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 the potential to elevate an operation that manages more significant number of older residents. However, the concepts, definitions, and types of smart technology, integrated medical services, and stakeholders' acceptability of smart nursing homes 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 (Phase 1) and 11 electronic databases (Phase 2), for existing concepts of smart nursing home, on what and how technologies and medical services were implemented in nursing home settings, and acceptability assessment by the stakeholders. The publication year was inclusive from January 1999 to September 2021. The language was limited to English and Chinese. Included articles must report nursing home settings related to older adults ≥ 60 years old with or without medical demands but not bed-bound. Technology Readiness Levels were used to measure the readiness of new technologies and system designs. The analysis was guided by the Framework Method and the smart technology adoption behaviours of elder consumers theoretical model. The results were 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 the life enjoyment of their 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, conducting teleconsultation, managing health information, and improving the interaction between providers and residents. Fifty-five percent of the new technologies were ready for use in nursing homes (levels 6–7), and the remaining were proven the technical feasibility (levels 1–5). Healthcare professionals with higher education, better tech-savviness, fewer years at work, and older adults with more severe illnesses were more acceptable to smart technologies.
Introduction
The 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]. Smart technologies could help older adults extend their independence and well-being [2]. In the earlier stage, many sensors and actuators were used as a ubiquitous environment (u-healthcare) to monitor patients [3]. IBM's (International Business Machines Corporation) first introduced the concept of 'Smarter Planet' [4], which was briefed as 'smart'. Later, smart technologies were 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 (mHealth) [6].

Smart technologies empower older adults to 'live in place' and lead their activities to maintain a quality of life [7]. Several studies have proven that smart technologies were feasible to apply in health monitoring, disease prediction, and detection of abnormal situations for home-based care residents [8, 9]. However, admission to nursing homes is usually a significant 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 provides residents a more comfortable and safe environment [11]. Nursing homes integrating smart technologies could benefit caregivers by saving time and reducing unnecessary workload while providing efficient and effective care services for 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 operations [14–16]. Many nations are seeking solutions for alternative senior care to cope with the challenges of the ageing population and encouraging technique 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 nursing home supervision department, initiated a report to promote IoT-based projects for senior institutional care. The Chinese government would financially support the pilot projects in health monitoring, fall detection, location tracking, and any innovation in big data management or analysis [18]. However, a clear concept of technique-assistant nursing home and the appropriate technologies related to ‘smartness’ is yet to be defined [19, 20].

Accordingly, a scoping review is needed to provide a smart nursing home model which includes a definition 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 service scope of smart nursing homes would help introduce appropriate smart technologies in the nursing home settings. A clear concept would also allow stakeholders to evaluate and monitor the operations of smart nursing homes with an evidence-based reference and enhance their acceptability of the smart nursing home model [21].

Theoretical model
The smart technology adoption behaviours of elder consumers theoretical model by Golant (2017) is adopted to guide this scoping review (Fig. 1) [22]. The model offers an adequate explanation of older adults’ coping process regarding adopting smart technologies. The coping process may come from the older adults’ unmet needs in daily life, the user perspective of perceived efficaciousness (usefulness, relative advantage of adoption), usability (easy or complex of use), and collateral damages (unintended harms of use) until deciding to adopt the ‘new’ solution. This coping process is also influenced by internal information (potential users’ past experiences) and external information such as the cues, tips or persuasions of friends, family members, and doctors on the potentials of technology, electronic devices or smart gadgets in daily living. Other factors such as user sociodemographic characteristics may affect their acceptability. The non-senior stakeholders, for example, the healthcare professionals (HCPs), may have the same coping process when considering the older adults’ unmet needs. This model is appropriate for formulating the review objectives.

Conclusions: Smart nursing homes with integrated medical services have great potential to improve the quality of care and ensure older residents’ quality of life.

Keywords: Smart nursing homes, Smart technologies, Integration of medical services, Quality of care, Acceptability of stakeholders
Review objectives

This scoping review was conducted to map the concepts of smart nursing homes systematically and to examine the qualitative evidence on technological feasibility, integration of medical services, and the stakeholders’ acceptability of smart nursing homes, 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 smart nursing homes and the criteria of services (Phase 1). The search was continued on the 11 electronic databases for technologies and integrated medical services implemented in nursing home settings, as well as the acceptability as reported by stakeholders, including nursing home residents and HCPs (Phase 2). The eligible articles searched in Phase 2 were included for extracting the definition of smart nursing homes and the criteria of services if they stated the respective information. Technology Readiness Level (TRL) was adopted to evaluate the feasibility and the maturity of a newly developed technology for future implementation [24]. The data 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] (Supplementary file 1).

Eligibility criteria

The eligibility criteria include: 1) concepts or definitions of smart nursing home; 2) nursing home residents aged ≥ 60 years old with or without medical demands but not bed-bound; 3) assessment of any health information technologies or models that were considered ‘smartness’ 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 irrelevant to the study objectives or not in nursing home settings were excluded, for example, the smart technologies applied in home-based settings or technologies used in entertainment, environmental control, and transportation for older adults.

Information sources and search strategy

Following the plan of the published study protocol [20], the search on stakeholder websites was conducted on three popular search engines for the statement of smart nursing homes, including ‘Google’, ‘Yahoo’ and ‘Baidu (a Chinese engine)’. The search used the following Chinese and English keywords sequentially: ‘Yang Lao Yuan’ (nursing home in Chinese) and followed by ‘smart nursing home’, ‘concept of smart nursing home’, ‘definition of smart nursing home’, ‘criteria of smart nursing home’, and ‘standard of smart nursing home’.

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, integrated medical services, and user acceptability 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 and the Wanfang Data) were the Chinese description of smart nursing homes.
homes, for example, Zhi Neng Yang Lao Yuan, Zhi Hui nursing Yang Lao Yuan, and 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 technology’ was first introduced in 1999 to describe the limited size of wireless sensor networks and millimeter-scale nodes [27]. Supplementary file 2 provides the search strategy on databases. An updated search was conducted on the 11 bibliographic databases by using the same method 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. This scoping review was conducted to provide an overview of the existing evidence of smart nursing home concepts, technological feasibility, integration of medical services, and stakeholders’ acceptability of smart nursing homes regardless of methodological quality or risk of bias [26]. Quality appraisal of reviewed literature and individual source of evidence was not applicable. The third reviewer was involved in the discussion and decided the results when two reviewers had disagreements in the selection process (FKR, SSG and BHC).

Data charting
The Framework Method is used to thematically analyse the qualitative data in this scoping review. It is a comparative form of thematic analysis that combines inductive and deductive approaches to analyse texture data and summarise the results, such as using a combination of data description and abstraction (codes and themes) [20]. The data from stakeholder websites and electronic databases were categorised by type of smart technology, technology function, direct user, integrated medical services, and stakeholder acceptability. Three investigators (YYZ, NKD, and JS) extracted the textual statements on the concept of smart nursing homes, implemented technologies, the integration of medical services, and stakeholders’ acceptability. Preliminary codes and themes related to the research objectives were named after the most frequently recurring terms within the same clusters, and the generalisability of textural data gave those names. The codes labelled for stakeholders’ acceptability were referred to the theoretical model [22]. 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 at least three investigators reached a consensus.

Results
A total of 177 pieces of literature (Fig. 2 and supplementary file 3) were selected for review comprising 13 documents from stakeholders’ websites (Phase 1) and 164 articles from bibliographic databases (Phase 2).

Phase 1: Definition, concepts and criteria of a smart nursing home
Thirty documents and articles (supplementary file 3) were included to retrieve the definitions, concepts, and criteria of smart nursing homes. Of these, there were 13 documents searched from the stakeholder websites in Phase 1 and 17 research papers 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 three themes related to the concept of smart nursing homes (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].

The qualitative analysis defined a smart nursing home as a collective or individual senior care model. In particular, the smart nursing home integrates the older adults’ daily routine of life and healthcare needs with information technologies or engineering to provide continuous monitoring for its residents, connect communication within its care providers, and conduct teleconsultation with external medical resources. Technology-assisted nursing care ensures life enjoyment in an affordable and safe environment. The smart nursing home services with immediate health attention and people-centered respect are effective, efficient, and evidence-based. Supplementary file 4 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 [47] and one system design of engineering methodology [55], were only eligible to be included for exacting the definition of smart nursing homes. There were 162 articles searched in Phase 2 (Table 2) were included to extract the technological feasibility, integration of medical services, and stakeholders’ acceptability. Out of these, 50% \((n = 81)\) were studies of 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. Most resources were from the USA \((n = 40)\) and China, including Taiwan \((n = 41)\).

