Defining the Concepts of a Smart Nursing Home and Its Potential Technology Utilities That Integrate Medical Services and Are Acceptable to Stakeholders: a Scoping Review

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Abstract

Background and objectives:

Smart technology in nursing home settings has potential to elevate an operation that manages a larger number of elderly residents. However, the concepts, definitions and scopes of 'smartness', integrated medical services and stakeholders' acceptability of a smart nursing home are less clear. This scoping review aims to define a smart nursing home and examine the qualitative evidence on technological feasibility, integration of medical services and acceptability of the stakeholders.

Methods:

Comprehensive searches were conducted on stakeholders' websites and 11 electronic databases for existing concepts of a smart nursing home (Phase 1), and on what and how technologies and medical services were implemented in nursing home settings, as well as acceptability assessment by the stakeholders (Phase 2). The publication year was inclusive of January 1999 to September 2021. The language was limited to English and Chinese. Included articles must report nursing home settings and related to older adults ≥ 60 years old with or without medical demands but not bed-bound. New technology developments and system designs were measured by Technology Readiness Levels. The analysis was guided by Framework Method and *the smart technology adoption behaviours of elder consumers theoretical model*, and reported according to the PRISMA-ScR.

Results:

A total of 177 literature (13 website documents and 164 journal articles) were selected. Smart nursing homes are technology-assisted nursing homes that allow life enjoyment of its residents. They used IoT, computing technologies, cloud computing, big data and AI, information management systems, and digital health to integrate medical services in monitoring abnormal events, assisting daily living, teleconsultation, health information management, and improving interaction between providers and residents. Fifty-five percent of the new technologies were proven ready for use in nursing homes (level 6-7), and the remaining were proven of implementation feasibility (level 1-5). Providers with higher education, tech-savviness, fewer years at work, and older adults with more severe illnesses were more acceptable to smart technologies.

Conclusions:

Smart nursing homes with integrated medical services have great potential to improve the quality of care and ensure elderly residents' quality of life.

Introduction

Ageing population is associated with increased demand in healthcare and they would require a wide range of assistance in physical mobility and daily monitoring (1). However, smart technologies could help older adults extend their independent existence and well-being (2). In the earlier stage, a large number of sensors and actuators were used as a ubiquitous environment (u-healthcare) to monitor patients (3). The term 'smart' was initiated by IBM's (International Business Machines Corporation) concept of 'Smarter Planet' (4), and later, it was associated with a range of information technologies such as the Internet of Things (IoT), big data, cloud computing, and artificial intelligence (AI) in the medical field (5). The World Health Organisation (WHO) (2019) links smart healthcare with digital health including telemedicine and mobile health (6).

Smart technologies empower older adults to 'live in place' and meet their needs, so that they can lead active, fulfilling, and good life (7). Several studies have proved that smart technologies were feasibly applied in health monitoring, disease prediction, and detection of anomalous situations for home-based care residents (8, 9). However, admission to nursing homes is usually a major life event for most older adults due to the changes in health conditions with complex needs in healthcare (10). Using smart technology in nursing home settings could provide a more comfortable and safe environment for its residents (11). Nursing homes that integrate smart technologies could benefit caregivers by saving time and reducing unnecessary workload while providing efficient and effective care services for their residents, such as using wearable devices to collect biometric data (12). Moreover, it is possible to reduce healthcare costs by using more efficient healthcare resources (13).

Globally, the quality of care in most nursing homes is suboptimal, and the concerns are about the shortages of doctors and nurses, skills of nursing home staff, and safety of medical operation (14–16). To cope with the challenges related to ageing population, many nations are seeking solutions for alternative senior care and encouraging innovation in real-time monitoring of diseases, mobile phone-based healthcare assistance, electronic health record, and telemedicine at nursing homes (17). As one of the countries in the world facing the 'grey tsunami', the Chinese Ministry of Civil Affairs, a supervision department of nursing homes initiated a report to promote IoT-based projects for institutional senior care. These pilot projects include health monitoring, fall detection and location tracking, and any innovation on big data management or analysis would be supported financially (18). However, a clear concept of nursing homes and the 'smartness' of technology is yet to be defined (19, 20).

Accordingly, a scoping review is needed to provide a novel nursing home model which includes a definition of smart nursing homes, and the availability of smart technologies to meet the demands and aspirations of potential customers, such as older adults and their family members. Standardising the definition and scope of smart nursing home services would help future initiatives and the introduction of smart technologies in the nursing home settings. This would also allow evaluation and monitoring of smart nursing homes operation to have an evidence-based reference in

terms of scopes of nursing care services, information technologies, acceptability to the older adults, family members, nursing home staff, and nursing home stakeholders (21).

Theoretical model

The smart technology adoption behaviours of elder consumers theoretical model by Golant (2017) is adopted to guide this scoping review (Figure 1) (22). The model offers an adequate explanation of the technology appraisals of older adults with regard to adopting smart technologies. The coping process may come from the older adults' unmet needs, the user perspective of perceived efficaciousness, usability, and collateral damages until the stage of making a decision to adopt the 'new' solution. This coping process is also influenced by the internal information (potential users' past experiences) and external information such as the persuasiveness of friends, family members, and doctors pertaining to the technology. The coping process may be affected by other factors such as user sociodemographic characteristics. The non-senior stakeholders, for example, the healthcare professionals (HCPs) may have the same coping process when they consider the unmet needs of the older adults. This model is appropriate in formulating the review objectives.

Review objectives

This scoping review was conducted to systematically map the existing smart concepts and smart healthcare technologies within nursing home settings to examine the qualitative evidence on technological feasibility, integration of medical services, and acceptability of a smart nursing home by all stakeholders including the older adults aged ≥ 60 years old and their caregivers (23).

Method

Extended and comprehensive searches were conducted on stakeholder websites for existing concepts of a smart nursing home and criteria of its services (Phase 1). The search was continued on the 11 electronic databases for technologies and medical services that were implemented in nursing home settings, as well as the acceptability as reported by stakeholders including nursing home residents and healthcare professionals (Phase 2). Technology Readiness Level (TRL) was adopted to evaluate the feasibility of technologies and measure the maturity of a particular technology or the consistent comparison of maturity between different types of technology (24). The analysis was guided by the Framework Method (25) and the smart technology adoption behaviours of elder consumers theoretical model (22). Results were reported according to the PRISMA-ScR (26) (Related File 1).

Eligibility criteria

The eligibility criteria include: 1) concepts or definitions of a smart nursing home; 2) nursing home residents aged 60 years old or above with or without medical demands but not bed-bound; 3) assessment of any type of health information technologies, models that were considered 'smart' in nursing home settings; 4) perception and acceptability of smart nursing homes by the older adults and other stakeholders; 5) challenges and recommendations to implement information technologies that facilitate medical services in nursing homes. Other articles were irrelevant to the study objective and nursing homes, or the smart technologies in entertainment, environmental control, transportation, were excluded.

Information sources and search strategy

Following the plan of the published study protocol (20), an extended search on stakeholder websites for the statement of smart nursing homes was conducted on three popular search engines: 'Google', 'Yahoo' and 'Baidu (a Chinese engine)' using English and Chinese keywords 'nursing home', 'Yang Lao Yuan' (养老院), and 'retirement home' and followed by 'smart nursing home', 'concept of smart nursing home', 'definition of smart nursing home' and 'criteria of smart nursing home' or 'standard of smart nursing home' sequentially.

Additionally, the keywords: smart nursing home, smart health*(care), Internet of Things (IoT), digital health*, remote health*(care), telemedicine, mobile health*(care), mHealth (including telemedicine), eHealth, point-of-care, wireless sensor network (WSN), artificial intelligence (AI) and ubiquitous healthcare (u-healthcare) were used for searching the published articles on technological feasibility and user acceptance or acceptability in nursing homes on the English bibliographic databases (PubMed, IEEE Explore, CINAHL, Scopus, Cochrane Library, Health Systems Evidence, Social Systems Evidence, ProQuest Dissertations & Theses Global, Psychology and Behavioral Sciences Collection). The keywords applied on the selected Chinese bibliographic databases (China National Knowledge Infrastructure 'CNKI' and the Wanfang Data 'Wanfang') were the Chinese description of smart nursing homes, for example, 智护养老 (Zhi Neng Yang Lao Yuan), 智慧养老 (Zhi Hui nursing Yang Lao Yuan), and 颐康养老 (Yi Liao Kang Yang). The language was limited to English and Chinese. The publication year was limited to those published between January 1999 and May 2020 as the label 'smart dust' to wireless sensor networks was first given in 1999 (27). Additional File 1 provides the search strategy on databases. An updated search was conducted on the 11 bibliographic databases by applying the same strategy to identify the latest publication from May 2020 to September 2021. Due to the license from the university, the search on Scopus was updated to December 2019.

