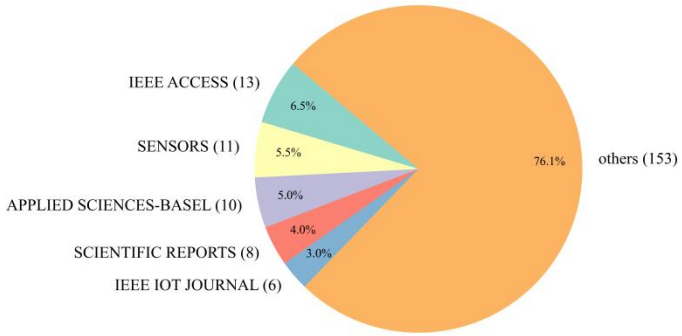

Figure 3. Journal distribution.

3.2. Authors and International Collaboration

As illustrated in Figure 4, the co-authorship network highlights the collaborative character of research in this domain. Of the 201 publications included, 198 were co-authored, yielding a collaboration rate of 98.5%. This high proportion underscores the importance of team science, particularly across disciplines and institutions, in advancing the field [5]. To better evaluate individual contributions, this study also employed the fractionalized score metric, which allocates credit proportionally among co-authors. Compared with simple publication counts, fractionalization offers a more accurate reflection of a researcher's influence within collaborative networks by mitigating inflation from multi-authorship [6].

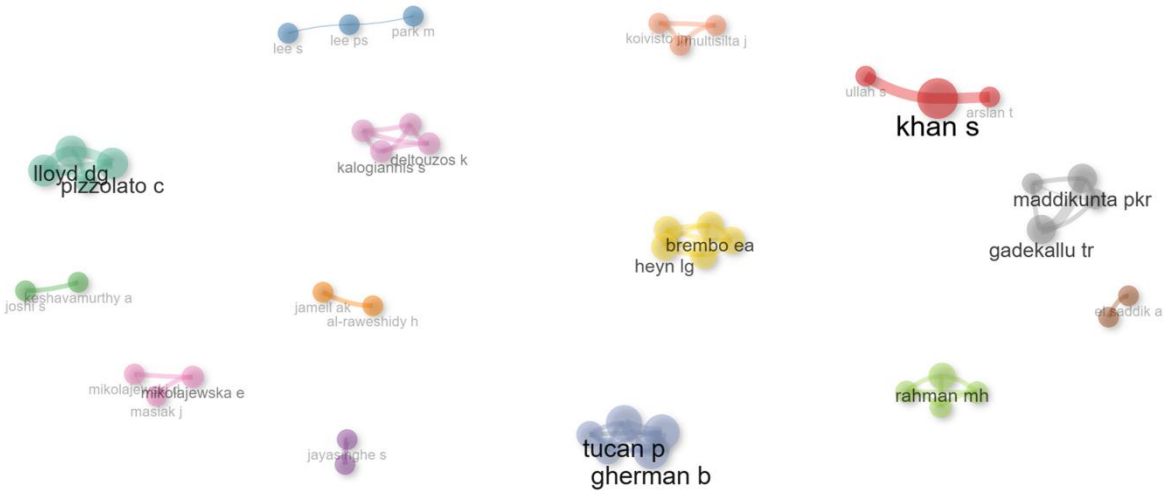

Figure 4. Co-authorship network.

Results based on this measure identify KHAN S (6 publications, score 1.40) as the most prolific and influential, followed by ARSLAN T (3, 0.70), GADEKALLU TR (3, 0.37), GHERMAN B (3, 0.42), and LLOYD DG (3, 0.29) (see Table 1). The leadership role of KHAN S is particularly evident, as indicated by both volume and contribution share.

Table 1. Top five authors by output and fractionalized score.

Author	Publications	Fractionalized Score
KHAN S	6 (2%)	1.40
ARSLAN T	3 (1%)	0.70
GADEKALLU TR	3 (1%)	0.37
GHERMAN B	3 (1%)	0.42
LLOYD DG	3 (1%)	0.29

Figure 5 illustrates a global collaboration network characterized by multinational and cross-regional linkages. China (120 publications) and the United States (109) lead in both research output and network centrality, forming the backbone of international collaboration. Australia (53), the United Kingdom (43), and India (39) follow closely, establishing stable research communities. Collectively, these countries exert strong academic influence in the study of digital twins and health monitoring, providing a solid foundation for advancing interdisciplinary and global research collaborations (as shown in Table 2).