Technologies related to ‘smartness’

Smart technologies offer much more interaction between the nursing home resident and HCPs, enhance safety, and improve the quality of care [11, 202]. Out of 162 articles, 41% articles \((n = 66)\) reported on IoT, 35% \((n = 57)\) on digital health, 12% \((n = 20)\) on information management.
### Table 1  The codes of defining the concepts and criteria of a smart nursing home

| Authors and year | Codes | Description | Themes |
|------------------|-------|-------------|--------|
| a. Concept of smart nursing homes | IoT<sup>a</sup> | 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) |
| Baidu, 2018 [29]; Ce.cn, 2019 [30]; Chen & Li, 2012 [31]; Gamberini et al., 2018 [11]; Huang et al., 2019 [12]; Korte [32]; Lee et al., 2018 [33]; Mahieu et al., 2019 [34]; MCA, 2014 [18]; Roh & Park, 2017 [35]; Shenghuo, 2020 [36]; Tang et al., 2019 [37]; Wang, 2014 [19]; Wang, 2020 [38]; Xie, 2017 [39]; Xiexiebang, 2019 [40]; Xu & Tuo, 2019 [41] | Computing technologies | |
| Korte [32]; SheCuiTong [43]; Cui et al., 2020 [42]; Telpo [44] | Cloud computing | Cloud computing | |
| Cui et al., 2020 [42]; Mahieu et al., 2019 [34]; MHURD [45]; Telpo [44]; Xu & Tuo, 2019 [41] | Big data and AI<sup>b</sup> | Big data and AI<sup>b</sup> | |
| Baidu, 2018 [29]; Liuye [46]; MHURD [45]; Morley, 2012 [47] | Information management system (IMS) | Information management system (IMS) | |
| BOE Technology Group Co., 2018 [48]; MHURD [45]; Morley, 2012 [47]; Shenghuo, 2020 [36]; Telpo [44] | Digital health | Digital health | |
| Shenghuo, 2020 [36]; Siciliano & Khatib, 2016 [49]; Sun et al., 2015 [50] | Assistive devices | Assistive devices | |
| Cui et al., 2020 [42]; Deng, 2019 [51]; MCA, 2014 [18]; Tang et al., 2019 [57] | Intelligent nursing | 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 |
| Korte [32]; Lee et al., 2018 [33]; Xie, 2017 [39] | Automated tracking, monitoring and alerts | Automated tracking, monitoring and alerts | |
| Huang, 2019 [52]; Korte [32]; Wang, 2014 [19] | Improving quality of life | Improving quality of life | |
| Baidu, 2018 [29]; Cui et al., 2020 [42]; MHURD [45]; Tang et al., 2019 [57] | Meeting older adults and users' satisfaction | Meeting older adults and users' satisfaction | |
| Cui et al., 2020 [42]; Korte [32]; Morley, 2012 [47] | Similar to smart home | Similar to smart home | Combination of smart home and hospital model |
| Cui et al., 2020 [42]; Korte [32] | Home and hospital models | Home and hospital models | |
| Gamberini et al., 2018 [11] | More comfortable and safe environments | More comfortable and safe environments | |
| Cui et al., 2020 [42]; Siciliano & Khatib, 2016 [49] | Special users—older adults and caregivers | Special users—older adults and caregivers | |
| Authors and year | Codes | Description | Themes |
|------------------|-------|-------------|--------|
| b. Criteria of smart nursing homes | 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 |
| Baidu, 2018 [29]; Huang et al., 2019 [12]; Korte [32]; Matusitz et al., 2013 [53]; MHURD [45]; Tang et al., 2019 [37] | Safe | | |
| Huang et al., 2019 [12]; MHURD [45]; Siciliano & Khatib, 2016 [49]; Wang, 2020 [38]; Xiexiebang, 2019 [40] | Effective | | |
| Baidu, 2018 [29]; Betgé-Brezetz et al., 2009 [54]; Cui et al., 2020 [42]; MHURD [45]; Shenghuo, 2020 [36]; Tang et al., 2019 [37] | Efficient | | |
| Baidu, 2018 [29]; Cui et al., 2020 [42]; SheCuiTong [43]; Siciliano & Khatib, 2016 [49]; Tang et al., 2019 [37]; Xiexiebang, 2019 [40] | People-centered (PC) | | |
| Cui et al., 2020 [42]; Huang et al., 2019 [12]; Korte [32]; MHURD [45]; Telpo [44]; Wang, 2014 [19] | | | |