Selection of sources of evidence

A comprehensive screening of eligible articles was conducted by a reviewer (YYZ). All sources were imported into the Endnotes X9 library and the duplicates have been removed. Endnotes X9 library was shared with a second reviewer (NKD). Documents in the Chinese language were double

reviewed by another reviewer (JS). Eligible criteria were applied to both abstracts and full-texts. Quality appraisal of individual sources of evidence was not done because this scoping review was conducted to provide an overview of the existing evidence of smart nursing home concepts, technological feasibility, medical services integration, and acceptability of a smart nursing home regardless of methodological quality or risk of bias (26). In the selection process, any disagreements between two reviewers were addressed by consulting the third reviewer (FKR, SSG and BHC).

Data charting

The Framework Method was used to guide the process of data analysis by applying codes, categorising themes, and summarising the results (20). The data from stakeholder websites and electronic databases were categorised by type of technology related to 'smartness', the function of technology, direct user, integrated medical services, and stakeholder acceptability. The textual statements on the concept of smart nursing homes, integration of medical services, and acceptability of the stakeholders were extracted by three investigators (YYZ, NKD and JS). Preliminary codes and themes related to the research objectives were named after the most frequently recurring terms within the same clusters, and those names were given by the generalisability of textual data. Data extraction and translation from Chinese to English were also done (YYZ). The individual data extraction and analysis were subsequently discussed by all investigators (YYZ, FKR, SSG and BHC). The coding categories were defined and refined until the consensus was reached among at least three of the four investigators.

Results

A total of 177 literature (Figure 2 and Additional File 2) were selected for review comprising 13 documents from websites and 164 articles from the bibliographic databases.

Phase 1: Definition, concepts and criteria of a smart nursing home

Thirty documents and articles (Additional File 2) were selected from which information on the definition, concepts, and criteria of a smart nursing home was retrieved. Of these, 13 documents were selected from the stakeholder websites in Phase 1, and the other 17 articles were research papers searched in Phase 2. The sources of the 13 documents from stakeholder websites were government authorities (n=4), smart technology providers (n=4), home pages of nursing home (n=3), construction company of nursing home (n=1), and respective research institute (n=1).

The qualitative analysis generated 3 themes related to the concept (Table 1): 1) application of smart technologies, 2) technology-assisted nursing care, and 3) combination of smart home and hospital models. In addition, quality of care (QoC) defined by WHO (28) was adopted and applied to measure the criteria and outcome of smart nursing home services that are provided to its residents. In order to achieve better services, health care must be safe, effective, timely, efficient, equitable, and people-centered (28).

Based on the qualitative analysis, we defined a smart nursing home as a collective or individual senior care model that integrates tending of life routines and healthcare needs of its residents with information technologies or engineering that may provide continuous monitoring to its residents, connected communication within its care providers, and teleconsultation with external medical resources. Technology-assisted nursing care ensures life enjoyment in an affordable and safe environment, and immediate health attention with people-centered care that is effective, efficient, and evidence-based. Additional File 3 presents the quotations and the categories of the code.

Phase 2: Technological feasibility, integration of medical services and acceptability

A total of 164 articles from 28 countries and regions across four continents were eligible for data extraction. Two of the 164 articles including an editorial on bringing smart technologies into a nursing home (29) and one system design of engineering methodology (30) were only eligible to be included in Phase 1 for extracting the definition of smart nursing homes. There were 162 articles reviewed in Phase 2 (Table 2). Out of these, 50% (n=81) were studies on system designs, 7% (n=12) experimental, 23% (n=38) non-experimental, 8% (n=13) qualitative studies, 3% (n=4) mixed methods, 9% (n=14) non-research articles including literature reviews, perspective, and editorial. Fifty-seven percent (n=93) were journal articles, 31% (n=50) conference papers, 9% (n=15) student dissertations/theses and 3% (n=4) book chapters. Major resources were from China including Taiwan (n=41), and the USA (n=40).

Technologies related to 'smartness'

Out of 162 articles, 41% articles (n=66) were on IoT, 35% (n=57) on digital health, 12% (n=20) on information management system (IMS), 8% (n=13) on big data and AI, 3% (n=5) on computing technologies and 1% (n=1) on cloud computing. The technology smartness offers much more interaction between the nursing home resident and HCPs, enhances safety, and improves quality of care (11, 31).

Function of smart technologies in nursing home settings and direct users

Forty-seven percent of included articles (n=76) reported technologies on monitoring and notification of abnormal events such as health monitoring, fall detection, and location tracking, 35% of articles (n=57) on remote clinical services through digital health, 12% (n=20) on information management and decision making, 3% (n=5) on clinical data analysis by AI approach, and 3% (n=4) on daily living assistance. The direct users of

those smart technologies were nursing home residents (n=132) and HCPs (n=30), such as nursing home staff and health professionals in remote hospitals which provided health services for nursing homes. There was none related to family members as the direct users.

Monitoring and notification of abnormal events: Monitoring devices have been proven to ensure the safety of the nursing home residents in fall prevention (32–45), automatic monitoring of health conditions, and notification of emerging events such as heart attacks and fatal accidents (11, 12, 19, 31, 46–103). The vital sign of older adults could be collected and recorded by the wearable devices such as clothes and shoes on nursing home residents (35, 95). Sensors were installed in the mattresses and rooms to monitor the behaviours and sleeping quality of older adults, especially used for the residents with limited mobility (80, 90). Biosensors, ultrasonic sensors, infrared sensors, radio frequency identification (RFID), GPS were mainly used with IoT terminals (63, 68, 74, 77). Cameras, mobile devices, and personal computers were embedded with sensor networks to assist the real-time monitoring, and family members could also be given access to the real-time monitoring of their senior family members in the nursing homes (34). Such a solution improved care efficiency and decision-making from nursing home HCPs, especially in managing a high number of residents and older adults with cognitive disorders (85).

Remote clinical services through digital health: Digital health including telemedicine and mHealth has shown to benefit the older adults at the nursing homes in rural areas with good internet or communication coverage (104–133). During the COVID-19 pandemic, telemedicine was shown to reduce unnecessary hospitalisation (134, 135). Electronic stethoscopes, otoscopes, dermascopes, dental scopes, and electrocardiograms could also be implemented through the internet and live video, and the digital images of residents could be transmitted in real-time to hospital specialists (136). Telehealth and mHealth were widely applied in managing cognitive disorders (137–140), dermatologic conditions (141–143), cardiovascular diseases (107, 115, 144), diabetes mellitus (145), rehabilitation of disabilities (31, 146), dentistry (147) and ophthalmology (148) in distance. The portable X-ray machine attached with mobile devices were successfully conducted x-ray for nursing home residents to reduce unnecessary transmission to the hospitals, and the services were of comparable quality to hospital-based examinations (149–154). Telemedicine with designed software helped doctors to prescribe medicines remotely and avoid adverse drug events (155, 156).

Information management and decision making: There was a growing use of electronic documentation in many nursing homes requiring proper information management for patients' medical records, nursing projects management, care quality assessment, clinical task schedule, and medication records (157–161). The health information of nursing home residents was manually collected by nursing home staff or through technology-based devices such as mobile phones, tablets, personal computers, and sensors to input into the electronic medical records (EMR) systems (162, 163). The information management systems also improved clinical decision-making by sharing and tracking patients' medical records and enhanced HCPs' communication to reduce errors in clinical practices (163–176).

Clinical data analysis by AI: AI approach helped with health-related parameter analysis and big data management (177, 178) Using AI to analyse biometric data collected from older adults enabled the identification of potential relationships between parameters and frailty (179, 180). As an emerging technology, big data analytic, data mining, and classification using in nursing home management would transform the available data into structured knowledge, enhance data reliability, and enable accurate diagnosis such as detection of disuse syndrome (78).

Activities of daily living (ADLs) assistance: Based on the IoT and computing technologies, smart toolkits had been developed to assist older adults with chronic diseases in their activities of daily living for example smart pill-boxes with automagical medication reminders, recording, and pill-dispensing that assisted them in taking their daily medications that improved medication adherence (181–183). Humanoid robots were developed to monitor nursing home residents' activities and ensure their safety in certain areas (184).

Technology Readiness Level (TRL) measurement

TRL classifies 9 levels of developmental stages from basic principles and technology concepts formulated to the actual system completed and proved (185). Of the 81 articles on system designs, three (Chen et al., 2021; Danielsen, 2016; Montanini et al., 2017) were not able to be evaluated by TRLs because these were only abstracts with inadequate information, 6.5% (n=5) were judged to be at level 1, 15% (n=12) at level 2, 14% (n=11) at level 3, 6.5% (n=5) at level 4, 4% (n=3) at level 5, 19% (n=15) at level 6, and 35% (n=27) at level 7 (Table 3). Among newly developed technologies, 82% (n=64) were applications used for health and abnormal events monitoring, fall detection, and notification systems. The remaining 18% (n=14) were related to activities of daily living assistance, information management, big data analysis, and remote clinical services.