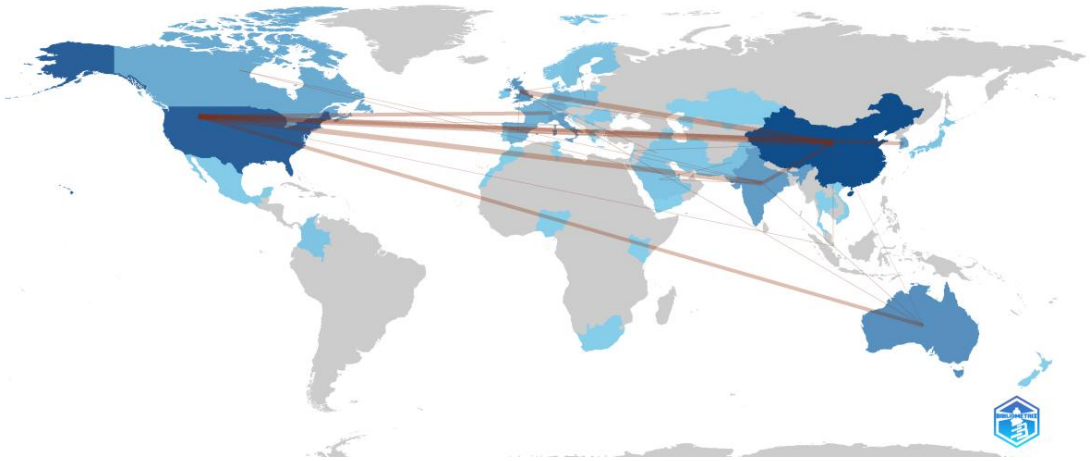

Figure 5. International collaboration network.

Table 2. Top five contributing countries.

Rank	Country	Publications
1	CHINA	120
2	USA	109
3	AUSTRALIA	53
4	UK	43
5	INDIA	39

3.3. Thematic Clustering and Research Evolution Analysis

As shown in Figure 6, the thematic clustering analysis revealed that research hotspots are primarily concentrated in several major directions, forming distinct clusters. Specifically, "#0 real-time systems" emphasize intelligent perception, data acquisition, and real-time feedback mechanisms that support continuous home health monitoring. "#1 digital health" focuses on integrating telemedicine and mobile platforms to enable personalized and data-driven healthcare. "#2 clinical competence" underscores the growing role of technology in clinical training and decision support. Meanwhile, emerging themes such as digital twins and virtual reality continue to gain attention, reflecting the field's evolution toward interdisciplinary integration and technology-driven development.

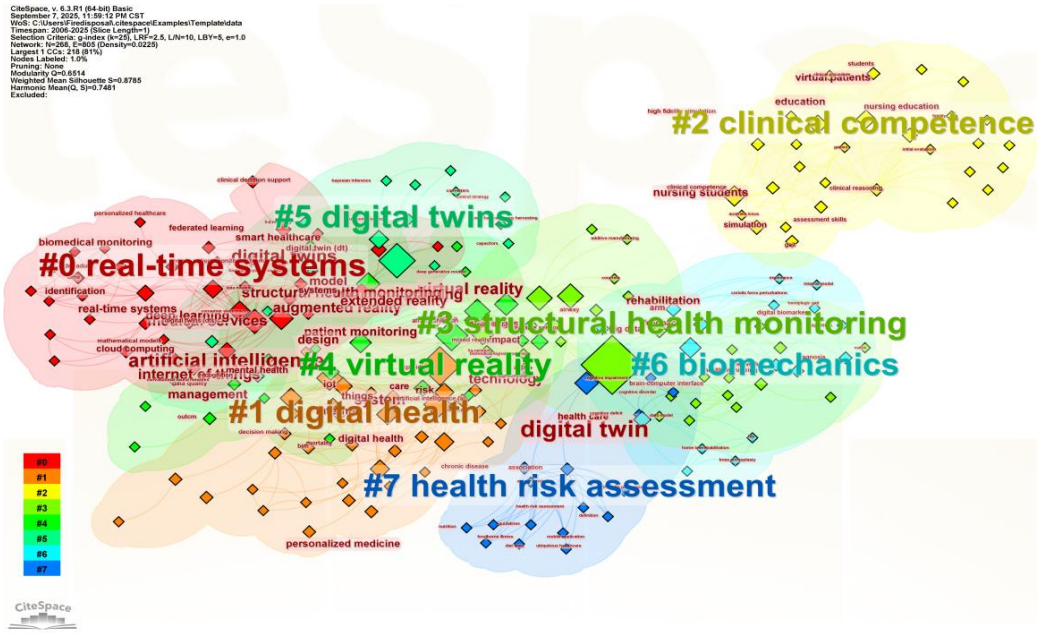

Figure 6. Thematic clustering analysis of the literature.