*a IoT Internet of things

b AI Artificial intelligence
| 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 [56] | Japan         | Journal article     | System design | Monitoring abnormal events (only location)                               | IoT                                 | Residents*  | Monitoring and notification of abnormal events |
| 2  | Fischer et al., 2008 [57] | Australia     | Conference paper    | System design | Monitoring abnormal events                                               | IoT                                 | Residents   |                        |
| 3  | Lin et al., 2008 [58] | Taiwan, China | Conference paper    | System design | Monitoring abnormal events                                               | IoT                                 | Residents   |                        |
| 4  | Betgé-Brezetz et al., 2009 [54] | USA          | Conference paper    | System design | Notification for specific events                                         | Computing technologies             | Residents   |                        |
| 5  | Biswas et al., 2009 [59] | Singapore     | Book                | System design | Monitoring abnormal events (Sleeping monitoring)                        | IoT                                 | Residents   |                        |
| 6  | Hu et al., 2009 [60] | USA           | Journal article     | System design | Monitoring abnormal events                                               | IoT                                 | NHP staffs  |                        |
| 7  | Fraile et al., 2010 [61] | Spain         | Conference paper    | System design | Monitoring abnormal events                                               | IoT                                 | Residents   |                        |
| 8  | Pallikonda Rajasekaran et al., 2010 [62] | India        | Journal article     | System design | Monitoring abnormal events                                               | IoT                                 | Residents   |                        |
| 9  | Gower et al., 2011 [63] | Italy         | Conference paper    | System design | Monitoring abnormal events                                               | IoT                                 | Residents   |                        |
| 10 | Lee et al., 2011 [64] | South Korea   | Journal article     | System design | Monitoring abnormal events                                               | IoT                                 | Residents   |                        |
| 11 | Sun, 2011 [65] | China          | Book                | System design | Monitoring abnormal events                                               | IoT                                 | Residents   |                        |
| 12 | Wu & Huang, 2011 [66] | Taiwan, China | Conference paper    | System design | Monitoring abnormal events                                               | IoT                                 | Residents   |                        |
| 13 | Back et al., 2012 [67] | Finland       | Journal article     | System design | Monitoring abnormal events                                               | IoT                                 | Residents   |                        |
| 14 | Chang et al., 2012 [68] | Taiwan, China | Journal article     | System design | Monitoring abnormal events                                               | IoT                                 | Residents   |                        |
| 15 | Chen & Li, 2012 [31] | China         | Thesis              | System design | Monitoring abnormal events                                               | IoT                                 | Residents   |                        |
| 16 | Nijhof et al., 2012 [69] | Netherlands   | Journal article     | Mixed methods  | Monitoring abnormal events (Sleep/wake rhythm monitoring)                | IoT                                 | Residents   |                        |
| 17 | Ghorbel et al, 2013 [70] | France        | Journal article     | System design | Notification for specific events                                         | Computing technologies             | Residents   |                        |
| 18 | Huang et al., 2013 [71] | Taiwan, China | Conference paper    | System design | Monitoring abnormal events                                               | IoT                                 | Residents   |                        |
| No. | Authors and year | Country | Type of Publication | Study design | Technologies related to ‘smartness’ | Direct User Function of Technology |
|-----|------------------|---------|--------------------|--------------|-------------------------------------|-----------------------------------|
| 19  | Matsui et al., 2013 [72] | USA | Journal article | System design | Monitoring abnormal events | Residents |
| 20  | Neuhaeuser & D’Angelo, 2013 [73] | Germany | Conference paper | System design | Monitoring abnormal events | Residents |
| 21  | Pan, 2013 [74] | China | Thesis | System design | Monitoring abnormal events | Residents |
| 22  | Tseng et al., 2013 [75] | USA | Journal article | System design | Monitoring abnormal events | Residents |
| 23  | Abbate et al., 2014 [76] | Italy | Thesis | System design | Fall detection | Residents |
| 24  | Chu et al., 2014 [77] | China | Journal article | System design | Monitoring abnormal events | Residents |
| 25  | Liu & Hai, 2014 [78] | Taiwan, China | Journal article | System design | Monitoring abnormal events (Smart mattress) | Residents |
| 26  | Wang, 2014 [79] | Japan | Thesis | System design | Monitoring abnormal events (Sleep monitoring) | Residents |
| 27  | Zhu et al., 2014 [80] | China | Thesis | System design | Monitoring abnormal events | Residents |
| 28  | Andò et al., 2015 [81] | Italy | Conference paper | System design | Monitoring abnormal events | Residents |
| 29  | Carvalho et al., 2015 [82] | France | Conference paper | System design | Monitoring abnormal events | Residents |
| 30  | Yu et al., 2015 [83] | UK | Journal article | System design | Monitoring abnormal events | Residents |
| 31  | Danielson et al., 2016 [84] | Norway | Conference paper | System design | Monitoring abnormal events | Residents |
| 32  | Chao et al., 2016 [85] | Spain | Journal article | System design | Monitoring abnormal events | Residents |
| 33  | Lopez-Samaniego & Garcia-Zapirain, 2016 [86] | Spain | Conference paper | System design | Monitoring abnormal events | Residents |
| 34  | Ameneiref et al., 2017 [87] | Indonesia | Conference paper | System design | Monitoring abnormal events | Residents |
| 35  | Jiang, 2017 [88] | China | Thesis | System design | Monitoring abnormal events | Residents |
| 36  | Mendes et al., 2017 [89] | Portugal | Conference paper | System design | Monitoring abnormal events | Residents |
| 37  | Mendes et al., 2018 [90] | Philippines | Conference paper | System design | Monitoring abnormal events | Residents |
| No | Authors and year | Country | Type of Publication | Study design | Application | Technologies related to ‘smartness’ | Direct User | Function of Technology |
|----|-----------------|---------|---------------------|--------------|-------------|-----------------------------------|-------------|------------------------|
| 38 | Montanini et al., 2017 [90] | Italy | Conference paper | System design | Monitoring abnormal events (Night monitoring of patients with dementia) | IoT | Residents |
| 39 | Saad et al., 2017 [91] | Malaysia | Conference paper | System design | Monitoring abnormal events | IoT | Residents |
| 40 | Singh et al., 2017 [92] | Austria | Conference paper | Qualitative | Monitoring abnormal events | IoT | Residents |
| 41 | Wu et al., 2017 [93] | China | Conference paper | System design | Monitoring abnormal events | Computing technologies | Residents |
| 42 | Xie, 2017 [39] | China | Thesis | System design | Monitoring abnormal events | Big data and AI | Residents |
| 43 | Bleda et al., 2018 [94] | Spain | Conference paper | System design | Monitoring abnormal events (Smart mattress) | IoT | Residents |
| 44 | Donnelly et al., 2018 [95] | Ireland | Journal article | Qualitative | Fall detection | IoT | Residents |
| 45 | Gamberini et al., 2018 [11] | Italy | Book | Non-research article | Monitoring abnormal events | IoT | Residents |
| 46 | Lee et al., 2018 [33] | South Korea | Conference paper | System design | Monitoring abnormal events | IoT | Residents |
| 47 | Mahfuz et al., 2018 [96] | Canada | Conference paper | System design | Fall detection | IoT | Residents |
| 48 | Morita et al., 2018 [97] | Japan | Conference paper | System design | Monitoring abnormal events | Big data and AI | Residents |
| 49 | Wu et al., 2018 [98] | China | Journal article | System design | Monitoring abnormal events | IoT | Residents |
| 50 | Borelli et al., 2019 [99] | Italy | Journal article | System design | Monitoring abnormal events | IoT | Residents |
| 51 | Cai & Wang, 2019 [100] | China | Journal article | System design | Fall detection | IoT | Residents |
| 52 | Delmastro et al., 2019 [101] | Italy | Journal article | Experimental | Monitoring abnormal events | Cloud computing | Residents |
| 53 | Deng, 2019 [51] | China | Thesis | System design | Monitoring abnormal events | IoT | Residents |
| 54 | Fong et al., 2019 [102] | USA | Conference paper | System design | Monitoring abnormal events | IoT | Residents |
| 55 | Ghosh et al., 2019 [103] | India | Conference paper | System design | Monitoring abnormal events | Big data and AI | Residents |
| 56 | Huang, 2019 [52] | China | Thesis | System design | Fall detection | Big data and AI | Residents |
| No | Authors and year | Country       | Type of Publication | Study design | Application              | Technologies related to ‘smartness’ | Direct User | Function of Technology |
|----|------------------|---------------|---------------------|--------------|--------------------------|------------------------------------|-------------|------------------------|
| 57 | Huang et al., 2019 [12] | Taiwan, China | Conference paper   | System design | Monitoring abnormal events | IoT | Residents |
| 58 | Lenoir, 2019 [104] | Japan         | Conference paper   | System design | Monitoring abnormal events | IoT | Residents |
| 59 | Shen, 2019 [105]  | China         | Journal article    | System design | Monitoring abnormal events | IoT | Residents |
| 60 | Takahashi et al., 2019 [106] | Japan | Conference paper   | System design | Monitoring abnormal events (only location) | IoT | Residents |
| 61 | Tang et al., 2019 [37] | China         | Journal article    | System design | Monitoring abnormal events | IoT | Residents |
| 62 | Toda & Shinomiya, 2019 [107] | Japan | Conference paper   | System design | Fall detection | IoT | Residents |
| 63 | Xiao, 2019 [108]  | China         | Thesis             | System design | Monitoring abnormal events (Smart mattress) | IoT | Residents |
| 64 | Xu & Tuo, 2019 [108] | China         | Journal article    | Non-research article | Monitoring abnormal events | IoT | Residents |
| 65 | Yoo et al., 2019 [109] | South Korea  | Conference paper   | System design | Monitoring abnormal events | IoT | Residents |
| 66 | Buisseret et al. 2020 [110] | Belgium      | Journal article    | System design | Fall prediction | Big data and AI | Residents |
| 67 | Chen et al. 2021 [111] | China         | Conference paper   | System design | Fall prediction | Big data and AI | Residents |
| 68 | Gharti 2020 [112] | Australia     | Conference Paper   | Non-research article | Fall detection | IoT | Residents |
| 69 | Lanza et al. 2020 [113] | Italy         | Journal article    | System design | Monitoring abnormal events | Big data and AI | Residents |
| 70 | Lee et al. 2020 [114] | South Korea  | Journal article    | System design | Fall prediction | Big data and AI | HCPs |
| 71 | Mishkhal et al. 2020 [115] | Iraq         | Conference paper   | System design | Fall prediction | IoT | Residents |
| 72 | Suzuki et al. 2020 [56] | Japan         | Journal article    | Non-experimental | Fall prediction | Big data and AI | Residents |
| 73 | Wang, 2020 [38]  | China         | Thesis             | System design | Monitoring abnormal events | IoT | Residents |
| 74 | Wan et al. 2021 [116] | China         | Journal article    | System design | Fall detection | IoT | Residents |
| 75 | Chen et al. 2021 [111, 117] | Taiwan, China | Conference paper   | System design | Monitoring abnormal events | IoT | Residents |
| 76 | Flores-Martin et al. 2021 [118] | Spain       | Journal article    | System design | Monitoring abnormal events | IoT | Residents |
| No. | Authors and year | Country       | Type of Publication | Study design | Application Technologies related to ‘smartness’ | Function of Technology | Direct User | Function of Technology                  |
|-----|-----------------|---------------|---------------------|--------------|-----------------------------------------------|------------------------|-------------|----------------------------------------|
| 77  | Chan et al., 2001 | China         | Journal article     | Non-experimental | Non-experimental Telmedicine Digital health   | Residents              | Residents   | Remote clinical services through digital health |
| 78  | Paliwal & Lim, 2001 | Singapore     | Journal article     | Non-experimental | Experimental Telmedicine  | Residents              | Residents   | Residency                 |
| 79  | Weiner et al., 2002 | China         | Journal article     | Experimental   | Experimental Telmedicine Digital health      | Residents              | Residents   | Residency                 |
| 80  | Hui & Woo, 2002  | USA           | Journal article     | Non-experimental | Experimental Telmedicine Digital health      | Residents              | Residents   | Residency                 |
| 81  | Sawant & et al., 2002 | Sweden       | Journal article     | Experimental   | Experimental Telmedicine Digital health      | Residents              | Residents   | Residency                 |
| 82  | Weiner et al., 2001 | USA           | Conference paper    | Experimental   | Experimental Telmedicine Digital health      | Residents              | Residents   | Residency                 |
| 83  | Zelckson et al., 2003 | USA          | Journal article     | Non-experimental | Experimental Telmedicine Digital health      | Residents              | Residents   | Residency                 |
| 84  | Amer et al., 2004 | USA           | Journal article     | Experimental   | Experimental Telmedicine Digital health      | Residents              | Residents   | Residency                 |
| 85  | Savenstedt et al., 2004 | Sweden     | Journal article     | Qualitative    | Qualitative Telmedicine Digital health Mobile X-ray | Digital health         | Residents   | Residency                 |
| 86  | Daly et al., 2005  | USA           | Conference paper    | Experimental   | Experimental Teledermatology (Clinical assessment system) | Digital health         | Residents   | Residency                 |