Integration of medical services

There were 44 out of 162 articles that reported the integration of medical services in nursing homes. Telemedicine (31/44, 70%), mHealth (10/44, 23%), and clinical information management (3/44, 7%) were used to integrate medical services from distant hospitals and clinical specialists to assist the nursing homes (Table 4 and Additional File 4).

Integration of medical services in telemedicine: The integration of medical services was widely used in the field of telemedicine for example videoconferencing (16/31, 52%), telemonitoring (8 /31, 26%), information technologies (5/31, 16%), and remote specialist decision making (2/31, 6%) have been integrated to overcome the issues of accessibility and timeliness of medical services for nursing home residents. As a form of telemedicine, teleconsultation that integrated real-time videoconference conducted on videophones or computers combined with cameras and microphones was applicable to replace face-to-face consultations in nursing homes, and it enhanced clinical efficiency and cost-effectiveness of healthcare delivery (109, 136, 137, 186). Teleconsultation that integrated health monitoring devices such as mobile phones or smartwatches

provided a telemonitoring service by electronically recording heart rate and blood pressure, and it could enable prompt response and management of urgent health conditions that raised in the older adults in remote nursing homes (19, 43, 53, 90, 123, 176). Telemedicine integrated computing technologies have been shown to help remote HCPs make good decisions in clinical management after reviewing patients' digital health records which were shared through emails or web-based health management systems (112, 140–143).

Integration of medical services through mHealth: Monitoring abnormal events (31, 34, 69, 78), radiography (130, 151, 187) and teleconsultation (116, 146, 148) could be implemented through mobile devices. mHealth personalised nursing home services, improved efficiency in terms of a closer connection between HCPs and nursing home residents, lowered incidences of unnoticed events, and ensured the quality of life (156). Mobile devices that connected with sensor-based devices enabled HCPs to monitor and interact with older adults in real-time, and abnormal events such as activities related to falls would be reported to prevent (78). Mobile applications could assist HCPs at point-of-care to schedule clinical tasks, perform radiography, digitally record their clinical practices that resulting in time-saving and error reduction (130). Besides, personal mobiles or tablets were used to connect nursing home residents to conduct teleconsultation (116).

Integration of clinical information: Integration of clinical information could improve the quality of care in different medical organisations, for example, sharing patients' clinical information between nursing homes and differently external care departments such as the department of pathology, pharmacy, physical therapy, and other social agents increased valuable support for nursing care, enhanced coordination with multiple specialty consultants, and improved administrative practices (159, 163).

Stakeholders' acceptability

Guided by the theoretical model proposed by Golant (2017) (22), we observed both the expected and unexpected reasons of stakeholders' acceptability of smart technologies. In addition, individual attributes are associated with the adoption of smart solutions (Table 5 and Additional File 5).

Persuasiveness of external information and internal information: Older adults became more aware and were willing to use new technology when they felt persuaded or compelled of the potential benefit of the technology from external resources such as their family members or healthcare providers (32, 188). This coping process is also influenced by internal information such as user experienced helpfulness, ease of use, and presence of safety features of the technology (120, 150). These factors resulted in user satisfaction, enhanced positive attitudes, and final adoption of smart technologies (59, 107).

The perceived efficaciousness: The nursing home residents who had experienced or perceived how smart technologies usefulness to meet their healthcare needs and demands were more acceptable to the technologies (49). Similarly, HCPs perceived helpfulness in assisting care delivery and care efficiency that increased their acceptability of smart technology for example using health information exchange systems efficiently improved doctor-patient communication (159). Using smart technologies to enhance HCPs' daily routines, improve medication safety, and deal with the events of emergency could be a better solution to improve the quality of care and ensure the older adults' quality of life (105, 156).

Perceived usability (positive and negative): Smart technology improved access to healthcare for nursing home residents (150). The users increased their awareness and consideration of adopting smart technologies when they recognised that smart solutions would be necessary for care (67, 121). The appraisals of ease of use or ease to learn with the new technology (112, 120, 142), user-friendly (63, 142, 165), and convenience (106, 146) in coping process that enhanced user acceptability to the new smart technological solutions. Users also preferred the "human-centric" designs to fit their lifestyles (32, 89). The affordability of smart technology is one of the considerations in coping process for example the smart solution would be better accepted if the cost was not too costly or if not more expensive than the conventional care model (32). Adequate tech support and regular training were expected to support new technology user engagement, confidence, and continuous operation (165, 186). In addition, the appropriate domestication of new technology could improve user acceptability (125). Domestication is a dynamic process when users in a variety of environments adapt and start to use the new technologies (189).

In contrast, appraisals of unusefulness or uncertainty of usefulness of a smart solution (120, 142), not easy to use or to learn (190, 191), lacking in supportive resources (132, 172) or tech-support (167) were reported to negatively affect the user acceptability. Some HCPs perceived new technologies as a burden when they disrupted routines or brought added workloads, reducing their time to provide essential nursing care for the residents. For example, when initiating a new information system that required manual input of residents' health records into the system caused frustrations among the HCPs (63, 173).

Perceived collateral damages: Potential medical risks, sensitivity or reliability of technology, errors during the operation, and increased costs were the main concerns that have been reported (120, 121, 188) to associated with the unintended and harmful effects of using smart technology (22).

Acceptability differs by the attributes of residents and HCPs: Attributes of residents and HCPs were found to be associated with the acceptability and adoption of new technologies. The attribute of residents identified from the reviewed articles was the severity of illness (63). The positive attributes of HCPs in accepting new technological solutions in nursing homes were higher educational attainment (108), a few of year working experience, and tech-savviness (49, 112, 156).

Discussion

To the best of our knowledge, this is the first scoping review that identified the gaps and scope of evidence on the concept of a smart nursing home, explored the smart technologies to be used in nursing home settings, and described medical services that could be integrated and implemented in nursing homes. We evaluated the feasibility of innovative technologies in development by applying the TRLs. This review has also captured the stakeholders' acceptability of the smart technologies, especially from the older adults and HCPs perspectives.

In previous studies, a smart nursing home was seen as a smart building equipped with IoT technologies (177). Our review concurs and notes that health status and emergency situations of nursing home residents were mainly monitored and collected by sensors through wearable devices, and the sensors installed on walls less on the user themselves achieved comfort and safe environment (11, 86). In particular, a smart nursing home would offer technology-assisted nursing care for older adults with the needs of health monitoring, activities of daily living, and safety (96, 192). Based on this, a comprehensive concept of smart nursing homes has to be supported by smart technologies to provide integrated nursing care, personalised monitoring of abnormal events, and assistance in activities of daily living. This smart nursing home model also emphasises the integration of medical services from remote clinical specialists and hospitals to support nursing and medical cares that are convenient, comfortable, and safe to the residents (11). As a result, the services in smart nursing homes could be more effective and efficient in care delivery that achieve the expectations of all stakeholders including the nursing home residents, family members, and nursing home staff (12). Figure 3 illustrates the concept of a smart nursing home.

With regards to the feasibility of smart technology in nursing home settings, the wide range of technologies reported in the literature can be classified as IoT, computing technologies, cloud computing, big data, and AI, information management system and digital health, and these technologies contribute to the 'smartness'. A few published articles had classified the functions of smart technology for senior care in hospital and home-based care settings, and the most important functions were identified as health status and mobility monitoring (193). In hospital settings, smart technologies were used particularly to improve clinical decision-making (21) while in home-based care, smart technologies assisted in the self-management of chronic diseases and remote health monitoring (194, 195). In nursing homes, the feasible technologies identified were mainly used in monitoring abnormal events, connecting to remote clinical services, clinical information management, big data analysis, and devices development for assisting activities of daily living. The TRL evaluation showed that 54% of new system designs were at level 6 to level 7 which have been proven ready for use in nursing homes, and the function of technology was mainly for monitoring abnormal events. The development of these new technologies is expected to progress to the higher levels of TRL 8 and 9 to be ready for commercialisation and future public use. Therefore, the technologies supporting ageing in place have been developed more maturely and some of the applications such as health monitoring, ADLs, and safety improvement have been reached to TRL 8 and 9 (192).

The integration of medical services is a network of healthcare services and advanced technologies, and it could achieve clinical efficiency or overcome the limited access to healthcare (196). Electronic clinical information, telemedicine, and mHealth were increasingly used and shown to be successful to some extent in overcoming shortages of medical resources and improving healthcare access and the standards of clinical practices in nursing homes (132). From our scoping review, clinical information management and remote clinical services, especially telemedicine have been broadly implemented in some nursing homes, and these services were reported to be acceptable to many stakeholders (146). With the effective implementation of smart technologies and integration of medical services, many nursing homes were able in managing a large number of residents and providing customised care to older adults (93).

