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Research Status and Trend Analysis of Aging Friendly Bathroom Facilities Based on Citespace

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Abstract: Based on the CiteSpace visualization knowledge graph, this article conducts a visual analysis of the evolution of publication volume, distribution of national institutions, keyword clustering, and other related literature on aging friendly bathroom facilities in 502 Chinese and English articles, in order to analyze the research status, hotspots, and future research directions in this field. Through analysis, it was found that research in this field is showing an increasing trend, but there is still a need for relevant experts to actively engage in cross institutional, cross disciplinary, and cross national exchanges and cooperation. Emerging concepts such as smart homes and informatization have become new research hotspots. Moreover, research trend has shifted from macro level discussions to specific optimizations, and has shown characteristics of disciplinary integration and technology driven development. Overall, this study has identified the development direction for improving the level of technological application, emphasizing the importance of interdisciplinary and international cooperation, and providing certain guidance for the construction of a research system for aging friendly bathroom facilities.

Keywords: Age friendly; Bathroom facilities; CiteSpace; Visualization analysis; Design trends

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1. Introduction

According to population age structure data from the National Bureau of Statistics, the population aged 65 and above in China increased from 190.64 million at the end of 2020 to 220.23 million by the end of 2024, representing a growth rate of 15.52% [1]. With the accelerating aging process, improving living environments and sanitary facilities to meet the physiological and psychological needs of the elderly has become a widely discussed social concern.

Scholars have explored this topic and proposed several feasible approaches. Zhou applied the Kano-QFD design process to identify user needs and improve the design of integrated age-friendly shower systems [2]. Lü analyzed the bathing behaviors of older adults and, with the aid of simulation software, developed an ergonomically optimized age-friendly shower seat [3]. Wang, using a scenario perception method, examined elderly users' interactions with smart bathroom systems and proposed design strategies tailored to three distinct usage contexts [4]. However, several limitations can be observed in existing studies as follows:

(1) Research remains fragmented and lacks systematic disciplinary integration;
(2) Most studies focus on physical space and hardware renovation, while emerging themes such as user experience and technological integration receive limited attention;
(3) Discrepancies exist between domestic and international research frontiers, with insufficient comparative and trend analyses.

Therefore, a systematic review and trend analysis of research on age-friendly bathroom facilities are necessary to provide theoretical support and guidance for future studies.

2. Data sources and research methods

2.1. Data sources

To comprehensively reflect the research status and development trends in this field, this study retrieved data from two major databases: Chinese CNKI and international Web of Science (WOS).

The search terms used in CNKI were: "bathroom products + bathroom space + bathroom facilities + shower room + restroom + bathing room" AND "age-friendly + aging renovation + aging design + aging facilities + aging research."

For the WOS database, the keywords included: "bathroom OR toilet OR restroom OR shower room OR sanitary ware OR sanitary facilities" AND "age-friendly OR aging in place OR aging-friendly design OR elderly OR older adults OR universal design OR assistive facility OR barrier-free design."

No disciplinary restrictions were applied. The search period spanned from August 1, 2015, to August 1, 2025. After removing duplicates, news articles, and non-academic results, a total of 407 Chinese and 95 English documents were retained for analysis.

2.2. Research methods

Given the large volume of literature, the extended time span, and the inclusion of both Chinese and English databases, traditional literature review methods may result in omissions and biases, making it difficult to objectively and comprehensively represent research trends. In contrast, CiteSpace, a bibliometric and visual knowledge mapping tool, effectively reveals patterns of academic development, interdisciplinary connections, research hotspots, and emerging trends over time [5]. Therefore, this study employed CiteSpace to visualize and analyze publication volume, disciplinary distribution, and keyword co-occurrence in both Chinese and English datasets, aiming to summarize domestic and international research trends, identify current hotspots, and explore potential future directions in the field.

3. Analysis of domestic and international research status

3.1. Analysis of publication volume and research stages

Publication volume is an important indicator for assessing the development dynamics and research intensity of a given field. By analyzing the number of related publications in Chinese and English databases from 2015 to 2025, the developmental trajectory of aging-friendly bathroom facilities research can be clearly illustrated. Meanwhile, keyword burst analysis helps reveal the key research focuses and thematic transitions at different stages. Hence, combining these two methods provides a more comprehensive picture of the overall evolution of this research domain.

As shown in **Figure 1**, keywords such as "Affordable Housing," "Elderly Care Architecture," and "Spatial Design" appeared intensively in Chinese literature between 2016 and 2017, indicating that early domestic studies

focused on the aging adaptation of housing and spatial design. In contrast, terms like "Residential Space" and "Old Community" began to emerge after 2023, reflecting a gradual shift toward renovation of existing housing and optimization of age-friendly community environments. In the English-language literature, the keyword "Older People" appeared relatively early (around 2015), indicating an early international focus on aging populations. In contrast, the term "Aging in Place" did not emerge until after 2022, reflecting a growing recent emphasis on enabling older adults to remain in their homes and communities.

In terms of both the number and timing of keyword bursts, the years 2019–2020 represent a period of concentrated growth. During this stage, several emerging themes, such as "Integration of Medical Care and Nursing," "Architectural Design," and "Living Environment", began to surface in the Chinese literature. In the meantime, the English corpus exhibited bursts in keywords like "Activity" and "Recognition," suggesting that domestic and international research simultaneously entered a phase of rapid thematic expansion. Regarding keyword burst strength, "Affordable Housing" (Strength = 4.08) and "Elderly Care Architecture" (Strength = 4.17) ranked highest in Chinese studies, indicating that housing security and elderly facility construction were the central topics domestically. Although the overall strength of English keywords was slightly lower, "Accidental Falls" (Strength = 1.89) and "Activity Recognition" (Strength = 1.47) still showed high intensity, suggesting that foreign scholars tended to focus more on health risks and behavioral analysis.