| 87  | Lavanya et al., 2006 | Singapore     | Journal article     | Non-experimental | Non-experimental Telmedicine Digital health  | Residents              | Residents   | Residency                 |
| 88  | Lo et al., 2006  | USA           | Journal article     | Non-experimental | Experimental Telmedicine Digital health      | Residents              | Residents   | Residency                 |
| 89  | Shu et al., 2006  | Canada        | Journal article     | Non-experimental | Non-experimental Telmedicine Digital health  | Residents              | Residents   | Residency                 |
| 90  | Gu et al., 2006  | USA           | Journal article     | Experimental   | Experimental Telmedicine Digital health      | Residents              | Residents   | Residency                 |
| 91  | Worahalan et al., 2007 | Singapore | Journal article     | Non-experimental | Experimental Telmedicine Digital health      | Residents              | Residents   | Residency                 |
| 92  | Pujari et al., 2009  | Canada        | Journal article     | Experimental   | Experimental Telmedicine Digital health      | Residents              | Residents   | Residency                 |
| 93  | Chang et al., 2009 | USA           | Journal article     | Non-experimental | Non-experimental Telmedicine Digital health  | Residents              | Residents   | Residency                 |
| 94  | Qadri et al., 2009 | USA           | Conference paper    | Mixed methods   | Mixed methods Telmedicine Digital health Mobile X-ray | Digital health         | Nurses and Dermatologists | Residents |
| 95  | Chang et al., 2010 | Taiwan, China | Journal article     | Non-experimental | Non-experimental Telmedicine Digital health  | Residents              | Residents   | Residency                 |
| 96  | Rabo et al., 2010 | Sweden        | Journal article     | Non-experimental | Non-experimental Telmedicine Digital health  | Residents              | Residents   | Residency                 |
| 97  | Wanka et al., 2011 | USA           | Journal article     | Non-experimental | Non-experimental Telmedicine Digital health  | Residents              | Residents   | Residency                 |
| 98  | Blund et al., 2012  | USA           | Journal article     | Non-experimental | Non-experimental Telmedicine Digital health  | Residents              | Residents   | Residency                 |
| 99  | Gray et al., 2013  | Australia      | Journal article     | Non-experimental | Non-experimental Telmedicine Digital health  | Residents              | Residents   | Residency                 |
| 100 | Handler et al., 2013 | USA          | Journal article     | Non-experimental | Non-experimental Telmedicine Digital health  | Residents              | Residents   | Residency                 |
| No | Authors and year | Country | Type of Publication | Study design | Application | Technologies related to ‘smartness’ | Direct User | Function of Technology |
|----|------------------|---------|---------------------|--------------|-------------|------------------------------------|-------------|------------------------|
| 101 | Novak et al., 2013 [143] | USA | Conference paper | Experimental | Telemedicine | Digital health | Residents |
| 102 | Vowden & Vowden, 2013 [144] | UK | Journal article | Experimental | Telemedicine | Digital health | Residents |
| 103 | Catic et al., 2014 [145] | USA | Journal article | Non-experimental | Telemedicine | Digital health | Residents |
| 104 | Grabowski & O’Malley, 2014 [146] | USA | Journal article | Experimental | Telemedicine | Digital health | Residents |
| 105 | Crotty et al., 2014 [147] | Australia | Journal article | Experimental | Telemedicine | Digital health | Residents |
| 106 | Doumbouya et al., 2015 [148] | France | Journal article | System design | Telemedicine | Digital health | Residents |
| 107 | F. Huang et al., 2015 [149] | Taiwan, China | Journal article | Experimental | Telemedicine | Digital health | Residents |
| 108 | Montalto et al., 2015 [150] | Australia | Conference paper | Non-experimental | Telemedicine (Mobile X-ray) | Digital health | Residents |
| 109 | Toh et al., 2015b [151] | Singapore | Conference paper | Qualitative | Telemedicine | Digital health | Residents |
| 110 | Toh et al., 2015a [152] | Singapore | Conference paper | Non-experimental | Telemedicine | Digital health | Residents |
| 111 | Volicier, 2015 [153] | USA | Journal article | Non-research article | Telemedicine | Digital health | Residents |
| 112 | De Luca et al., 2016 [154] | Italy | Journal article | Experimental | Telemedicine | Digital health | Residents |
| 113 | Dizet et al., 2016 [155] | Sweden | Journal article | Non-experimental | Telemedicine (Mobile X-ray) | Digital health | Residents |
| 114 | Driesen et al., 2016 [156] | USA | Journal article | Non-experimental | Telemedicine | Digital health | Residents |
| 115 | Guglielmi et al., 2016 [157] | France | Conference paper | Qualitative | Telemedicine | Digital health | Residents |
| 116 | Gillespie et al., 2016 [158] | USA | Journal article | Non-experimental | Telemedicine | Digital health | Residents |
| 117 | Morley, 2016 [159] | USA | Journal article | Non-research article | Telemedicine | Digital health | Residents |
| 118 | Schneider et al., 2016 [160] | USA | Journal article | Non-experimental | Telemedicine | Digital health | Residents |
| 119 | Kjelle & Lysdahl, 2017 [161] | Norway | Journal article | Non-research article | Telemedicine (Mobile X-ray) | Digital health | Residents |
| 120 | Newbould et al., 2017 [162] | UK | Book | Non-experimental | Telemedicine | Digital health | Residents |
| 121 | Quevauvilliers et al., 2017 [163] | France | Journal article | Non-experimental | Telemedicine | Digital health | Residents |
| 122 | Delmastro et al., 2018 [101, 164] | Italy | Conference paper | Non-experimental | Telemedicine | Digital health | Residents |
| 123 | Kjelle et al., 2018 [165] | Norway | Journal article | Qualitative | Telemedicine (Mobile X-ray) | Digital health | Residents |
| No | Authors and year | Country | Type of Publication | Study design | Application | Technologies related to ‘smartness’ | Direct User | Function of Technology |
|----|------------------|---------|---------------------|--------------|-------------|-----------------------------------|-------------|------------------------|
| 124 | Esteves et al., 2019 [166] | Portugal | Journal article | System design | Telemedicine | Digital health | HCPs | |
| 125 | Gentry et al., 2019 [167] | USA | Journal article | Non-research article | Telemedicine | Digital health | Residents | |
| 126 | Ozkaynak et al., 2019 [168] | USA | Journal article | Qualitative | Telemedicine (Clinical assessment system) | Digital health | NH staffs | |
| 127 | Shaheen Hanjani et al., 2019 [169] | Australia | Journal article | Mixed methods | Telemedicine | Digital health | Residents | |
| 128 | Cormi et al., 2020 [170] | France | Journal article | Non-research article | Telemedicine | Digital health | Residents | |
| 129 | Lai et al., 2020 [171] | USA | Journal article | Non-experimental | Teleophthalmology | Digital health | Residents | |
| 130 | Low et al., 2020 [172] | Singapore | Journal article | Non-experimental | Telemedicine | Digital health | Residents | |
| 131 | Ohligs et al., 2020 [173] | Germany | Journal article | Non-experimental | Telemedicine | Digital health | Residents | |
| 132 | Alexander et al., 2021 [174] | USA | Journal article | Non-experimental | Telemedicine | Digital health | Residents | |
| 133 | Okamoto et al., 2021 [175] | USA | Conference paper | Non-research article | Telemedicine | Digital health | Residents | |
| 134 | Lenderink & Egberts, 2004 [176] | Netherlands | Journal article | Non-experimental | Information management and decision making | IMS² | Nurses | Information management and decision making |
| 135 | Alexander, 2005 [177] | USA | Thesis | Non-experimental | Information management and decision making | IMS | Administrative staffs | |
| 136 | Byrne, 2005 [178] | USA | Thesis | Experimental | Information management and decision making | IMS | NH staffs | |
| 137 | Celler et al., 2006 [179] | Australia | Conference paper | Non-experimental | Information management and decision making | IMS | NH staffs | |
| 138 | Cherry, 2006 [180] | USA | Thesis | Qualitative | Information management and decision making | IMS | HCPs | |
| 139 | Alexander et al., 2007 [181] | USA | Journal article | Qualitative | Information management and decision making | IMS | NH staffs | |
| 140 | Alexander, 2008 [182] | USA | Journal article | Non-experimental | Information management and decision making | IMS | NH staffs | |
| 141 | Breen & Zhang, 2008 [183] | USA | Journal article | Non-research article | Information management and decision making | IMS | Nurses and other medical practitioners |
| No  | Authors and year       | Country  | Type of Publication | Study design  | Application                                                                 | Technologies related to 'smartness' | Direct User | Function of Technology                                                                 |
|-----|------------------------|----------|---------------------|---------------|-----------------------------------------------------------------------------|-------------------------------------|-------------|---------------------------------------------------------------------------------------|
| 142 | Yu et al., 2008 [184]  | 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 [186] | USA | Journal article | Non-experimental | Information management and decision making                                 | IMS                                 | Practitioners, nursing staffs, medication administrators and NH leadership |                                                        |
| 145 | Ohol, 2010 [187]       | USA      | Thesis              | System design | Information management and decision making                                 | IMS                                 | Clinical staffs |                                                                                       |
| 146 | Matusitz et al., 2013 [53] | USA | Journal article | Non-research article | Information management and decision making                                 | IMS                                 | Healthcare practitioners |                                                                                       |
| 147 | Alexander et al., 2015 [188] | USA | Journal article | Qualitative     | Information management and decision making                                 | IMS                                 | Clinical staffs |                                                                                       |
| 148 | Z. Huang et al., 2015 [189] | China | Journal article | System design | Information management and decision making                                 | IMS                                 | NH staffs and administration |                                                                                       |
| 149 | Wang, 2016 [190]       | China    | Journal article     | Non-research article | Information management and decision making                                 | IMS                                 | HCPs and administration |                                                                                       |
| 150 | Zhang, 2017 [191]      | China    | Thesis              | System design  | Information management and decision making                                 | IMS                                 | Doctors, nurses and caregivers |                                                                                       |
| 151 | Xie, 2016 [192]        | China    | Thesis              | System design  | Information management and decision making                                 | IMS                                 | Caregivers  |                                                                                       |
| 152 | Ausserhofer et al. 2021 [193] | Switzerland | Journal article | Non-experimental | Information management and decision making                                 | IMS                                 | Care workers and nurses |                                                                                       |
| 153 | Kei Hong et al. 2021 [194] | China | Journal article | Non-experimental | Information management and decision making                                 | IMS                                 | HCPs |                                                                                       |
| 154 | Masuda & Numao, 2017 [195] | Japan | Conference paper | System design | Clinical data analysis (Diagnosis)                                           | IoT                                 | Residents | Clinical data analysis by AI |
| No | Authors and year | Country      | Type of Publication | Study design         | Application                          | Technologies related to 'smartness' | Direct User | Function of Technology |
|----|------------------|--------------|---------------------|----------------------|--------------------------------------|------------------------------------|-------------|------------------------|
| 155 | Roh & Park, 2017 [35] | South Korea | Journal article    | System design        | Quality of Life measurements        | Big data and AI                     | HCPs        |                        |
| 156 | González et al., 2019 [196] | Spain      | Journal article    | System design        | Clinical data analysis (frailty and cognition status) | IoT                                | HCPs        |                        |
| 157 | Kokubo & Kamiya, 2019 [197] | 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 [198] | Australia | Journal article    | Non-experimental     | Identifying frailty by using artificial intelligence (AI) algorithms | Big data and AI                     | HCPs        |                        |
| 159 | Hsu et al., 2010 [199] | Taiwan, China | Journal article    | System design        | ADLs assistance (Pillbox)            | IoT                                | Residents   | Activities of daily living (ADLs) assistance |
| 160 | Chang et al., 2011 [200] | Taiwan, China | Journal article    | System design        | ADLs assistance (Pillbox)            | IoT                                | Residents   |                        |
| 161 | Sun et al., 2015 [50] | China       | Journal article    | System design        | ADLs assistance (Intelligent robot)  | Computing technologies             | Residents   |                        |
| 162 | Tsai et al., 2017 [201] | Taiwan, China | 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
system (IMS), 8% \((n=13)\) on big data and AI, 3% \((n=5)\) on computing technologies and 1% \((n=1)\) on cloud computing.