As illustrated in Figure 7, the thematic clusters reveal two distinct stages of evolution. From 2016 to 2020, research was mainly focused on the theoretical foundations of digital twin technology and its exploratory applications in industrial and engineering contexts, laying the groundwork for future healthcare use. From 2020 to 2025, the focus shifted markedly toward healthcare, particularly home health monitoring, where digital twin technology was increasingly integrated with health management and rehabilitation. In this period, studies began to explore innovative approaches such as the use of generative AI and edge computing, along with stronger interdisciplinary and cross-domain collaborations. Overall, the field demonstrates a trajectory from theoretical and technical exploration toward healthcare-centered, intelligent, and integrated applications.

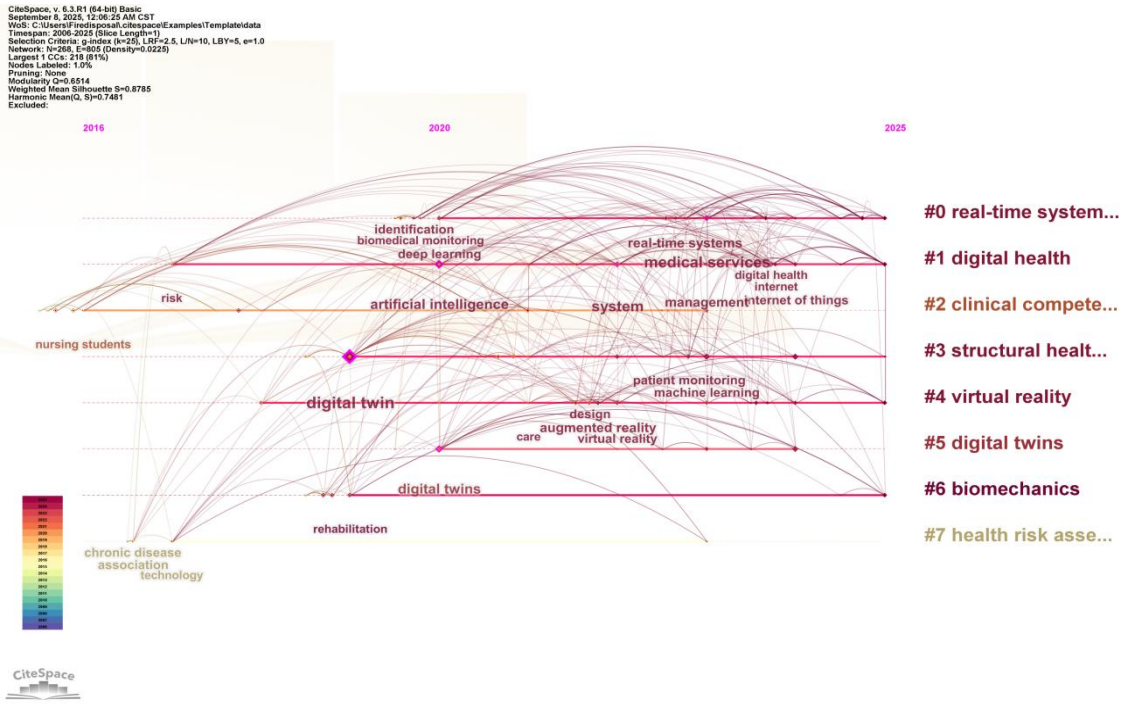

Figure 7. Temporal evolution of clusters.

3.4. High-Frequency Keyword Analysis

Figure 8 illustrates the overall distribution of keywords through a word cloud. The statistical results of high-frequency keywords indicate that research topics in this field are relatively concentrated. The top five keywords are:"digital twin" (88 occurrences), "artificial intelligence" (25), "rehabilitation" (20), and "virtual reality" (16). Among these, "digital twins" rank at the top, underscoring their significance as core research themes, especially in applications of home health monitoring. The frequent occurrence of "artificial intelligence" and "machine learning" highlights the critical role of intelligent algorithms in data processing and system optimization. Meanwhile, "rehabilitation" and "virtual reality" reflect the academic community's focus on rehabilitation interventions and interactive virtual applications. In summary, high-frequency keywords not only underscore the central role of digital twin technology in home health monitoring but also reveal the integration trend of intelligent algorithms with rehabilitation and virtual reality, providing direct insights into research hotspots in the field.