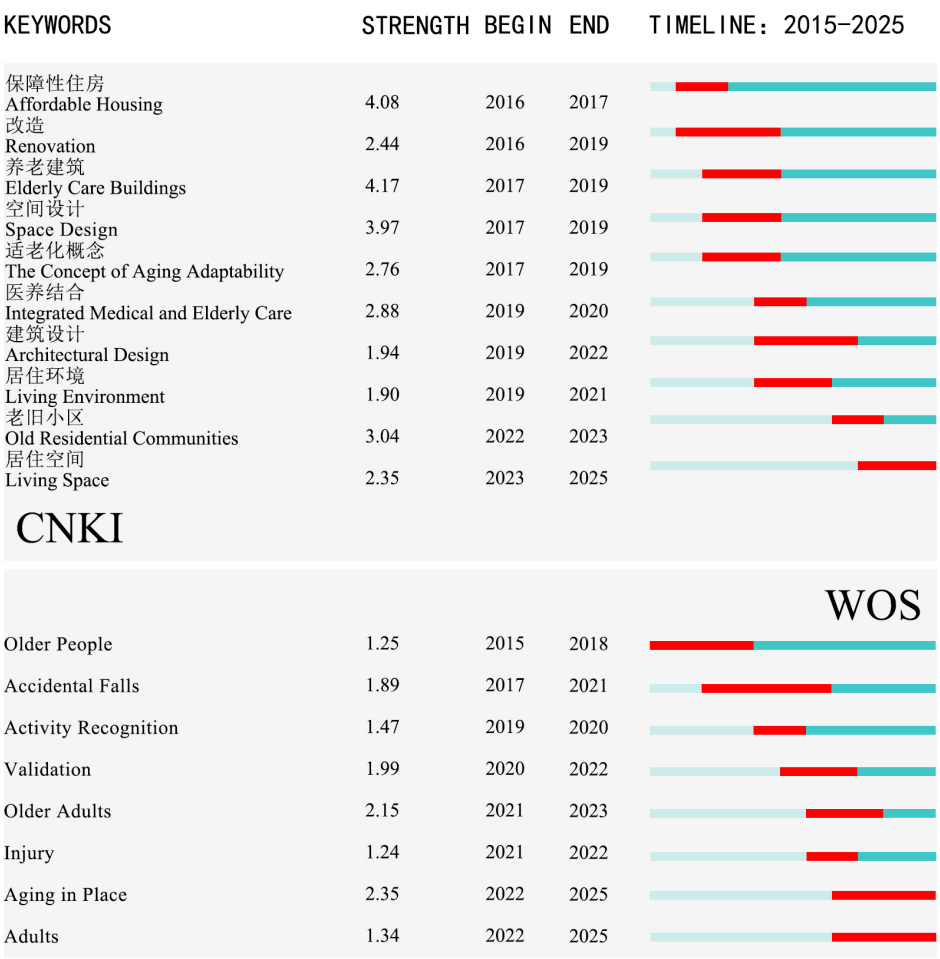

Figure 1. Keyword burst maps of Chinese and English literature.

Based on the above analysis and **Figure 2**, research in this field over the past decade can be divided into three stages:

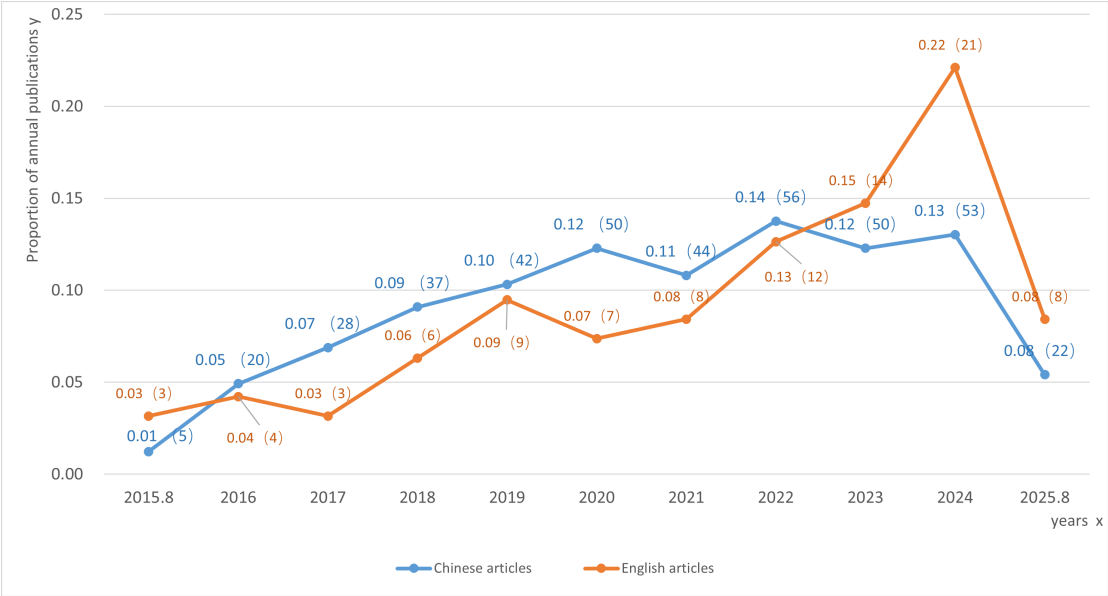

Figure 2. Annual publication trends in Chinese and English literature.