The literature suggested that stakeholders' acceptability of smart technologies was determined by the persuasiveness of external and internal information, perceived efficaciousness, perceived usability, and perceived collateral damages (22). These determinants were also identified and extracted from the reviewed articles. We also observed that the older adults' severity of illnesses, the users with a higher level of education and tech-savviness, and the healthcare providers with fewer years of working experience (younger age) were associated with higher acceptability of smart technologies (49, 63, 108, 112, 156). These findings were consistent with a literature review of older adults' acceptance of technology for ageing in place, in which the factors of technology acceptability included positive experiences with the technology such as ease of use, increased safety, and security for care, perceived need to use, the concerns of technical errors, social influence, and their physical conditions (192). However, we did not find any evidence on the older adults' unmet needs and the description of their resilience to smart technology. The older adults did not seem to take concrete actions to adopt a smart technology according to their stressful unmet needs, or the different level of resilience to adversity from the new technologies as indicated in the theoretical model (22).

There are some limitations to be aware of when using the findings in this review. Business reports were not published in the 11 selected databases which we searched on, and it might cause the review to miss the new technologies or actual systems which have been approved to use in the nursing homes (TRL 8 and 9). Nevertheless, the number and types of databases that this review has conducted searches on are believed to have captured informative literature to the review objectives. Meta-analysis and quality assessment were not applicable in this scoping review because the literature and studies informed about the scope and extent of the smart nursing home concepts, technology utilities with its integrated medical services, and acceptability by stakeholders disregarding the literature risk of biases. In the future, researchers could conduct an in-depth exploration of the characteristics and feasibility of smart technologies implemented in nursing homes by the functions that we categorised, for example, the technologies in the monitoring of abnormal events and activities of daily living assistance.

Conclusion

Smart nursing homes with integrated medical services have great potential to be a future trend to replace the traditional nursing home. The motivation of transferring from a traditional model to a smart one includes having advanced and safe information technologies, well-trained staff who deliver the nursing care and medical services, and meeting the expectations of all stakeholders. However, technology readiness needs to catch up (clinical data analysis by AI approach and cloud computing technologies) even though much has already been presented (IoT, telemedicine, and information management system). The technology appraisal process was determined by perceived efficaciousness, perceived usability, and perceived collateral damages of adopting the smart technology. Older adults living with severe illnesses and the stakeholders who were persuaded with the information about the smart solutions from external and internal resources were more acceptable to new technological solutions in nursing homes. Meanwhile, the HCPs with higher educational attainment, fewer years of working experience, and good tech-savviness had higher acceptability of smart technologies.

The results of this scoping review are relevant to a broad base of readers who are interested in this research and to most developed and developing countries that have nursing homes. Future research on introducing smart technologies into nursing homes or developing a successful smart nursing home model could refer to the results of this scoping review for the types and scope of smart technologies that integrate multidisciplinary biomedical informatics and medical services, stakeholders' attribute preparedness, and preparation. This is applicable in the planning, evaluation and monitoring of the feasible, and functional technologies when those are integrated with different types of medical services.

Abbreviations

IoT: internet of Things; AI: artificial intelligence; HCPs: healthcare professionals; TRL: technology readiness level; ADLs: activities of daily living.

Declarations

Acknowledgement

Not Applicable

Authors' contributions

All authors were involved in the review process. YYZ proposed the task and conducted the qualitative scoping review. FZR and NKD contributed to study selection and reviewed the literature published in English. JS was involved in selecting the literature in Chinese. BHC, SGS, and FZR were involved in the thematic analysis and verified the retrieved textual data. All authors have made substantive intellectual contributions to the development of this scoping review and approved the final manuscript for submission to the journal.

Protocol Registration

The protocol of this scoping review has registered on osf.io (URL: <https://osf.io/qtwz2/>) and published in BMJ Open (20).

Ethics Approval and Consent to Participate

Not applicable.

Consent for Publication

Not applicable.

Availability of Data and Materials

The authors declare that all data supporting the findings of this study are already made available in the supplementary files (see additional files 1-5). If further data clarification is required, please contact the corresponding author or Ms. Yuanyuan Zhao at helenzhao78@qq.com or pcshelenzhao@gmail.com.

Competing interests

We have no conflict of interest to declare.

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Tables

Table 1: The Codes of Defining the Concepts and Criteria of a Smart Nursing Home

Table 1a: Concept of Smart Nursing Homes

Authors and year	Codes	Description	Themes
Baidu, 2018; Ce.cn, 2019; Chen & Li, 2012; Gamberini et al., 2018; Huang et al., 2019; Korte; Lee et al., 2018; Mahieu et al., 2019; MCA, 2014; Roh & Park, 2017; Shenghuo, 2020; Tang et al., 2019; Wang, 2014; Wang, 2020; Xie, 2017; Xiexiebang, 2019; Xu & Tuo, 2019	IoT ^a	The concept of smartness in nursing home settings is using a new generation of information technologies such as the internet of things (IoT), computing technologies, cloud computing, big data and AI, information management system and digital health, to transform traditional nursing care in an all-round way, making healthcare more efficient, more effective, and more personalised.	Application of smart technologies (Smartness)
Cui et al., 2020; Korte; SheCuiTong; Telpo	Computing technologies		
Ce.cn, 2019	Cloud computing		
Cui et al., 2020; Mahieu et al., 2019; MHURD; Telpo; Xu & Tuo, 2019	Big data and AI ^b		
Baidu, 2018; Liuye; MHURD; Morley, 2012	Information management system (IMS)		
BOE Technology Group Co., 2018; MHURD; Morley, 2012; Shenghuo, 2020; Telpo	Digital health		
Shenghuo, 2020; Siciliano & Khatib, 2016; Sun et al., 2015	Assistive devices	A nursing home offers technology-assisted nursing care for the people who require a lot of assistance with activities of daily living to improve their quality of life in relation to their goals, expectations, standards and concerns.	Technology-assisted nursing care
Cui et al., 2020; Deng, 2019; MCA, 2014; Tang et al., 2019	Intelligent nursing		
Korte; Lee et al., 2018; Xie, 2017	Automated tracking, monitoring and alerts		
Huang, 2019; Korte; Wang, 2014	Improving quality of life		
Baidu, 2018; Cui et al., 2020; MHURD; Tang et al., 2019	Meeting older adults and users' satisfaction		
Cui et al., 2020; Korte; Morley, 2012	Similar to smart home	The concept belongs to smart homes with specific users. It performs as a home-based care with the functions of both home and hospital to guarantee a better environment for older adults.	Combination of smart home and hospital model
Cui et al., 2020; Korte	Home and hospital models		
Gamberini et al., 2018	More comfortable and safe environments		
Cui et al., 2020; Siciliano & Khatib, 2016	Special users-older adults and caregivers		

Table 1b: Criteria of Smart Nursing Homes

Authors and year	Codes	Description	Themes
Baidu, 2018; Huang et al., 2019; Korte; Matusitz et al., 2013; MHURD; Tang et al., 2019	Provide/improve quality of care	The quality of care is the extent to which health care services provided to individuals and patient populations improve desired health outcomes. In order to achieve this, health care must be safe, effective, timely, efficient, equitable and people-centered. (WHO).	Quality of care
Huang et al., 2019; MHURD; Siciliano & Khatib, 2016; Wang, 2020; Xiexiebang, 2019	Safe		
Baidu, 2018; Betgé-Brezetz et al., 2009; Cui et al., 2020; MHURD; Shenghuo, 2020; Tang et al., 2019	Effective		
Baidu, 2018; Cui et al., 2020; SheCuiTong; Siciliano & Khatib, 2016; Tang et al., 2019; Xiexiebang, 2019	Efficient		
Cui et al., 2020; Huang et al., 2019; Korte; MHURD; Telpo; Wang, 2014	People-centered (PC)		