Figure 8. Word cloud of high-frequency keywords.

4. Discussion

4.1. Technological Development and Application Status

In recent years, the application of digital twin technology in home health monitoring has been steadily emerging, forming a pathway centered on sensor-based data collection, processing, virtual modeling, and intelligent analysis. IoT and wearable devices enable multi-source data acquisition, while AI and edge computing enhance modeling and prediction. For example, the framework proposed by JiaMeil et al. (2025) enables continuous monitoring of indicators such as heart rate, blood oxygen, and body temperature [7], offering a reference for standardized architectures. Current research primarily focuses on older adults and patients with chronic diseases, covering cardiovascular conditions, respiratory disorders, and cognitive decline. Zafar et al. (2024) noted that fall detection, sleep assessment, and rehabilitation training are common scenarios [8], suggesting a shift from broad exploration toward more specific populations and functions.

4.2. Major Challenges

Despite progress, the practical application of digital twin technology still faces challenges. First, the lack of data standards and interoperability restricts model generalizability across devices and platforms [9]. Second, model robustness and interpretability remain limited, as noise and missing data affect predictive accuracy and user trust [10]. In addition, home-based monitoring involves sensitive data, raising concerns about privacy and ethical governance [11]. These limitations indicate that digital twin technology is still at a pilot stage, requiring further development before large-scale deployment.

4.3. Research Hotspots

Recent studies reveal three main trends. First, technological integration is accelerating, with AI, edge computing, and generative models increasingly combined with digital twins. Chen et al. (2024) noted that generative AI can mitigate small-sample and sparse-data issues, improving the completeness and predictive performance of digital twins [12]. Second, privacy protection and trust mechanisms are gaining attention, with federated learning, differential privacy, and encryption techniques introduced into home health monitoring. The FedHome framework, integrating edge computing and federated learning, helps reduce data leakage risks [8]. Third, research is moving from laboratory simulations to real-world validations in households and communities, with pilot studies assessing user experience and system feasibility [13].

4.4. Future Prospects

Future research can expand in three directions. First, promoting unified data standards and governance frameworks will be essential to address data silos and interoperability issues while clarifying data ownership and usage norms [14]. Second, building closed-loop management models—covering monitoring, analysis, intervention, and feedback—can shift health management from passive recording to proactive intervention [10]. Third, strengthening interdisciplinary collaboration and policy support will be vital, with medicine, nursing, engineering, data science, and law working together, alongside input from users and caregivers to enhance usability and equity

[15]. Research may also extend to rehabilitation, mental health, virtual reality interaction, and environmental health [8,13], further broadening the application boundaries of digital twin technology.

5. Conclusions

This study systematically analyzed the research status and development trends of digital twin technology in home health monitoring through bibliometric methods. Existing findings indicate that this technology has gradually formed a technical pathway composed of sensor data collection, data fusion, and intelligent analysis, showing potential in elderly care and chronic disease management. However, insufficient data standardization, model robustness, and privacy protection remain critical bottlenecks hindering broader adoption.

Research hotspots suggest that digital twin technology is moving toward technological integration, multimodal intelligence, and real-world application validation, evolving from single-indicator monitoring to comprehensive health support. In the future, breakthroughs in standardization, closed-loop management, and interdisciplinary collaboration could drive home health monitoring from “passive response” to “proactive intervention,” with greater impact in rehabilitation, mental health, and environmental adaptation. Overall, digital twin technology holds promise as a key enabler for enhancing home health levels and improving quality of life.

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Author Contributions

Writing—original draft, H.S., Y.C., Z.Q., X.B., J.X. and S.C.; writing—review and editing, H.S., Y.C., Z.Q., X.B., J.X. and S.C. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement

Not applicable. The study did not involve humans or animals.

Informed Consent Statement

Not applicable. No human participants were involved in this research.

Data Availability Statement

Not applicable. No new data were created in this study.

Conflicts of Interest

The authors declare no conflict of interest.

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