3.1.1. Stage I: Initial exploration period (2015–2018)

During this period, the number of Chinese and English publications remained relatively low but showed a gradual upward trend. Research mainly focused on macro-level topics such as "Affordable Housing" and "Elderly Care Architecture," reflecting scholars' preliminary attention to the issues arising from population aging. For instance, Gao analyzed the physiological and psychological characteristics of older adults and summarized the housing layout requirements of low- and middle-income groups, exploring the spatial characteristics of aging-friendly affordable housing to provide more comfortable living environments for elderly residents [6]. Overall, research at this stage remained in the theoretical exploration and problem-identification phase.

3.1.2. Stage II: Rapid growth period (2019–2021)

During this period, both Chinese and English publication volumes increased steadily. Chinese research began focusing on systematic issues such as "Spatial Design," "Elderly Architecture," and the "Concept of Aging Adaptation." For example, Miao proposed design solutions for aging-friendly bathing facilities to improve the bathing experience and psychological well-being of semi-dependent and dependent elderly individuals [7]. In contrast, English studies centered around "Accidental Falls" and "Activities," such as the work by Gefenaite *et al.*, who explored the relationship between residential accessibility and older adults' daily activities, demonstrating that improving living environments enhances independence and reduces risks like falls [8]. Unlike the spatial optimization focus of Chinese studies, international research leaned toward medical and public health perspectives.

3.1.3. Stage III: Diversified expansion period (2022–2025)

During this stage, research activity in both Chinese and English literature remained at a high level. Chinese publications peaked in 2022 (56 papers), while English publications peaked in 2024 (21 papers), reflecting concentrated global academic attention. Emerging Chinese keywords included "Old Communities" and "Residential

Space." For example, Hao, drawing on ergonomics and universal design principles, analyzed key parameters of barrier-free design in residential spaces across spatial layout, safety configuration, and technological application dimensions [9]. English literature highlighted keywords such as "Injury" and "Aging in Place." Murawski *et al.*, based on a survey of nearly 300 elderly participants, identified conflicts between home modification and safety-health concerns in aging-in-place practices and proposed mitigating approaches [10]. Collectively, research in this stage shifted from macro conceptualization to practical renovation, showing a trend toward depth and implementation.

3.2. Analysis of country and institutional distribution

The distribution of research institutions and countries reflects the landscape and collaborative structure of this research field: on one hand, it reveals the clustering characteristics of academic development. On the other hand, it highlights differences in policy orientation, social demand, and resource allocation. Based on CiteSpace, this study conducted a visual analysis of country distribution in foreign-language literature on aging-friendly bathroom facilities. In the analysis, the key indicator "Count" quantifies how often a term appears in the literature database, indicating its importance within the field, while "Centrality" represents the positional weight of the node within the network, where the higher the value, the greater its bridging role in connecting different nodes.

As shown in **Figure 3**, a total of 31 nodes (N = 31) and 19 links (E = 19) were generated. China (Count = 18; Centrality = 0.05) and the United States (Count = 17; Centrality = 0.07) occupy relatively dominant positions, while countries such as Australia (Count = 5; Centrality = 0.00) and Japan (Count = 10; Centrality = 0.00) have related research but lack numerical advantages and exhibit limited international collaboration. This pattern may be closely related to differences in the degree of population aging, policy incentives, lifestyle patterns, and research resource allocation.

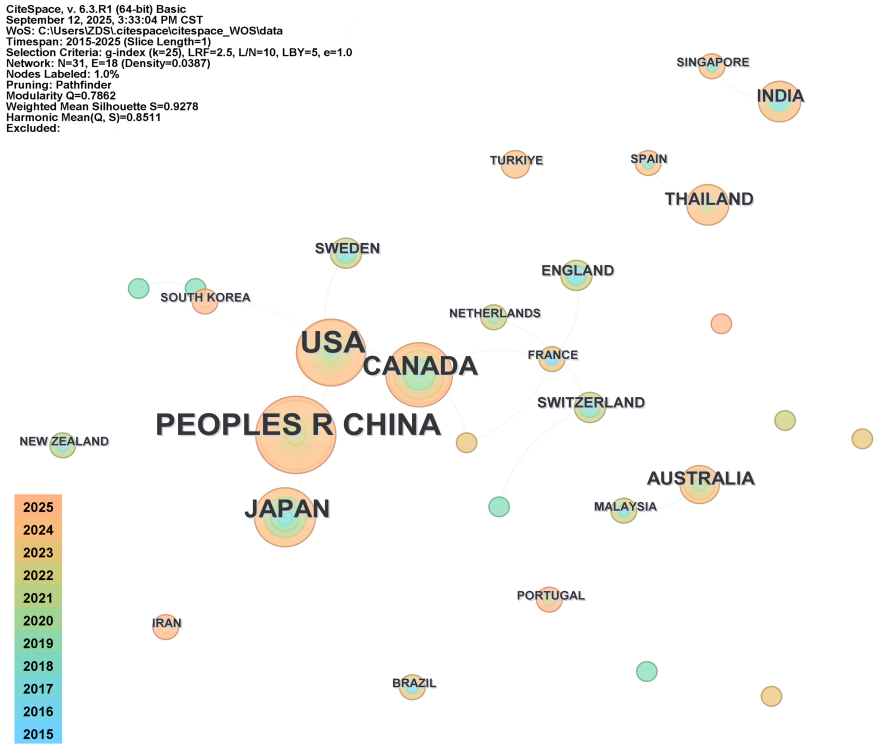

Figure 3. Country distribution of related research in foreign databases.