**Functions of smart technology in nursing home settings and direct users**

Forty-seven percent of included articles \((n=76)\) reported technologies for monitoring and notification of abnormal events, such as health monitoring, fall detection, and location tracking, 35% \((n=57)\) for remote clinical services through digital health, 12% \((n=20)\) for information management and decision making, 3% \((n=5)\) for clinical data analysis by AI approach, and 3% \((n=4)\) for 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 were 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 \([52, 76, 84, 95, 96, 100, 107, 110–112, 114–116]\), automatic monitoring of health conditions, and notification of emerging events, such as heart attacks and fatal accidents \([11, 12, 19, 31, 33, 37–39, 41, 51, 54, 57–75, 77–83, 85–94, 97–109, 113, 118, 202, 203]\). The vital sign of older adults could be collected and recorded by the wearable devices, such as clothes and shoes on nursing home residents \([96, 106]\). Sensors were installed in the mattresses and rooms to monitor the older adults’ behaviours and sleeping quality, especially used for residents with limited mobility \([51, 90]\). Biosensors, ultrasonic sensors, infrared sensors, radio frequency identification (RFID), and GPS were mainly used with IoT terminals \([71, 77, 83, 87]\). Cameras, mobile devices, and personal computers were embedded with sensor networks to assist the real-time monitoring. Family members could also be given access to the real-time monitoring of their senior family members in the nursing homes \([95]\). Such a solution improved care efficiency and decision-making of nursing home HCPs, especially in managing a large number of nursing home residents with cognitive disorders \([94]\).

**Remote clinical services through digital health**

Digital health, including telemedicine and mHealth, has shown to benefit the older adults in nursing homes in rural areas with good internet or communication coverage \([119, 120, 122, 124, 126, 127, 131–134, 136, 137, 139, 141, 146, 148, 149, 151, 152, 154, 156–162, 166, 168, 204]\). During the COVID-19 pandemic, telemedicine reduced unnecessary hospitalisation \([170, 175]\). Digital images of the residents could be transmitted in real-time to hospital specialists, and that enabled the electronic stethoscopes, otoscopes, dermoscopic, dental scopes, and electrocardiograms to be implemented through the internet and live video to assist clinical practices \([128]\). Telehealth and mHealth were widely applied in managing cognitive disorders \([145, 153, 172]\), dermatologic conditions \([125–144]\), cardiovascular diseases \([124, 137, 173]\), diabetes mellitus \([143]\), rehabilitation of disabilities \([147, 202]\), dentistry \([163]\) and ophthalmology \([171]\) in the distance. The portable X-ray machine attached with mobile devices 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 \([130, 140, 150, 155, 161]\). Telemedicine with designed software helped doctors to prescribe medicines remotely and avoid adverse drug events \([123, 142]\).

**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, care quality assessment, clinical task schedule, and medication records \([179, 180, 186, 188]\). 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 \([182, 187]\). 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 \([53, 176–178, 181, 183–185, 187, 189, 191, 193, 194]\).

**Clinical data analysis by AI**

AI approach helped with health-related parameter analysis and big data management \([35, 197]\). Using AI to analyse biometric data collected from older adults enabled the identification of potential relationships between parameters and frailty \([196, 198]\). As an emerging technology, big data analytics, data mining, and classification used 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 \([88]\).

**Activities of daily living (ADLs) assistance**

Based on the IoT and computing technologies, smart toolkits have 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 helped
them in taking their daily medications to improve medication adherence [199–201]. Humanoid robots were developed to monitor nursing home residents’ activities and ensure their safety in certain areas [50].

**Technology Readiness Level (TRL) measurement**

TRL classifies nine levels of developmental stages, from basic principles and technology concepts formulated to the completion and proof of actual system [205]. Of the 81 articles on system designs, three [83, 90, 117] 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 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**

Forty-four out of 162 articles 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 supplementary file 5).