^a IoT=Internet of things

^b AI= Artificial intelligence

Table 2: The Codes of Smart Technologies

No.	Authors and year	Country	Type of Publication	Study design	Application	Technologies related to 'smartness'	Direct User	Function of Technology
1	Suzuki et al., 2006	Japan	Journal article	System design	Monitoring abnormal events (only location)	IoT	Residents ^a	Monitoring and notification of abnormal events
2	Fischer et al., 2008	Australia	Conference paper	System design	Monitoring abnormal events	IoT	Residents	
3	Lin et al., 2008	<i>Taiwan, China</i>	Conference paper	System design	Monitoring abnormal events	IoT	Residents	
4	Betgé-Brezetz et al., 2009	USA	Conference paper	System design	Notification for specific events	Computing technologies	Residents	
5	Biswas et al., 2009	Singapore	Book	System design	Monitoring abnormal events (Sleeping monitoring)	IoT	Residents	
6	Hu et al., 2009	USA	Journal article	System design	Monitoring abnormal events	IoT	NH ^b staffs	
7	Fraille et al., 2010	Spain	Conference paper	System design	Monitoring abnormal events	IoT	Residents	
8	Pallikonda Rajasekaran et al., 2010	India	Journal article	System design	Monitoring abnormal events	IoT	Residents	
9	Gower et al., 2011	Italy	Conference paper	System design	Monitoring abnormal events	IoT	Residents	
10	Lee et al., 2011	South Korea	Journal article	System design	Monitoring abnormal events	IoT	Residents	
11	Sun, 2011	China	Book	System design	Monitoring abnormal events	IoT	Residents	
12	Wu & Huang, 2011	<i>Taiwan, China</i>	Conference paper	System design	Monitoring abnormal events	IoT	Residents	
13	Back et al., 2012	Finland	Journal article	System design	Monitoring abnormal events	IoT	Residents	
14	Chang et al., 2012	<i>Taiwan, China</i>	Journal article	System design	Monitoring abnormal events	IoT	Residents	
15	Chen & Li, 2012	China	Thesis	System design	Monitoring abnormal events	IoT	Residents	
16	Nijhof et al., 2012	Netherlands	Journal article	Mixed methods	Monitoring abnormal events (Sleep/wake rhythm monitoring)	IoT	Residents	
17	Ghorbel et al., 2013	France	Journal article	System design	Notification for specific events	Computing technologies	Residents	
18	Huang et al., 2013	<i>Taiwan, China</i>	Conference paper	System design	Monitoring abnormal events	IoT	Residents	
19	Matsui et al., 2013	USA	Journal article	System design	Monitoring abnormal events	Computing technologies	Residents	
20	Neuhaeuser & D'Angelo, 2013	Germany	Conference paper	System design	Monitoring abnormal events	IoT	Residents	
21	Pan, 2013	China	Thesis	System design	Monitoring abnormal events	IoT	Residents	
22	Tseng et al., 2013	USA	Journal article	System design	Monitoring abnormal events	IoT	Residents	
23	Abbate et al., 2014	Italy	Journal article	Experimental ^c	Fall detection	IoT	Residents	

24	Chu et al., 2014	China	Journal article	System design	Monitoring abnormal events	IoT	Residents
25	Liu & Hsu, 2014	<i>Taiwan, China</i>	Journal article	System design	Monitoring abnormal events (Smart mattress)	IoT	Residents
26	Wang, 2014	China	Thesis	System design	Monitoring abnormal events	IoT	Residents
27	Zhu et al., 2014	Japan	Conference paper	System design	Monitoring abnormal events (Sleep monitoring)	IoT	Residents
28	Andò et al., 2015	Italy	Conference paper	System design	Monitoring abnormal events	IoT	Residents
29	Carvalho et al., 2015	France	Conference paper	System design	Monitoring abnormal events	IoT	Residents
30	Yu et al., 2015	UK	Conference paper	System design	Monitoring abnormal events	IoT	Residents
31	Danielsen, 2016	Norway	Journal article	System design	Monitoring abnormal events	IoT	Residents
32	Dias et al., 2016	Brazil	Conference paper	System design	Fall detection	IoT	Residents
33	Lopez-Samaniego & Garcia-Zapirain, 2016	Spain	Journal article	System design	Monitoring abnormal events	IoT	Residents
34	Ansefine et al., 2017	Indonesia	Conference paper	System design	Monitoring abnormal events	IoT	Residents
35	Jiang, 2017	China	Thesis	System design	Monitoring abnormal events	IoT	Residents
36	Mendes et al., 2017	Portugal	Conference paper	System design	Monitoring abnormal events	Big data and AI	Residents
37	Mendoza et al., 2017	Philippines	Conference paper	System design	Monitoring abnormal events	IoT	Residents
38	Montanini et al., 2017	Italy	Conference paper	System design	Monitoring abnormal events (Night monitoring of patients with dementia)	IoT	Residents
39	Saod et al., 2017	Malaysia	Conference paper	System design	Monitoring abnormal events	IoT	Residents
40	Singh et al., 2017	Austria	Conference paper	Qualitative	Monitoring abnormal events	IoT	Residents
41	Wu et al., 2017	China	Conference paper	System design	Monitoring abnormal events	Computing technologies	Residents
42	Xie, 2017	China	Thesis	System design	Monitoring abnormal events	Big data and AI	Residents
43	Bleda et al., 2018	Spain	Conference paper	System design	Monitoring abnormal events (Smart mattress)	IoT	Residents
44	Donnelly et al., 2018	Ireland	Journal article	Qualitative	Fall detection	IoT	Residents
45	Gamberini et al., 2018	Italy	Book	Non-research article ^d	Monitoring abnormal events	IoT	Residents
46	Lee et al., 2018	South Korea	Conference paper	System design	Monitoring abnormal events	IoT	Residents
47	Mahfuz et	Canada	Conference	System	Fall detection	IoT	Residents

	al., 2018		paper	design			
48	Morita et al., 2018	Japan	Conference paper	System design	Monitoring abnormal events	Big data and AI	Residents
49	Wu et al., 2018	China	Journal article	System design	Monitoring abnormal events	IoT	Residents
50	Borelli et al., 2019	Italy	Journal article	System design	Monitoring abnormal events	IoT	Residents
51	Cai & Wang, 2019	China	Journal article	System design	Fall detection	IoT	Residents
52	Delmastro et al., 2019	Italy	Journal article	Experimental	Monitoring abnormal events	Cloud computing	Residents
53	Deng, 2019	China	Thesis	System design	Monitoring abnormal events	IoT	Residents
54	Fong et al., 2019	USA	Conference paper	System design	Monitoring abnormal events	IoT	Residents
55	Ghosh et al., 2019	India	Conference paper	System design	Monitoring abnormal events	Big data and AI	Residents
56	Huang, 2019	China	Thesis	System design	Fall detection	Big data and AI	Residents
57	Huang et al., 2019	<i>Taiwan, China</i>	Conference paper	System design	Monitoring abnormal events	IoT	Residents
58	Lenoir, 2019	Japan	Conference paper	System design	Monitoring abnormal events	IoT	Residents
59	Shen, 2019	China	Journal article	System design	Monitoring abnormal events	IoT	Residents
60	Takahashi et al., 2019	Japan	Conference paper	System design	Monitoring abnormal events (only location)	IoT	Residents
61	Tang et al., 2019	China	Journal article	System design	Monitoring abnormal events	IoT	Residents
62	Toda & Shinomiya, 2019	Japan	Conference paper	System design	Fall detection	IoT	Residents
63	Xiao, 2019	China	Thesis	System design	Monitoring abnormal events (Smart mattress)	IoT	Residents
64	Xu & Tuo, 2019	China	Journal article	Non-research article	Monitoring abnormal events	IoT	Residents
65	Yoo et al., 2019	South Korea	Conference paper	System design	Monitoring abnormal events	IoT	Residents
66	Buisseret et al. 2020	Belgium	Journal article	System design	Fall prediction	Big data and AI	Residents
67	Chen et al. 2021	China	Conference paper	System design	Fall prediction	Big data and AI	Residents
68	Gharti 2020	<i>Australia</i>	Conference Paper	Non-research article	Fall detection	IoT	Residents
69	Lanza et al. 2020	Italy	Journal article	System design	Monitoring abnormal events	Big data and AI	Residents
70	Lee et al. 2020	South Korea	Journal article	System design	Fall prediction	Big data and AI	HCPs ^e
71	Mishkhal et al. 2020	Iraq	Conference paper	System design	Fall prediction	IoT	Residents
72	Suzuki et al. 2020	Japan	Journal article	Non-experimental ^f	Fall prediction	Big data and AI	Residents
73	Wang, 2020	China	Thesis	System design	Monitoring abnormal events	IoT	Residents