Regarding institutional distribution in China, **Figure 4** shows that 182 nodes (N = 182) and 27 links (E = 27) were generated, indicating relatively limited inter-institutional connections and a largely isolated structure. All institutions have a centrality value of zero (Centrality = 0), suggesting the absence of a core institution serving as a central hub in the current network. High-frequency nodes are mainly concentrated in architectural and design universities such as Xi'an University of Architecture and Technology (Count = 25), Shenyang Jianzhu University (Count = 11), and Southwest Jiaotong University (Count = 10).

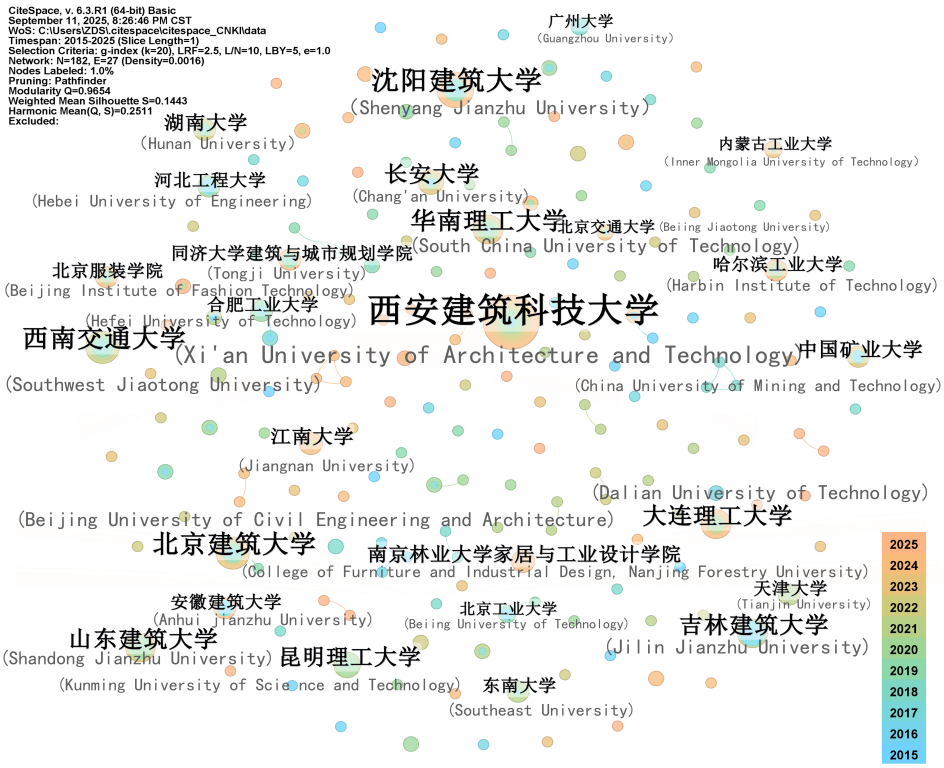

Figure 4. Institutional distribution of related research in Chinese databases.

Hence, the institutional distribution in China presents the following characteristics:

(1) Architecture and design universities are highly active, indicating a close connection between this research field and disciplines such as architecture, interior design, and product design;

(2) Several comprehensive universities and research institutes also exhibit high node weights, suggesting that the field is gradually moving toward interdisciplinary collaboration rather than remaining confined to a single discipline;

(3) Inter-institutional collaboration remains limited.

Although certain clustering effects are observed in the visual network, overall network density is low, with most research currently conducted by single institutions or small teams, lacking extensive and stable cross-institutional cooperation.

3.3. Keyword co-occurrence and cluster analysis

Keywords represent a high-level summary of a paper's core themes. The co-occurrence relationships among keywords reveal the internal connections between research objects, thereby uncovering the knowledge structure

and hotspot distribution of a scientific field. Cluster analysis, based on this, groups highly correlated keywords into the same category to further clarify the internal organization and evolution of research topics. In CiteSpace-generated maps, keyword nodes are displayed as ring diagrams, where node size corresponds to the Count value, the larger the node, the higher the frequency. The color transition from the inner to the outer ring indicates the temporal occurrence of research, while the ring thickness is proportional to the keyword frequency in that year [11].

3.3.1. Keyword co-occurrence analysis in Chinese and English literature

As shown in **Figure 5**, the Chinese keyword co-occurrence network generated 260 nodes (N = 260) and 344 links (E = 344), with a node density of 0.0102 (Density = 0.0102), indicating that domestic research in this field covers a broad range of topics and shows a trend toward diversification. Chinese keywords mainly cluster around "Aging-Friendly Design," "Home-Based Elderly Care," and "Bathroom Products." Among them, "Aging-Friendly Design" occupies the core position with 208 occurrences (Count = 208) and a centrality of 0.57 (Centrality = 0.57), closely linked with terms such as "Aging Renovation" (Count = 47; Centrality = 0.26), "Nursing Home" (Count = 5; Centrality = 0.44), and "Elderly People" (Count = 46; Centrality = 0.31). This reflects the practical significance of aging renovation research under the dual context of China's urbanization process and old community renewal policies. In addition, keywords such as "Spatial Design," "Residential Environment," "Bathroom," and "Toilet" further highlight the applied orientation of this research field, emphasizing efforts to enhance elderly safety and convenience through spatial optimization.