**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 systems (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 integrating real-time videoconference was applicable to replace face-to-face consultations in nursing homes through videophones or computers combined with cameras and microphones, and it enhanced clinical efficiency and cost-effectiveness of healthcare delivery [127, 128, 138, 145]. Teleconsultation integrated health monitoring devices, such as mobile phones or smartwatches, provided a telemonitoring service to record heart rate and blood pressure electronically, and it enabled the HCPs to take prompt responses to the older adults’ urgent health conditions in remote nursing homes [19, 51, 62, 115, 154, 191]. 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 [125, 133, 144, 172].

**Integration of medical services through mHealth**

Abnormal events monitoring [78, 88, 95, 202], radiography [150, 166, 206], and teleconsultation [139, 147, 171] could be implemented through mobile devices. mHealth personalised nursing home services, improved efficiency in the closer connection between HCPs and nursing home residents, lowered incidences of unnoticed events, and ensured the residents’ quality of life [142]. Mobile devices 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 [88]. Mobile applications could assist HCPs at point-of-care in scheduling clinical tasks, performing radiography, digitally recording their clinical practices resulting in time-saving and error reduction [166]. Besides, personal mobiles or tablets were used to connect nursing home residents to conduct teleconsultation [139].

**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 [187, 188].

**Stakeholders’ acceptability**

Guided by the theoretical model proposed by Golant (2017) [22], the scoping review observed both the expected and unexpected reasons related to stakeholders’ acceptability of smart technologies. In addition, individual attributes were associated with the adoption of smart technologies (Table 5 and supplementary file 6).

**Persuasiveness of external information and internal information**

Older adults became more aware and willing to use new technology when persuaded or compelled by the potential benefit of the technology from external resources, for example, their family members or HCPs [76, 135]. This coping process is also influenced by internal information, such as user-experienced helpfulness, ease of use, and safety features of the technology [140, 149]. These factors resulted in user satisfaction and enhanced positive attitudes to the final adoption of smart technologies [68, 124].
| No | Authors and year | Country       | Study design | Function of Technology | Technologies related to 'smartness' |
|----|------------------|---------------|--------------|------------------------|-------------------------------------|
| 1  | Sun et al., 2015 | China         | System design | Assisting ADLs, Information management and decision making | Computing technologies |
| 2  | Xie, 2016        | China         | System design | Information management and decision making | Digital health |
| 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 | Taiwan, China | System design | Monitoring abnormal events | IOT |
| 6  | Lin et al., 2008 | Taiwan, China | System design | Monitoring abnormal events | IOT |
| 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 | Taiwan, China | 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 | Z. 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 |
| 19 | Andö 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 |
| 30 | Hsu et al., 2010  | Taiwan, China | System design | Assisting ADLs         | IOT |
| 31 | Chang et al., 2011 | Taiwan, China | 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 |
| 35 | Borelli et al., 2019 | Italy | System design | Monitoring abnormal events | IOT |
| 36 | Mishkhal et al., 2020 | Iraq | System design | Fall prediction | IOT |
| No | Authors and year          | Country      | Study design| Function of Technology                          | Technologies related to ‘smartness’ | TRLs |
|----|---------------------------|--------------|-------------|-------------------------------------------------|-----------------------------------|------|
| 37 | Sax & Lawrence, 2009 [185]| Australia    | System design| Information management and decision making       | IMS                               | L 6 g|
| 38 | Gower et al., 2011 [63]  | Italy        | System design| Monitoring abnormal events                       | IoT                               |      |
| 39 | Lee et al., 2011 [64]     | South Korea  | System design| Monitoring abnormal events                       | IoT                               |      |
| 40 | Wang, 2014 [19]           | China        | System design| Monitoring abnormal events                       | IoT                               |      |
| 41 | Doumbouya et al., 2015 [148]| France     | System design| Telemedicine                                     | Digital health                    |      |
| 42 | Dias et al., 2016 [84]    | Brazil       | System design| Fall detection                                   | IoT                               |      |
| 43 | Ansefine et al., 2017 [86]| Indonesia    | System design| Monitoring abnormal events                       | IoT                               |      |
| 44 | Soak et al., 2017 [91]    | Malaysia     | System design| Monitoring abnormal events                       | IoT                               |      |
| 45 | Xie, 2017 [39]            | China        | System design| Monitoring abnormal events                       | Big data and AI                   |      |
| 46 | Zhang, 2017 [191]         | China        | System design| Information management and decision making       | IMS                               |      |
| 47 | Cai & Wang, 2019 [100]    | China        | System design| Fall detection                                   | IoT                               |      |
| 48 | Deng, 2019 [51]           | China        | System design| Monitoring abnormal events                       | IoT                               |      |
| 49 | Toda & Shinomiya, 2019 [107]| Japan      | System design| Fall detection                                   | IoT                               |      |
| 50 | Yoo et al., 2019 [109]    | South Korea  | System design| Monitoring abnormal events                       | IoT                               |      |
| 51 | Wang, 2020 [38]           | China        | System design| Monitoring abnormal events                       | IoT                               |      |
| 52 | Suzuki et al., 2006 [203]| Japan        | System design| Monitoring abnormal events                       | IoT                               | L 7 h|
| 53 | Betgé-Brezetz et al., 2009 [54]| USA    | System design| Notification for specific events                 | Computing technologies            |      |
| 54 | Biswas et al., 2009 [59]  | Singapore    | System design| Monitoring abnormal events                       | IoT                               |      |
| 55 | Fraile et al., 2010 [61]  | Spain        | System design| Monitoring abnormal events                       | IoT                               |      |
| 56 | Back et al., 2012 [67]    | Finland      | System design| Monitoring abnormal events                       | IoT                               |      |
| 57 | Chang et al., 2012 [68]   | Taiwan, China| System design| Monitoring abnormal events                       | IoT                               |      |
| 58 | Huang et al., 2013 [71]   | Taiwan, China| System design| Monitoring abnormal events                       | IoT                               |      |
| 59 | Matsui et al., 2013 [72]  | USA          | System design| Monitoring abnormal events                       | Computing technology              |      |
| 60 | Tseng et al., 2013 [75]   | USA          | System design| Monitoring abnormal events                       | IoT                               |      |
| 61 | Liu & Hsu, 2014 [78]      | Taiwan, China| System design| Monitoring abnormal events                       | IoT                               |      |
| 62 | Zhu et al., 2014 [79]     | Japan        | System design| Monitoring abnormal events                       | IoT                               |      |
| 63 | Lopez-Samaniego & Garcia-Zapirain, 2016 [85]| Spain    | System design| Monitoring abnormal events                       | IoT                               |      |
| 64 | Masuda & Numao, 2017 [195]| Japan        | System design| Clinical data analysis (diagnosis)               | IoT                               |      |
| 65 | Mendoza et al., 2017 [89] | Philippines  | System design| Monitoring abnormal events                       | IoT                               |      |
| 66 | Tsai et al., 2017 [201]   | Taiwan, China| System design| Assisting ADLs                                   | IoT                               |      |
Perceived efficaciousness
The nursing home residents who had experienced or perceived the usefulness of smart technologies in meeting their healthcare demands were more accepting of the technologies [54]. Similarly, HCPs perceived helpfulness in assisting care delivery to improve care efficiency increased their acceptability of smart technology, for example, using health information exchange systems efficiently improved doctor-patient communication [188]. Using smart technologies to improve HCPs’ daily routines, enhance medication safety, and deal with the events of emergencies could be a better solution to ensure the quality of care in nursing homes and the older adults’ quality of life [120, 142].

Perceived usability (positive and negative)
Smart technology improved access to healthcare for nursing home residents [140]. The users increased their awareness and consideration of adopting smart technologies when they recognised that smart solutions would be necessary for care [75, 152]. The appraisals of new technology on ease of use or ease to learn [129, 133, 149], user-friendly [71, 129, 184], and convenience [122, 147] in the coping process enhanced user acceptability of smart technology. Users also preferred the “human-centric” designs to fit their lifestyles [76, 99]. The affordability of smart technology is one of the considerations in the coping process, for example, the smart solution would be better accepted if the cost was not higher or not more expensive than the conventional care model [76]. HCPs expected adequate tech support and regular training in applying new technology to enhance the user engagement, confidence, and continuous operation [138, 184]. In addition, appropriate domestication of new technology could improve user acceptability [157]. Domestication is a dynamic process when users in various environments adapt and start to use the new technologies [207].