74	Wan et al. 2021	China	Journal article	System design	Fall detection	IoT	Residents	Remote clinical services through digital health
75	Chen et al. 2021	<i>Taiwan, China</i>	Conference paper	System design	Monitoring abnormal events	IoT	Residents	
76	Flores-Martin et al. 2021	Spain	Journal article	System design	Monitoring abnormal events	IoT	Residents	
77	Chan et al., 2001	China	Journal article	Non-experimental	Telemedicine	Digital health	Residents	
78	Pallawala & Lun, 2001	Singapore	Journal article	Non-experimental	Telemedicine	Digital health	Residents	
79	Weiner et al., 2001	USA	Journal article	Experimental	Telemedicine	Digital health	Residents	
80	Hui & Woo, 2002	China	Journal article	Non-experimental	Telemedicine	Digital health	Residents	
81	Savenstedt et al., 2002	Sweden	Journal article	Qualitative	Telemedicine	Digital health	Residents	
82	Weiner et al., 2003	USA	Conference paper	Experimental	Telemedicine	Digital health	Residents	
83	Zelickson, 2003	USA	Journal article	Non-experimental	Telemedicine	Digital health	Residents	
84	Armer et al., 2004	USA	Journal article	Experimental	Telemedicine	Digital health	Residents	
85	Savenstedt et al., 2004	Sweden	Journal article	Qualitative	Telemedicine	Digital health	Residents	
86	Daly et al., 2005	USA	Journal article	Non-research article	Telemedicine	Digital health	Residents	
87	Lavanya et al., 2006	Singapore	Conference paper	Non-experimental	Teledermatology (Clinical assessment system)	Digital health	Nurses and dermatologists	
88	Loeb et al., 2006	Canada	Journal article	Non-experimental	Telemedicine (Mobile x-ray)	Digital health	Residents	
89	Shulman et al., 2006	Canada	Conference paper	Non-research article	Telemedicine	Digital health	Residents	
90	Cusack et al., 2008	USA	Journal article	Non-experimental	Telemedicine	Digital health	Residents	
91	Janardhanan et al., 2008	Singapore	Journal article	Non-experimental	Telemedicine	Digital health	Residents	
92	Biglan et al., 2009	USA	Journal article	Qualitative	Telemedicine	Digital health	Residents	
93	Chang et al., 2009	<i>Taiwan, China</i>	Journal article	Non-experimental	Telemedicine	Digital health	Residents	
94	Qadri et al., 2009	USA	Journal article	Mixed methods	Telemedicine (Clinical assessment system)	Digital health	Nurses	
95	Chang et al., 2010	<i>Taiwan, China</i>	Journal article	Non-experimental	Telemedicine	Digital health	Residents	
96	Rabinowitz et al., 2010	USA	Journal article	Non-experimental	Telemedicine	Digital health	Residents	
97	Wälivaara et al., 2011	Sweden	Journal article	Qualitative	Telemedicine	Digital health	Residents	
98	Eklund et al., 2012	Sweden	Journal article	Non-experimental	Telemedicine (Mobile X-ray)	Digital health	Residents	
99	Gray et al., 2012	Australia	Journal article	Non-experimental	Telemedicine	Digital health	Residents	
100	Handler et	USA	Journal	Non-	Telemedicine	Digital health	Residents	

	al., 2013		article	experimental			
101	Novak et al., 2013	USA	Conference paper	Experimental	Telemedicine	Digital health	Residents
102	Vowden & Vowden, 2013	UK	Journal article	Experimental	Telemedicine	Digital health	Residents
103	Catic et al., 2014	USA	Journal article	Non-experimental	Telemedicine	Digital health	Residents
104	Grabowski & O'Malley, 2014	USA	Journal article	Experimental	Telemedicine	Digital health	Residents
105	Crotty et al., 2014	Australia	Journal article	Experimental	Telemedicine	Digital health	Residents
106	Doumbouya et al., 2015	France	Journal article	System design	Telemedicine	Digital health	Residents
107	F. Huang et al., 2015	<i>Taiwan, China</i>	Journal article	Experimental	Telemedicine	Digital health	Residents
108	Montalto et al., 2015	Australia	Conference paper	Non-experimental	Telemedicine (Mobile X-ray)	Digital health	Residents
109	Toh et al., 2015b	Singapore	Conference paper	Qualitative	Telemedicine	Digital health	Residents
110	Toh et al., 2015a	Singapore	Conference paper	Non-experimental	Telemedicine	Digital health	Residents
111	Volicer, 2015	USA	Journal article	Non-research article	Telemedicine	Digital health	Residents
112	De Luca et al., 2016	Italy	Journal article	Experimental	Telemedicine	Digital health	Residents
113	Dozet et al., 2016	Sweden	Journal article	Non-experimental	Telemedicine (Mobile X-ray)	Digital health	Residents
114	Driessen et al., 2016	USA	Journal article	Non-experimental	Telemedicine	Digital health	Residents
115	Gaglio et al., 2016	France	Conference paper	Qualitative	Telemedicine	Digital health	Residents
116	Gillespie et al., 2016	USA	Journal article	Non-experimental	Telemedicine	Digital health	Residents
117	Morley, 2016	USA	Journal article	Non-research article	Telemedicine	Digital health	Residents
118	Schneider et al., 2016	USA	Journal article	Non-experimental	Telemedicine	Digital health	Residents
119	Kjelle & Lysdahl, 2017	Norway	Journal article	Non-research article	Telemedicine (Mobile X-ray)	Digital health	Residents
120	Newbould et al., 2017	UK	Book	Non-experimental	Telemedicine	Digital health	Residents
121	Queyroux et al., 2017	France	Journal article	Non-experimental	Telemedicine	Digital health	Residents
122	Delmastro et al., 2018	Italy	Conference paper	Non-experimental	Telemedicine	Digital health	Residents
123	Kjelle et al., 2018	Norway	Journal article	Qualitative	Telemedicine (Mobile X-ray)	Digital health	Residents
124	Esteves et al., 2019	Portugal	Journal article	System design	Telemedicine	Digital health	HCPs
125	Gentry et al., 2019	USA	Journal article	Non-research article	Telemedicine	Digital health	Residents

126	Ozkaynak et al., 2019	USA	Journal article	Qualitative	Telemedicine(Clinical assessment system)	Digital health	NH staffs	Information management and decision making
127	Shafiee Hanjani et al., 2019	Australia	Journal article	Mixed methods	Telemedicine	Digital health	Residents	
128	Cormi et al. 2020	France	Journal article	Non-research article	Telemedicine	Digital health	Residents	
129	Lai et al. 2020	USA	Journal article	Non-experimental	Teleophthalmology	Digital health	Residents	
130	Low et al. 2020	Singapore	Journal article	Non-experimental	Telemedicine	Digital health	Residents	
131	Ohligs et al. 2020	Germany	Journal article	Non-experimental	Telemedicine	Digital health	Residents	
132	Alexander et al. 2021	USA	Journal article	Non-experimental	Telemedicine	Digital health	Residents	
133	Okamoto et al. 2021	USA	Conference paper	Non research article	Telemedicine	Digital health	Residents	
134	Lenderink & Egberts, 2004	Netherlands	Journal article	Non-experimental	Information management and decision making	IMS ⁹	Nurses	
135	Alexander, 2005	USA	Thesis	Non-experimental	Information management and decision making	IMS	Administrative staffs	
136	Byrne, 2005	USA	Thesis	Experimental	Information management and decision making	IMS	NH staffs	
137	Celler et al., 2006	Australia	Conference paper	Non-experimental	Information management and decision making	IMS	NH staffs	
138	Cherry, 2006	USA	Thesis	Qualitative	Information management and decision making	IMS	HCPs	
139	Alexander et al., 2007	USA	Journal article	Qualitative	Information management and decision making	IMS	NH staffs	
140	Alexander, 2008	USA	Journal article	Non-experimental	Information management and decision making	IMS	NH staffs	
141	Breen & Zhang, 2008	USA	Journal article	Non-research article	Information management and decision making	IMS	Nurses and other medical practitioners	
142	Yu et al., 2008	China	Journal article	Mixed methods	Information management and decision making	IMS	Caregivers	
143	Sax & Lawrence, 2009	Australia	Conference paper	System design	Information management and decision making	IMS	Nurses	
144	Scott-Cawiezell et al., 2009	USA	Journal article	Non-experimental	Information management and decision making	IMS	Practitioners, nursing staffs, medication administrators and NH leadership	
145	Ohol, 2010	USA	Thesis	System design	Information management and decision making	IMS	Clinical staffs	
146	Matusitz et al., 2013	USA	Journal article	Non-research article	Information management and decision making	IMS	Healthcare practitioners	
147	Alexander et al., 2015	USA	Journal article	Qualitative	Information management and decision making	IMS	Clinical staffs	