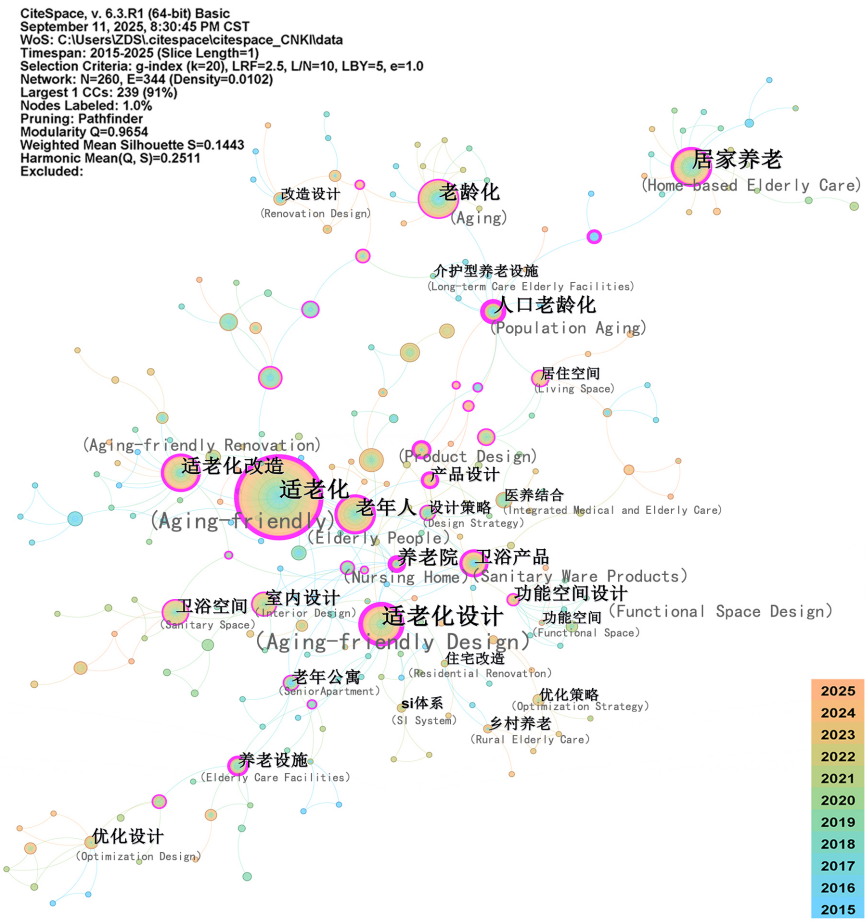

Figure 5. Keyword co-occurrence map of Chinese literature.

As shown in **Figure 6**, the English keyword co-occurrence network generated 234 nodes (N = 234) and 569 links (E = 569), with a node density of 0.0209 (Density = 0.0209). Compared with Chinese literature, the English network, though smaller in node quantity, shows a denser interconnection, indicating a more frequent and cohesive collaboration structure in international studies. The high-frequency keywords include "Activities of Daily Living," "Health," "Accidental Falls," and "Aging in Place," revealing that while both domestic and foreign research revolve around the central theme of "Aging-Friendly Design," their research paths differ: Chinese studies emphasize spatial and facility renovation, whereas international studies focus more on health risk management and elderly care models.