Table 3 (continued)

| No | Authors and year       | Country       | Study design | Function of Technology                  | Technologies related to ‘smartness’ | TRLs |
|----|------------------------|---------------|--------------|----------------------------------------|-------------------------------------|------|
| 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     | Taiwan, China | 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                                 |      |
| 80 | Danielsen 2016         | Norway        | System design| Monitoring abnormal events             | IoT                                 |      |
| 81 | Chen et al. 2021       | China         | System design| Fall prediction                        | Big data and AI                     |      |

*ADLs Activities of daily living

| L 1 = Level 1: Basic principles observed and reported |
| L 2 = Level 2: Technology concept and/or application formulated |
| L 3 = Level 3: Analytical and experimental critical function and/or characteristic proof-of-concept |
| L 4 = Level 4: Component and/or breadboard validation in laboratory environment |
| L 5 = Level 5: Component and/or breadboard validation in relevant environment |
| L 6 = Level 6: System/sub-system model or prototype demonstration in relevant environment |
| L 7 = Level 7: System prototype demonstration in relevant environment |
| No. | Authors and year | Sub-codes | Codes |
|-----|------------------|-----------|-------|
| 1   | Armer et al., 2004 [126] | Telemedicine, videoconferencing | Teleconsultation and videoconferencing with or without videoconferencing |
| 2   | Dey et al., 2005 [128] | Teleconsulting, live video and image transition | Teleconsultation and videoconferencing |
| 3   | Chan et al., 2001 [119]; Hui & Woo, 2002 [122]; Newbould et al., 2017 [162]; Rabinowitz et al., 2010 [138]; Schneider et al., 2016 [160]; Toh et al., 2015 [151, 152]; Weiner et al., 2001 [121]; Weiner et al., 2003 [124] | Videoconferencing and teleconsultation | Videoconferencing and telemedicine |
| 4   | Biglan et al., 2009 [134]; Grabowski & O'Malley, 2014 [146] | Videoconferencing and electronic medical records | Videoconferencing and telemedicine |
| 5   | Pallawala & Lun, 2001 [120] | Videoconferencing, teleconsultation and electronic medical records | Videoconferencing and telemedicine |
| 6   | Cusack et al., 2008 [132] | Store-and-forward, real-time video, hybrid systems and teleconsultation | Teleconsultation plus teleconsultation via videoconferencing |
| 7   | Catic et al., 2014 [145] | Video-consultation technology and teleconsultation | Teleconsultation and remote specialist decision making |
| 8   | Chang et al., 2010 [137] | Telemonitoring plus teleconsultation via videoconferencing | Teleconsultation and remote specialist decision making |
| 9   | De Luca et al., 2010 [137] | Telemonitoring | Teleconsultation and remote specialist decision making |
| 10  | Pallikonda Rajasekaran et al., 2010 [62] | Shared health information collected by wireless Sensor Networks (WSNs) and telemonitoring | Teleconsultation and remote specialist decision making |
| 11  | Zhang, 2017 [191] | Telemonitoring and wearable devices and web-based health information through an App | Teleconsultation and remote specialist decision making |
| 12  | Lavanya et al., 2006 [129] | Personal health information management system (D-PHIMS) and telemonitoring | Teleconsultation and remote specialist decision making |
| 13  | Doumbouia et al., 2015 [148] | Telemonitoring and teleconsultation for decision making | Teleconsultation and remote specialist decision making |
| 14  | Delmastro et al., 2019 [101]; Dong, 2019 [51]; Wang, 2014 [119]; Mishal et al., 2020 [115] | Internet (or email) and teleconsultation | Teleconsultation and remote specialist decision making |
| 15  | Vowden & Vowden, 2013 [144]; Zelickson, 2003 | Internet (or email) and teleconsultation | Teleconsultation and remote specialist decision making |
| 16  | Janardhanan et al., 2008 [133]; Low et al., 2020 | Internet (or email) and teleconsultation | Teleconsultation and remote specialist decision making |
| 17  | Doumbouia et al., 2015 [148] | Telemonitoring and wearable devices | Teleconsultation and remote specialist decision making |
| 18  | Shafee-Harjan et al., 2019 [169] | Telehealth and interprofessional collaboration | Teleconsultation and remote specialist decision making |

Table 4: The codes of integration of medical services
| No | Authors and year                     | The form of integrated medical services                     | Sub-codes                                      | Codes                                                                 |
|----|--------------------------------------|-------------------------------------------------------------|------------------------------------------------|------------------------------------------------------------------------|
| 19 | Liu & Hsu, 2014 [78]                | mhealth (App) and a soft motion-sensing mattress            | mHealth and abnormal event monitoring         | Integration of medical services through mHealth                        |
| 20 | Mendes et al., 2017 [88]            | Wearable devices and m-health personalised monitoring       |                                                |                                                                        |
| 21 | Delmastro et al., 2018 [164]        | Mobile and e-health personalised monitoring services        |                                                |                                                                        |
| 22 | Donnelly et al., 2018 [95]          | Mobile and wearable devices                                 |                                                |                                                                        |
| 23 | Montalto et al., 2015 [130], Dozet et al., 2016 [206], Esteves et al., 2019 [166] | Mobile and point-of-care (radiography)                     | mHealth and point-of-care                      |                                                                        |
| 24 | Wältivaara et al., 2011 [139]       | Teleconsultation and mobile distance-spanning technology (MDST) | mHealth and teleconsultation                  |                                                                        |
| 25 | Crotty et al., 2014 [147]           | Teleconsultation via videoconferencing and web-based health information through an App |                                                |                                                                        |
| 26 | Lai et al. 2020 [171]               | Smartphone-based teleophthalmology platforms                |                                                |                                                                        |
| 27 | Alexander, 2008 [182], Alexander et al., 2015 [188] | Information management and clinical practice in different care departments | Clinical information integration | Integration of clinical information                                    |
| 28 | Choi, 2010 [187]                    | Electronic health record and technology-based devices       |                                                |                                                                        |
| Authors and year                      | Sub-codes             | Description                                                                 | Codes                                                                 | Theme                                                                 |
|--------------------------------------|------------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------|
| Huang et al., 2013 [71]              | Severity of illness    | The attributes of older adults include the severity of illness and other individual sociodemographic variables | Attributes of residents                                             | Attributes of residents and HCPs*                                   |
| Armer et al., 2004 [126]             | Education attainment   | The identified attributes of HCPs include education attainment, clinical working experience and the level of tech-savvy | Attributes of HCPs                                                   |                                                                      |
| Handler et al., 2013 [142]           | Clinical working experience |                                                                             |                                                                      |                                                                      |
| Betgé-Brezetz et al., 2009 [54]; Handler et al., 2013 [142]; Janardhanan et al., 2008 [133] | The level of tech-savvy |                                                                             |                                                                      |                                                                      |
| Abbate et al., 2014 [76]; Chang et al., 2009 [135] | 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 [140]; Huang et al., 2015 [149, 189] | 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 [68]; Weiner et al., 2003 [124]; Yu et al, 2008 [184]; Zelikson, 2003 [125] | Achievement of user’s satisfaction |                                                                             |                                                                      |                                                                      |
| Betgé-Brezetz et al., 2009 [54]; Bleda et al, 2018 [94]; Delmastro et al, 2019 [101]; Qadri et al, 2009 [136]; Savenstedt et al, 2002 [123]; Wälivaara et al, 2011 [139] | 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 | Received efficaciousness |                                                                      |
| Alexander et al., 2007 [181]; Alexander et al, 2015 [188]; Handler et al., 2013 [142]; Janardhanan et al, 2008 [133]; Qadri et al, 2009 [136] | Helpfulness and improvement in care efficiency |                                                                             |                                                                      |                                                                      |
| Chan et al, 2001 [119]; Rabinowitz et al., 2010 [138]; Weiner et al, 2003 [124] | A better solution in administrative procedures |                                                                             |                                                                      |                                                                      |
| CroTTY et al, 2014 [147]; Handler et al, 2013 [142]; Lavanya et al, 2006 [129]; Pallavala & Lun, 2001 [120]; Qadri et al, 2009 [136]; Vowden & Vowden, 2013 [144]; Okamoto et al 2021 [175] | Improvement in quality of care |                                                                             |                                                                      |                                                                      |
| Eklund et al, 2012 [140]; Singh et al, 2017 [92] | Assurance of quality of life |                                                                             |                                                                      |                                                                      |
| Authors and year                       | Sub-codes                                      | Description                                                                 | Codes                                      | Theme                           |
|---------------------------------------|-----------------------------------------------|------------------------------------------------------------------------------|--------------------------------------------|---------------------------------|
| Eklund et al., 2012 [140]             | Improvement of healthcare accessibility and availability | The perceived usability includes effort expectancy, perceived ease of use, or perceived behavioral control (21). 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. | Received usability (positive)              |                                 |
| Toh et al., 2015 [151, 152]; Tseng et al., 2013 [75] | Necessity for care                          |                                                                              |                                            |                                 |
| Huang et al., 2015 [149, 189]; Janardhanan et al., 2008 [133]; Lavanya et al., 2006 [129]; Ohlins et al. 2020 [173] | Easy to use                                  |                                                                              |                                            |                                 |
| Huang et al., 2013 [71]; Lavanya et al., 2006 [129]; Yu et al., 2008 [184] | User-friendly                                |                                                                              |                                            |                                 |
| Crotty et al., 2014 [143]; Hui & Woo, 2002 [122] | Convenience                                |                                                                              |                                            |                                 |
| Abbate et al., 2014 [76]; Borelli et al., 2019 [99] | “Human-centric” designs to fit user lifestyles |                                                                              |                                            |                                 |
| Hui & Woo, 2002 [122]                  | Affordability                                 |                                                                              |                                            |                                 |
| Rabinowitz et al., 2010 [138]; Yu et al., 2008 [184] | Adequate tech-support and regular training |                                                                              |                                            |                                 |
| Gaglio et al., 2016 [157]             | Appropriate domestication of a new technology |                                                                              |                                            |                                 |
| Lavanya et al., 2006 [129]            | Unusefulness                                  |                                                                              | The negative perceiveness to the usability appraisals | Perceived usability (negative) |
| Huang et al., 2015 [149, 189]         | Uncertainty of usefulness                     |                                                                              |                                            |                                 |
| Fraile et al., 2010 [207]             | Not easy to learn                             |                                                                              |                                            |                                 |
| Delmastro et al., 2019 [101]          | Not easy to use                               |                                                                              |                                            |                                 |
| Alexander, 2005 [177]; Shafiee Hanjani et al., 2019 [169] | The difficulty of resources availability and accessibility | Lacking in supportive resources or tech-support |                                            |                                 |
| Byrne, 2005 [178]                    | Lacking in supportive resources or tech-support |                                                                              |                                            |                                 |
| Authors and year | Sub-codes | Description | Codes | Theme |
|-----------------|-----------|-------------|-------|-------|
| Alexander et al., 2007 [181]; Huang et al., 2013 [71] | Burden of using technology | | | |
| Toh et al., 2015 [151, 152] | Potential medical risks | The collateral damages refer to the unintended and harmful damages | | |
| Huang et al., 2015 [149, 189] | Sensitivity of technology and errors during the operation | | | |
| Chang et al., 2009 [135] | Overall concern of technology | | | |