148	Z. Huang et al., 2015	China	Journal article	System design	Information management and decision making	IMS	NH staffs and administration	
149	Wang, 2016	China	Journal article	Non-research article	Information management and decision making	IMS	HCPs and administration	
150	Zhang, 2017	China	Thesis	System design	Information management and decision making	IMS	Doctors, nurses and caregivers	
151	Xie, 2016	China	Thesis	System design	Information management and decision making	IMS	Caregivers	
152	Ausserhofer et al. 2021	Switzerland	Journal article	Non-experimental	Information management and decision making	IMS	Care workers and nurses	
153	Kei Hong et al. 2021	China	Journal article	Non-experimental	Information management and decision making	IMS	HCPs	
154	Masuda & Numao, 2017	Japan	Conference paper	System design	Clinical data analysis (Diagnosis)	IoT	Residents	Clinical data analysis by AI
155	Roh & Park, 2017	South Korea	Journal article	System design	Quality of Life measurements	Big data and AI	HCPs	
156	González et al., 2019	Spain	Journal article	System design	Clinical data analysis (frailty and cognition status)	IoT	HCPs	
157	Kokubo & Kamiya, 2019	USA	Conference paper	Non-experimental	A new signal parameter estimation algorithm for vital signs monitoring	Big data and AI	HCPs	
158	Ambagtsheer et al., 2020	Australia	Journal article	Non-experimental	Identifying frailty by using artificial intelligence (AI) algorithms	Big data and AI	HCPs	
159	Hsu et al., 2010	<i>Taiwan, China</i>	Journal article	System design	ADLs assistance (Pillbox)	IoT	Residents	Activities of daily living (ADLs ^h) assistance
160	Chang et al., 2011	<i>Taiwan, China</i>	Journal article	System design	ADLs assistance (Pillbox)	IoT	Residents	
161	Sun et al., 2015	China	Journal article	System design	ADLs assistance (Intelligent robot)	Computing technologies	Residents	
162	Tsai et al., 2017	<i>Taiwan, China</i>	Conference paper	System design	ADLs assistance (Pillbox)	IoT	Residents	

^a Residents=Nursing home residents

^b NH=Nursing home

^c Experimental study: The intervention or implementation of smart technologies with one or more control variables of the research subjects conducted in nursing home setting to measure or compare the effect of this manipulation on the users or medical outcomes

^d Non-research article: Non-original research articles such as review, perspective, controversies, and editorial

^e HCPs=Healthcare professionals

^f Non-experimental study: No control, manipulate or prediction of intervention and implementation of smart technologies, and the conclusion came through the interpretation, observation or interactions

^g IMS=Information management system

^h ADLs=Activities of daily living

Table 3: Technology Readiness Levels

No.	Authors and year	Country	Study design	Function of Technology	Technologies related to 'smartness'	TRLs
1	Sun et al., 2015	China	System design	Assisting ADLs ^a	Computing technologies	L 1 ^b
2	Xie, 2016	China	System design	Information management and decision making	IMS	
3	Esteves et al., 2019	Portugal	System design	Telemedicine	Digital health	
4	Shen, 2019	China	System design	Monitoring abnormal events	IoT	
5	Chen et al. 2021	<i>Taiwan, China</i>	System design	Monitoring abnormal events	IoT	
6	Lin et al., 2008	<i>Taiwan, China</i>	System design	Monitoring abnormal events	IoT	L 2 ^c
7	Hu et al., 2009	USA	System design	Monitoring abnormal events	IoT	
8	Ohol, 2010	USA	System design	Information management and decision making	IMS	
9	Pallikonda Rajasekaran et al., 2010	India	System design	Monitoring abnormal events	IoT	
10	Wu & Huang, 2011	<i>Taiwan, China</i>	System design	Monitoring abnormal events	IoT	
11	Ghorbel et al., 2013	France	System design	Notification for specific events	Computing technologies	
12	Neuhaeuser & D'Angelo, 2013	Germany	System design	Monitoring abnormal events	IoT	
13	Chu et al., 2014	China	System design	Monitoring abnormal events	IoT	
14	Huang et al., 2015	China	System design	Information management and decision making	IMS	
15	Yu et al., 2015	UK	System design	Monitoring abnormal events	IoT	
16	Roh & Park, 2017	South Korea	System design	Quality of Life measurements	Big data and AI	
17	Flores-Martin et al. 2021	Spain	System design	Monitoring abnormal events	IoT	
18	Sun, 2011	China	System design	Monitoring abnormal events	IoT	L 3 ^d
19	Andò et al., 2015	Italy	System design	Monitoring abnormal events	IoT	
20	Jiang, 2017	China	System design	Monitoring abnormal events	IoT	
21	Mendes et al., 2017	Portugal	System design	Monitoring abnormal events	Big data and AI	
22	Wu et al., 2017	China	System design	Monitoring abnormal events	Computing technology	
23	Mahfuz et al., 2018	Canada	System design	Fall detection	IoT	
24	Fong et al., 2019	USA	System design	Monitoring abnormal events	IoT	
25	Ghosh et al., 2019	India	System design	Monitoring abnormal events	Big data and AI	
26	Huang, 2019	China	System design	Fall detection	Big data and AI	
27	Xiao, 2019	China	System design	Monitoring abnormal events	IoT	

28	Lanza et al. 2020	Italy	System design	Monitoring abnormal events	Big data and AI	
29	Fischer et al., 2008	Australia	System design	Monitoring abnormal events	IoT	L 4 ^e
30	Hsu et al., 2010	<i>Taiwan, China</i>	System design	Assisting ADLs	IoT	
31	Chang et al., 2011	<i>Taiwan, China</i>	System design	Assisting ADLs	IoT	
32	Chen & Li, 2012	China	System design	Monitoring abnormal events	IoT	
33	Pan, 2013	China	System design	Monitoring abnormal events	IoT	
34	Carvalho et al., 2015	France	System design	Monitoring abnormal events	IoT	L 5 ^f
35	Borelli et al., 2019	Italy	System design	Monitoring abnormal events	IoT	
36	Mishkhal et al. 2020	Iraq	System design	Fall prediction	IoT	
37	Sax & Lawrence, 2009	Australia	System design	Information management and decision making	IMS	L 6 ^g
38	Gower et al., 2011	Italy	System design	Monitoring abnormal events	IoT	
39	Lee et al., 2011	South Korea	System design	Monitoring abnormal events	IoT	
40	Wang, 2014	China	System design	Monitoring abnormal events	IoT	
41	Doumbouya et al., 2015	France	System design	Telemedicine	Digital health	
42	Dias et al., 2016	Brazil	System design	Fall detection	IoT	
43	Ansefine et al., 2017	Indonesia	System design	Monitoring abnormal events	IoT	
44	Saod et al., 2017	Malaysia	System design	Monitoring abnormal events	IoT	
45	Xie, 2017	China	System design	Monitoring abnormal events	Big data and AI	
46	Zhang, 2017	China	System design	Information management and decision making	IMS	
47	Cai & Wang, 2019	China	System design	Fall detection	IoT	
48	Deng, 2019	China	System design	Monitoring abnormal events	IoT	
49	Toda & Shinomiya, 2019	Japan	System design	Fall detection	IoT	
50	Yoo et al., 2019	South Korea	System design	Monitoring abnormal events	IoT	
51	Wang, 2020	China	System design	Monitoring abnormal events	IoT	
52	Suzuki et al., 2006	Japan	System design	Monitoring abnormal events (location)	IoT	L 7 ^h
53	Betgé-Brezetz et al., 2009	USA	System design	Notification for specific events	Computing technologies	
54	Biswas et al., 2009	Singapore	System design	Monitoring abnormal events	IoT	
55	Fraile et al., 2010	Spain	System design	Monitoring abnormal events	IoT	

56	Back et al., 2012	Finland	System design	Monitoring abnormal events	IoT	Not applicable
57	Chang et al., 2012	<i>Taiwan, China</i>	System design	Monitoring abnormal events	IoT	
58	Huang et al., 2013	<i>Taiwan, China</i>	System design	Monitoring abnormal events	IoT	
59	Matsui et al., 2013	USA	System design	Monitoring abnormal events	Computing technology	
60	Tseng et al., 2013	USA	System design	Monitoring abnormal events	IoT	
61	Liu & Hsu, 2014	<i>Taiwan, China</i>	System design	Monitoring abnormal events in bed	IoT	
62	Zhu et al., 2014	Japan	System design	Monitoring abnormal events	IoT	
63	Lopez-Samaniego & Garcia-Zapirain, 2016	Spain	System design	Monitoring abnormal events	IoT	
64	Masuda & Numao, 2017	Japan	System design	Clinical data analysis (diagnosis)	IoT	
65	Mendoza et al., 2017	Philippines	System design	Monitoring abnormal events	IoT	
66	Tsai et al., 2017	<i>Taiwan, China</i>	System design	Assisting ADLs	IoT	
67	Bleda et al., 2018	Spain	System design	Monitoring abnormal events	IoT	
68	Lee et al., 2018	South Korea	System design	Monitoring abnormal events	IoT	
69	Morita et al., 2018	Japan	System design	Monitoring abnormal events	Big data and AI	
70	Wu et al., 2018	China	System design	Monitoring abnormal events	IoT	
71	Huang et al., 2019	<i>Taiwan, China</i>	System design	Monitoring abnormal events	IoT	
72	González et al., 2019	Spain	System design	Clinical data analysis (frailty and cognition status)	IoT	
73	Lenoir, 2019	Japan	System design	Monitoring abnormal events	IoT	
74	Takahashi et al., 2019	Japan	System design	Monitoring abnormal events (location)	IoT	
75	Tang et al., 2019	China	System design	Monitoring abnormal events	IoT	
76	Buisseret et al. 2020	Switzerland	System design	Fall prediction	Big data and AI	
77	Lee et al. 2020	South Korea	System design	Fall prediction	Big data and AI	
78	Wan et al. 2021	China	System design	Fall detection	IoT	
79	Montanini et al. 2017	Italy	System design	Monitoring abnormal events	IoT	Not applicable
80	Danielsen 2016	Norway	System design	Monitoring abnormal events	IoT	
81	Chen et al. 2021	China	System design	Fall prediction	Big data and AI	

^aADLs=Activities of daily living

^bL 1=Level 1: Basic principles observed and reported.