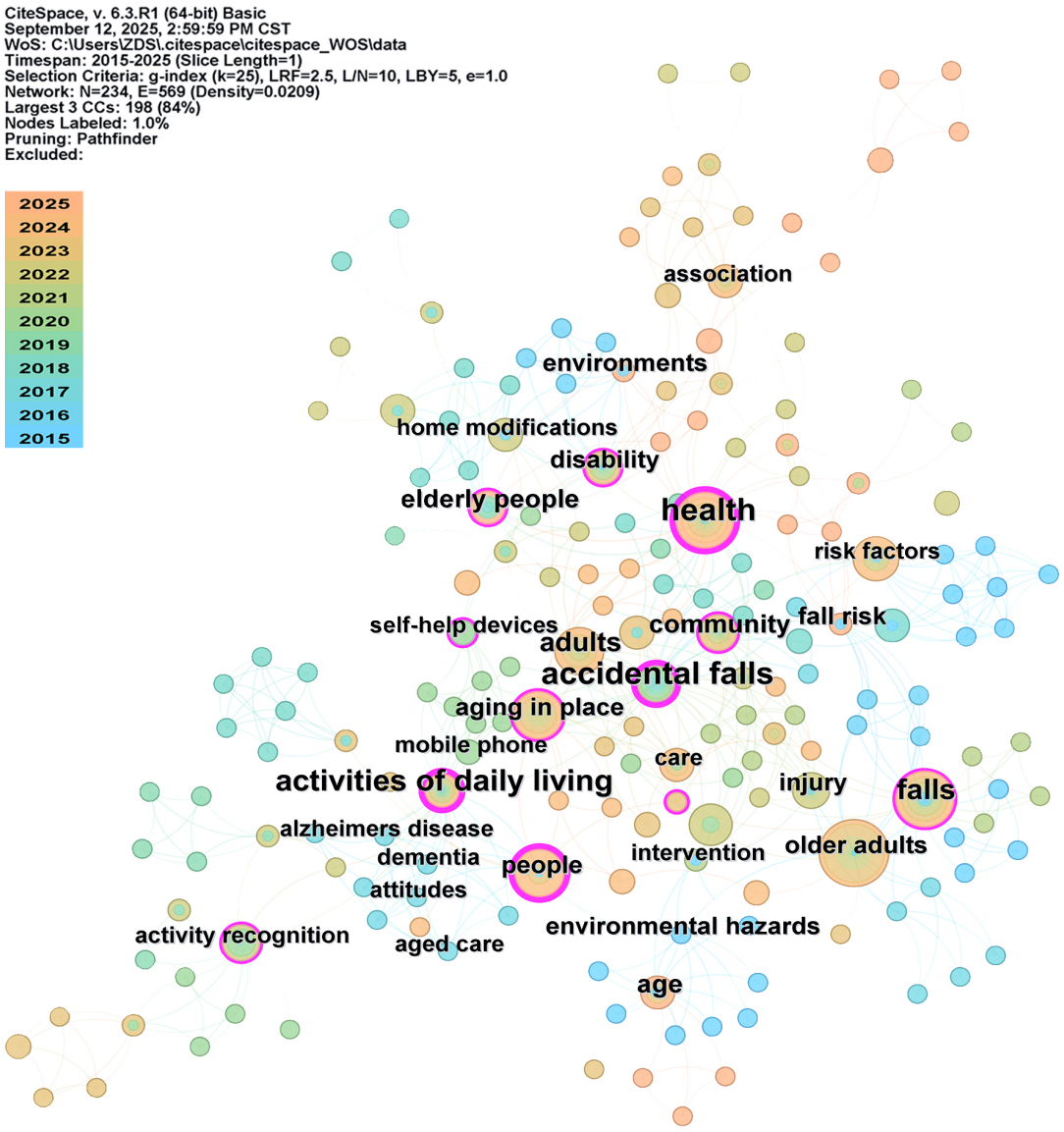

Figure 6. Keyword co-occurrence map of English literature.

3.3.2. Keyword cluster analysis in Chinese and English literature

The quality of clustering results is mainly evaluated using the Modularity (Q) and Mean Silhouette (S) values. When Q > 0.3, the clustering is significant; when S > 0.5, it is reasonable; and when S > 0.7, the results are

considered valid and reliable [12]. In this study, the Chinese keyword clustering yielded Q = 0.8459 and S = 0.9537, while the English clustering produced Q = 0.7862 and S = 0.9278, indicating both sets of results are significant and reliable (**Figure 7** and **Figure 8**).

According to the clustering results, keywords are divided into several relatively independent dimensions, indicating that this field has developed clear research orientations. The Chinese literature produced 15 clusters: #0 Interior Design, #1 Bathroom Products, #2 Home-Based Elderly Care, #3 Nursing Institutions, #4 Rural Housing, #5 Spatial Design, #6 AHP (Analytic Hierarchy Process), #7 Si System, #8 Housing, #9 Existing Housing, #10 Bathroom Space, #11 Rural Elderly Care, #12 Aging, #13 Optimization Design, and #14 Functional Space Design. The English literature produced 11 clusters: #0 Domains of Practice, #1 Older Adults, #2 Kansei Engineering, #3 Middle-Aged and Older Adults, #4 Behavioural Analysis, #5 Activities of Daily Living, #6 Accidental Falls, #7 Home Modifications, #8 Geriatric, #9 Force, and #10 Self-Assessment.