*HCPs: Healthcare professionals*
In contrast, the features of unusefulness or uncertainty of using smart technologies in the coping process were reported to affect the user acceptability negatively, such as the unusefulness [129, 149], difficulty in use or to learn [101, 208], and lacking supportive resources [169, 177] or tech-support in applying technologies [178]. Some HCPs perceived new technologies as a burden to disrupt routines or added workloads, and it may cause reducing their time to provide essential nursing care for the residents, for example, initiating a new information system requiring manual input of residents’ health records into the system caused frustrations among the HCPs [71, 181].

**Perceived collateral damages**
Potential medical risks, sensitivity and reliability of technology, errors during the operation, and increased costs were the main concerns that have been reported [135, 149, 152] 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 observed to associate with the acceptability and adoption of smart technologies. The attribute of residents identified from the reviewed articles was the severity of illness [71]. The attributes of HCPs in positively accepting smart technologies in nursing homes were higher educational attainment [126], a few of year working experience (younger age), and better tech-savviness [54, 133, 142].

**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 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 smart technologies, especially from the perspectives of older adults and HCPs.

Previous studies described a smart nursing home as a smart building equipped with IoT technologies [35]. This scoping review concluded that nursing home residents’ health status and emergency situations 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, 33]. 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 [37, 209]. Based on their demands, 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]. The services in smart nursing homes could be more effective and efficient in care delivery to 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.

The feasible smart technologies in nursing homes reported in the literature can be classified as IoT, computing technologies, cloud computing, big data and AI, information management system, and digital health. A few published articles classified the most important functions of smart technology in hospital and home-based care settings as health status and mobility monitoring [210]. Hospitals used smart technologies 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 [211, 212]. In nursing homes, the feasible technologies were mainly used in monitoring residents’ abnormal events, connecting to remote clinical services, managing clinical information, analysing big data, and developing device to for the older adults’ to assist their activities of daily living. The TRL evaluation showed that 54% of new system designs were at levels 6 and 7, which have been proven ready for use in nursing homes. The technology function was mainly for monitoring abnormal events in nursing homes. The development of these new technologies is ready to progress to the higher levels of TRL 8 and 9 for commercialisation and future public use. Therefore, the technologies supporting ‘ageing in place’ were developed more maturely, and some of the technologies such as the applications of health monitoring, ADLs, and safety improvement have reached TRL 8 and 9 [209].

Integrating medical services could achieve clinical efficiency and overcome the limited access to healthcare for the older adults who live in rural area [213]. Electronic clinical information, telemedicine, and mHealth have shown the feasibility in overcoming shortages of medical resources and improving healthcare access in nursing homes [169]. The scoping review found that clinical information management and remote clinical services, especially telemedicine, have been broadly implemented in some nursing homes and they were accepted by many stakeholders [147]. With the effective implementation of smart technologies and integration of medical services,
many nursing homes could manage a large number of residents and provide customised care to older adults [104].

The theoretical model [22] indicated that the potential users’ persuasiveness of external and internal information, perceived efficaciousness, perceived usability, and perceived collateral damages of using smart technologies determined their acceptability of smart solutions. This scoping review identified and extracted the same determinants from the reviewed articles. In addition, the older adults’ severity of illnesses, the users with a higher level of education and better tech-saviness, and the HCPs with fewer years of working experience (younger age) were associated with higher acceptability of smart technologies [54, 71, 126, 133, 142]. These findings were consistent with the results from a literature review in a home-based care setting. The identified factors that influenced users’ technology acceptability included positive experiences with using technologies, such as ease of use, increased safety, security for care, perceived need to use, concerns of technical errors, social influence, and older adults’ physical conditions [209]. However, the older adults’ unmet needs and the description of their resilience to smart technology did not mention in the reviewed articles. The older adults did not seem to take concrete actions to adopt a smart technology according to their stressful unmet needs or the different levels 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 we searched, and it might cause the review to miss the new technologies or actual systems that have been approved to use in the nursing homes (TRL 8 and 9). Nevertheless, the number and types of databases 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 explore the characteristics and feasibility of smart technologies implemented in nursing homes by the particular 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 conventional nursing home. The motivation for transferring from a conventional 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 for frontier technologies, such as clinical data analysis by AI approach and cloud computing technologies, needs to catch up even though much has been presented already, such as the 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 who were persuaded of the benefit of adopting smart solution by the external and internal resources were more accepting of new technologies in nursing homes. Meanwhile, the HCPs with higher educational attainment, fewer years of working experience, and better tech-savviness had higher acceptability of smart technologies.

This scoping review is relevant to a broad base of readers interested in this research and most developed and developing countries with nursing homes. The scoping review results may contribute to future research on introducing smart technologies into nursing homes or developing a successful smart nursing home model. The identified smart technologies that integrate multidisciplinary, such as biomedical informatics and medicine, may provide the technical scope of the smart nursing home model for all stakeholders. The results are also applicable in the planning, evaluating, and monitoring the feasible technologies and service criteria when smart nursing homes 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.

**Supplementary Information**
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Additional file 1. Systematic Reviews and Meta-Analyses (PRISMA) Checklist.
Additional file 2. Search Strategy on Databases.
Additional file 3. The Retrieved Literature for the Scoping Review.
Additional file 4. Code Sheet for Defining the Concepts and Criteria of a Smart Nursing Home.
Additional file 5. The Code Sheet of Integration of Medical Services.
Additional file 6. The Code Sheet of Stakeholders’ Acceptability.

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**Protocol registration**
The protocol of this scoping review has registered on osf.io (URL: https://osf.io/qtwz2/) and published in BMJ Open [20].

**Authors' contributions**
All authors were involved in the review process. YZZ 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.

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**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 2−6. If further data clarification is required, please contact the corresponding author or Ms. Yuanyuan Zhao at helenzhao78@qq.com or pcs.helenzhao@gmail.com.

**Declarations**

**Ethics approval and consent to participate**
Not applicable.

**Consent for publication**
Not applicable.

**Competing interests**
We have no conflict of interest to declare.

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