- ^cL 2=Level 2: Technology concept and/or application formulated.
- ^dL 3=Level 3: Analytical and experimental critical function and/or characteristic proof-of-concept.
- ^eL 4=Level 4: Component and/or breadboard validation in laboratory environment.
- ^fL 5=Level 5: Component and/or breadboard validation in relevant environment.
- ^gL 6=Level 6: System/sub-system model or prototype demonstration in relevant environment.
- ^hL 7=Level 7: System prototype demonstration in relevant environment.
- ⁱL 8=Level 8: Actual system completed and qualified through test and demonstration (not applicable)
- ^jL 9=Level 9: Actual system proven through successful mission operations (not applicable)

Table 4: The Codes of Integration of Medical Services

No.	Authors and year	The form of integrated medical services	Sub-codes	Codes
1	Armer et al., 2004	Telemedicine and videoconferencing or without videoconferencing	Teleconsultation and videoconferencing	Integration of medical services in telemedicine
2	Daly et al., 2005	Teleconsulting, live video and image transition		
3	Chan et al., 2001; Hui & Woo, 2002; Newbould et al., 2017; Rabinowitz et al., 2010; Schneider et al., 2016; Toh et al., 2015; Weiner et al., 2001; Weiner et al., 2003	Videoconferencing and teleconsultation		
4	Biglan et al., 2009; Grabowski & O'Malley, 2014	Videoconferencing and telemedicine		
5	Pallawala & Lun, 2001	Videoconferencing, teleconsultation and electronic medical records		
6	Savenstedt et al., 2004	Videophones and teleconsultation		
7	Cusack et al., 2008	Store-and-forward, real-time video, hybrid systems and teleconsultation		
8	Catic et al., 2014	Video-consultation technology and teleconsultation		
9	Chang et al., 2010	Telemonitoring plus teleconsultation via videoconferencing	Telemonitoring	Integration of medical services through mHealth
10	De Luca et al., 2016	Telemonitoring and teleconsulting		
11	Pallikonda Rajasekaran et al., 2010	Shared health information collected by wireless Sensor Networks (WSNs) and telemonitoring		
12	Zhang, 2017	Telemonitoring, wearable devices and web-based health information through an App		
13	Delmastro et al., 2019; Deng, 2019; Wang, 2014; Mishkhal et al. 2020	Telemonitoring and wearable devices		
14	Vowden & Vowden, 2013; Zelickson, 2003	Teleconsultation without videoconference (by digital documents)	Teleconsultation and information technologies	
15	Janardhanan et al., 2008; Low et al. 2020	Internet (or email) and teleconsultation		
16	Lavanya et al., 2006	Personal health information management system (D-PHIMS) and teleconsultation		
17	Doumbouya et al., 2015	Remote specialists and teleconsultation for decision making	Teleconsultation and remote specialist decision making	
18	Shafiee Hanjani et al., 2019	Telehealth and interprofessional collaboration		
19	Liu & Hsu, 2013	mhealth (App) and a soft motion-sensing mattress	mHealth and abnormal event monitoring	
20	Mendes et al., 2017	Wearable devices and m-health personalised monitoring		
21	Delmastro et al., 2018	Mobile and e-health personalised monitoring services		
22	Donnelly et al., 2018	Mobile and wearable devices		
23	Montalto et al., 2015; Dozet et al., 2016; Esteves et al., 2019	Mobile and point-of-care (radiography)	mHealth and point-of-care	
24	Wälivaara et al., 2011	Teleconsultation and mobile	mHealth and	

		distance-spanning technology (MDST)	teleconsultation	
25	Crotty et al., 2014	Teleconsultation via videoconferencing and web-based health information through an App		
26	Lai et al. 2020	Smartphone-based teleophthalmology platforms		
27	Alexander, 2008; Alexander et al., 2015	Information management and clinical practice in different care departments	Clinical information integration	Integration of clinical information
28	Ohol, 2010	Electronic health record and technology-based devices		

Table 5: The Codes of Stakeholders' Acceptability

Authors and year	Sub-codes	Description	Codes	Theme
Huang et al., 2013	Severity of illness	The attributes of older adults include the severity of illness and other individual sociodemographic variables. The identified attributes of HCPs include education attainment, clinical working experience and the level of tech-savvy.	Attributes of residents	Attributes of residents and HCPs ^a
Armer et al., 2004	Education attainment		Attributes of HCPs	
Handler et al., 2013	Clinical working experience			
Betgé-Brezetz et al., 2009; Handler et al., 2013; Janardhanan et al., 2008	The level of tech-savvy			
Abbate et al., 2014; Chang et al., 2009	Awareness from external resources	External information from HCPs, friends, family members, and media sources.	Persuasiveness of external information	Coping process for information and technology appraisals
Eklund et al., 2012; Huang et al., 2015	User experience of received benefit from using a new technology	People acquire internal information by remembering personal experiences from their earlier experiences and satisfaction.	Persuasiveness of internal information	
Chang et al., 2012; Weiner et al., 2003; Yu et al., 2008; Zelickson, 2003	Achievement of user's satisfaction			
Betgé-Brezetz et al., 2009; Bleda et al., 2018; Delmastro et al., 2019; Qadri et al., 2009; Savenstedt et al., 2002; Wälivaara et al., 2011	Usefulness	The perceived efficaciousness of smart technologies was linked to the perceived usefulness, performance expectancy, relative advantage and pleasure experience by the users which was instrumental in achieving medical outcomes and meeting personal demands.	Perceived efficaciousness	
Alexander et al., 2007; Alexander et al., 2015; Handler et al., 2013; Janardhanan et al., 2008; Qadri et al., 2009	Helpfulness and improvement in care efficiency			
Chan et al., 2001; Rabinowitz et al., 2010; Weiner et al., 2003	A better solution in administrative procedures			
Crotty et al., 2014; Handler et al., 2013; Lavanya et al., 2006; Pallawala & Lun, 2001; Qadri et al., 2009; Vowden & Vowden, 2013; Okamoto et al. 2021	Improvement in quality of care			
Eklund et al., 2012; Singh et al., 2017	Assurance of quality of life			
Eklund et al., 2012	Improvement of healthcare accessibility and availability	The perceived usability includes effort expectancy, perceived ease of use, or perceived behavioral control (22). The usability appraisals depend on the availability or accessibility of these options, necessary for care, easy to understand, learn and use, affordability, compatible, the availability of tech-support during having difficulties of using a product, and “human-centric” designs such as matching preferences of users, portable and enjoyable to use.	Perceived usability (positive)	
Toh et al., 2015; Tseng et al., 2013	Necessity for care			
Huang et al., 2015; Janardhanan et al., 2008; Lavanya et al., 2006; Ohligs et al. 2020	Easy to use			

Huang et al., 2013; Lavanya et al., 2006; Yu et al., 2008	User-friendly		
Crotty et al., 2014; Hui & Woo, 2002	Convenience		
Abbate et al., 2014; Borelli et al., 2019	"Human-centric" designs to fit user lifestyles		
Hui & Woo, 2002	Affordability		
Rabinowitz et al., 2010; Yu et al., 2008	Adequate tech-support and regular training		
Gaglio et al., 2016	Appropriate domestication of a new technology		
Lavanya et al., 2006	Unusefulness	The negative perceiveness to the usability appraisals.	Perceived usability (negative)
Huang et al., 2015	Uncertainty of usefulness		
Fraile et al., 2010	Not easy to learn		
Delmastro et al., 2019	Not easy to use		
Alexander, 2005; Shafiee Hanjani et al., 2019	The difficulty of resources availability and accessibility		
Byrne, 2005	Lacking in supportive resources or tech-support		
Alexander et al., 2007; Huang et al., 2013	Burden of using technology		
Toh et al., 2015	Potential medical risks	The collateral damages refer to the unintended and harmful damages.	Perceived collateral damages
Huang et al., 2015	Sensitivity of technology and errors during the operation		
Chang et al., 2009	Overall concern of technology		

^aHCPs=Healthcare professionals

Figures

Figure 1

The Smart Technology Adoption Behaviors of Elderly Consumer Theoretical Model

Figure 2

Scoping Review Flow Diagram

Figure 3

The Concept of a Smart Nursing Home

Supplementary Files

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