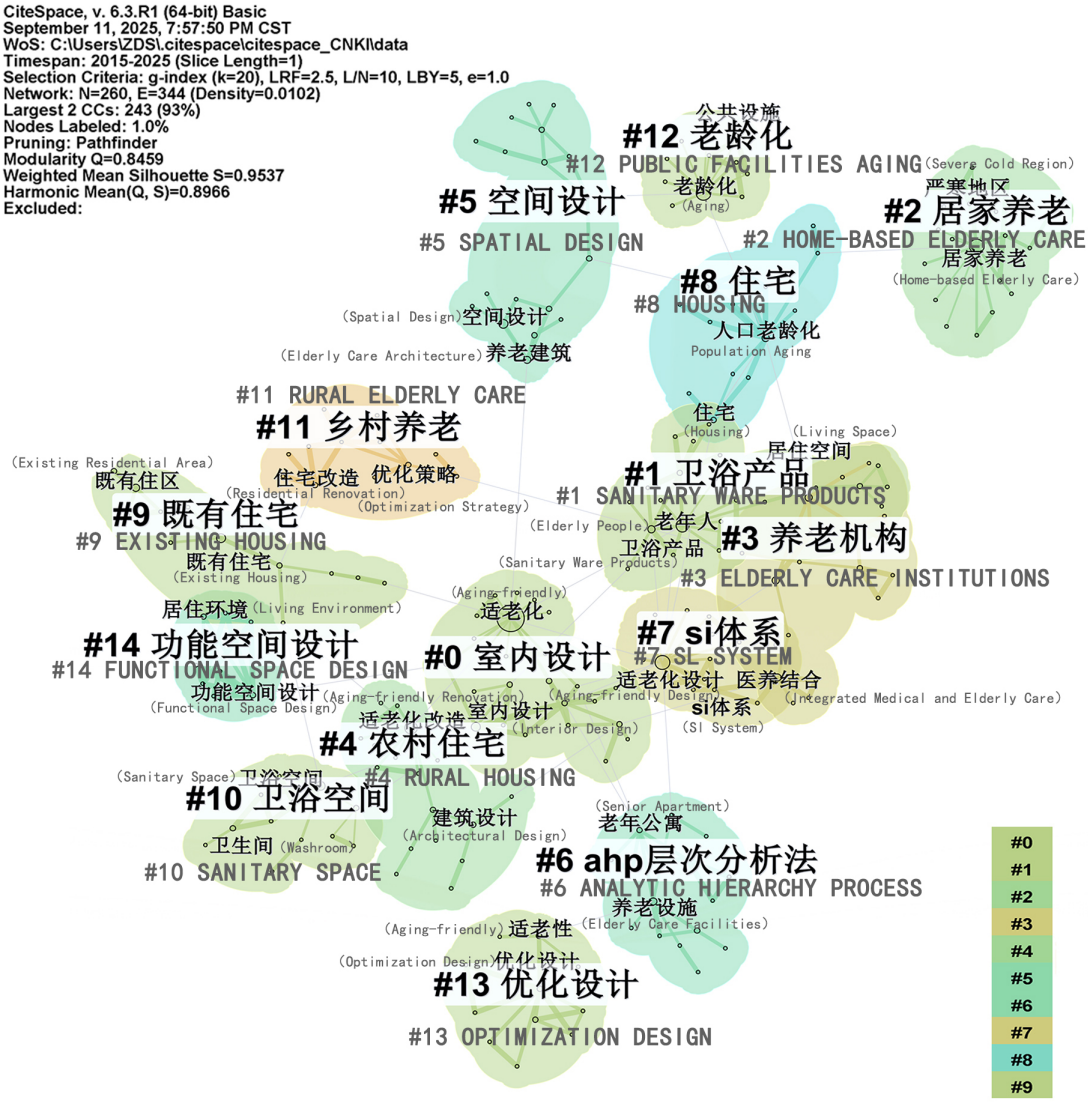

Figure 7. Keyword cluster map of Chinese literature.

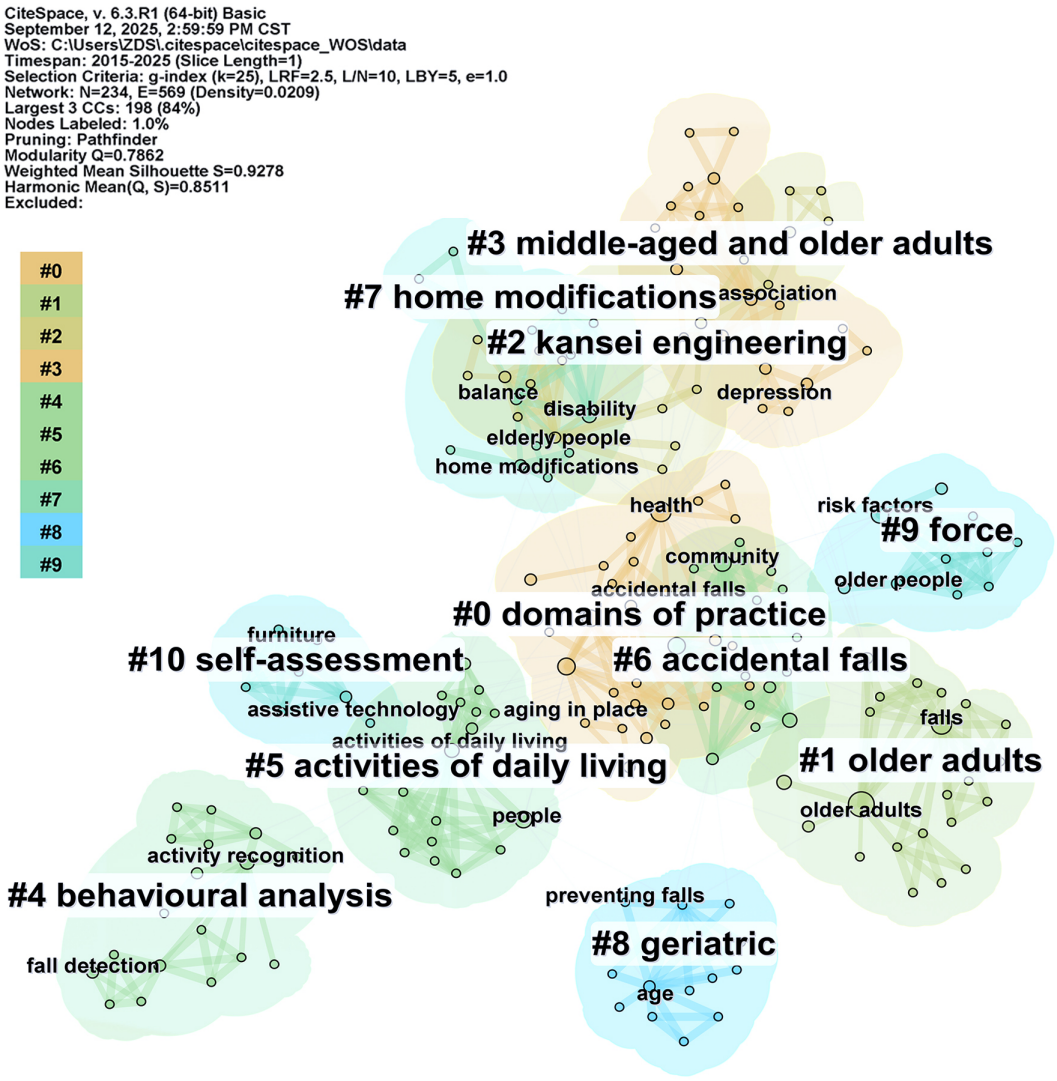

Figure 8. Keyword cluster map of English literature.

Since some cluster labels are semantically similar, these were merged to better highlight research hotspots. Combined with the preceding keyword analysis, the main knowledge domains of the Chinese and English literature on aging-friendly bathroom facilities were summarized [13]. As shown in **Table 1**, five major research dimensions were ultimately identified as outlined:

(1) Bathroom space and facility dimension;

(2) Health and risk prevention dimension;

(3) Residential environment and spatial dimension;

(4) Research methods and evaluation tools dimension;

(5) Elderly care model and service dimension.

Table 1. Main research dimensions of aging-friendly bathroom facilities

No	Research dimension	Dimension description	Main clustering labels
1	Bathroom space and facilities dimension	This dimension focuses on the functional configuration and product optimization within the bathroom space, serving as the fundamental direction of aging-friendly design research	#1 Bathroom Products (CNKI), #10 Bathroom Space (CNKI), #13 Optimization Design (CNKI), #9 Force (WOS)
2	Health and risk prevention dimension	This dimension addresses potential risks faced by the elderly during bathing activities, emphasizing the human–environment interaction relationship	#12 Aging (CNKI) , #5 Activities of Daily Living (WOS) , #6 Accidental Falls (WOS)
3	Living environment and spatial dimension	This dimension examines the relationship between the bathroom and the overall residential or community environment, reflecting a research trend from localized to systemic spatial perspectives	#0 Interior Design (CNKI) , #9 Existing Housing (CNKI) , #7 Home Modifications (WOS) , #0 Domains of Practice (WOS)
4	Elderly Care Model and Service Dimension	This dimension focuses on the alignment between facility configuration and service systems, reflecting the extension of design from the physical to virtual and service-oriented levels	#2 Aging in Place (CNKI) , #3 Nursing Institutions (CNKI) , #1 Older Adults (WOS), #8 Geriatric (WOS)
5	Research and evaluation methods dimension	This dimension reflects the methodological development trends in this field, providing quantitative support for aging-friendly design research	#6 Analytic Hierarchy Process (CNKI) , #2 Kansei Engineering (WOS) , #4 Behavioural Analysis (WOS)

4. Discussion

Through a comprehensive analysis of publication volume, keyword emergence, institutional and national distribution, as well as keyword co-occurrence and clustering, the development trend of research on aging-friendly bathroom facilities is clearly revealed. From the perspective of development stages, this field shows a gradual progression from initial exploration to deepening focus. Early studies mainly concentrated on macro-level issues such as “aging,” “spatial design,” and “housing renovation.” In the mid-stage, research began to focus on specific spaces and functions, emphasizing topics such as “bathroom,” “barrier-free design,” and “safety,” making the bathroom a central focus of aging-friendly renovation. In recent years, with the advancement of smart home systems and information technology, emerging keywords such as “living space,” “Aging in Place,” and “injury” indicate that research is increasingly moving toward interdisciplinary integration, focusing on enhancing the proactive safety capabilities of bathroom environments through technological and medical means.

The keyword co-occurrence and clustering analysis further reveal the structural framework of research in this field. On one hand, the clustering dimensions (1) and (2) identified earlier reflect themes such as “optimization of bathroom facilities,” “renovation of bathroom spaces,” and “daily activity studies,” indicating that researchers have closely linked elderly health risks with specific facility improvements, shifting their focus toward safety and user experience. For example, Lin studied elderly users’ daily activities through simulated bathroom scenarios and proposed three design strategies for aging-friendly bathroom products [14]. On top of that, Afacan adopted a user-centered approach, emphasizing the optimization of lighting, ventilation, and handrail systems in bathroom renovations, integrating comfort, accessibility, error prevention, and emergency management to enhance safety and user experience [15]. On the other hand, clustering dimensions (3) and (4) focus on macro-level issues such as “residential environment renovation,” “interior space optimization,” and “home and institutional care,” indicating that aging-friendly design extends beyond individual products or spaces to encompass the broader living environment and elderly care systems. For instance, Cheng discussed the principles of aging-friendly

interior design and the development of interior functional spaces that accommodate the physical and psychological needs of the elderly, emphasizing the improvement of living environments to better meet their daily needs [16]. In addition, the diverse research methods and evaluation tools encompassed in dimension (5) provide systematic and scientific support for the aforementioned research directions.

Based on the above analysis, several practical implications can be drawn:

(1) Product development should adhere to the principle of safety-first, prioritizing slip-resistant flooring, optimal handrail placement, and emergency assistance functions in bathroom spaces;
(2) Building and community renovation should prioritize home-based elderly care environments;
(3) At the macro level, industry standardization should be promoted, encouraging technological integration between advanced smart systems and traditional residential environments, while establishing reliable quantitative evaluation models.

5. Conclusion

Using the bibliometric tool CiteSpace, this paper conducted a visualization analysis of 502 Chinese and English publications from the CNKI and WOS databases, covering publication volume, institutional and national distribution, keyword co-occurrence, and clustering, thereby summarizing the current status, research hotspots, and future trends in aging-friendly bathroom facilities research both in China and abroad. The results indicate that the field demonstrates continuous growth and increasing depth, with research paths evolving from theoretical studies to practical applications, and from facility renovation to intelligent service systems. This study provides empirical data and theoretical support for future research on aging-friendly shower facilities, offers practical guidance for designers and related professionals, and validates the applicability and potential of the CiteSpace tool in this research domain.

Disclosure statement

The authors declare no conflict of interest.

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