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Artificial intelligence in elderly healthcare: A scoping review

Abstract

The ageing population has led to a surge in the adoption of artificial intelligence (AI) technologies in elderly healthcare worldwide. However, in the advancement of AI technologies, there is currently a lack of clarity about the types and roles of AI technologies in elderly healthcare. This scoping review aimed to provide a comprehensive overview of AI technologies in elderly healthcare by exploring the types of AI technologies employed, and identifying their roles in elderly healthcare based on existing studies. A total of 10 databases were searched for this review, from January 1 2000 to July 31 2022. Based on the inclusion criteria, 105 studies were included. The AI devices utilized in elderly healthcare were summarised as robots, exoskeleton devices, intelligent homes, AI-enabled health smart applications and wearables, voice-activated devices, and virtual reality. Five roles of AI technologies were identified: rehabilitation therapists, emotional supporters, social facilitators, supervisors, and cognitive promoters. Results showed that the impact of AI technologies on elderly healthcare is promising and that AI technologies are capable of satisfying the unmet care needs of older adults and demonstrating great potential in its further development in this area. More well-designed randomised controlled trials are needed in the future to validate the roles of AI technologies in elderly healthcare.

Keywords: Artificial intelligence, Elderly healthcare, Scoping review

1. Introduction

As a result of significant increases in life expectancy, the global population is aging at an alarming rate (Beard et al., 2016). The share of the population aged 60 years and over will increase from 1 billion in 2020–1.4 billion in 2030, accounting for 16.7 % of the global population, and this number is projected to double (2.1 billion) by 2050 (WHO, 2021). It has been reported that 92 % of older adults have at least one chronic disease and 81.5 % of those aged ⩾ 85 years have at least two chronic diseases (Salive, 2013, Tkatch et al., 2016).

Acceleration of aging is the most important driver of chronic diseases and multimorbidity (Prince et al., 2015). Aging has led to an inevitable increase in unmet healthcare needs in older adults, which further exacerbates the burden borne by the current healthcare system (Gao et al., 2022). Therefore, finding sustainable strategies to promote care in this age group is crucial.

Artificial intelligence (AI) is advancing rapidly in healthcare because of its potential to unleash the power of big data, gain insights to support evidence-based clinical decision-making, and enable value-based care (Chen and Decary, 2020). AI refers to learning and solving problems by simulating human intelligence using machines such as computers or robots, which are often programmed to imitate human cognitive functions in relation to other human minds (Lee and Yoon, 2021). The implementation of AI fosters disease prediction and surveillance, morbidity or mortality risk assessment, disease diagnosis and treatment, and health policy and planning (Guo et al., 2020, Noorbakhsh-Sabet et al., 2019, Schwalbe and Wahl, 2020). AI is not a single technology but a collection of techniques composed of computational models and algorithms that perform a variety of functions according to the real-world task or problem being dealt with (Chen and Decary, 2020). The widespread application of AI in healthcare has accelerated the processing of related elderly healthcare research. As a result, elderly healthcare-related AI studies have been booming in recent healthcare literature.

A consequence of the growing number of elderly healthcare-related AI studies is a surge in the application of AI technologies encompassing robots, exoskeletons, intelligent homes, wearables, and applications on smartphones or computers (Calabrò et al., 2015, Hu et al., 2021, Netz et al., 2021, Pu et al., 2021, Valero et al., 2014). Correspondingly, AI devices perform a variety of functions, including rehabilitation, social interaction, companionship and support, cognitive training, alerting, and monitoring (Follmann et al., 2021, Hsu et al., 2021, Park et al., 2021, Park, 2021, VandeWeerd et al., 2020). These functions can satisfy the growing unmet healthcare needs of older adults and compensate for the current situation of insufficient healthcare resources, thereby effectively alleviating pressure on today's healthcare system (Pilotto et al., 2018, Sapci and Sapci, 2019).

Existing reviews mainly focus on the employment of a specific type of AI technology in older adults, such as socially assistive robot technology (Abdi et al., 2018), humanoid robots (Tanioka, 2019), and robotic pets (Koh et al., 2021). These studies provide deep insights into the potential benefits of AI technologies in serving older adults. However, varying types of AI technologies provide different functions for the older adults. In fact, the overall application of AI technologies in elderly healthcare has rarely been evaluated with empirical evidence. Exploring the breadth and depth of literature in this field will gain a better understanding of the capabilities of AI technologies in elderly healthcare, which can subsequently provide key indications of its future role in society and open up new possibilities for elderly healthcare. Therefore, in this review, we aimed to provide a comprehensive overview of AI technologies in elderly healthcare by exploring the types of AI technologies employed, and identifying their roles in elderly healthcare based on existing studies.

2. Methodology

A scoping review was conducted according to the framework described by Arksey and O'Malley (2005) with an extended version by Levac et al. (2010). This review is reported based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018). Our protocol is registered in the Open Science Framework registries (https://osf.io/8fvq7).

2.1. Identifying the research question

This review explored existing literature on the implementation of AI in elderly healthcare. The research question was purposefully refined to cover the extensive range and nature of existing literature. The research questions were as follows: What kinds of AI are employed in elderly healthcare? What are the roles of AI in elderly healthcare?

2.2. Identifying relevant studies

A three-step search strategy was used for literature reported from January 1 2000 to July 31 2022. The first step involved a comprehensive literature search of 10 electronic databases, including MEDLINE, Cochrane Library, EMBASE, PubMed, Web of Science, PsycInfo, WanFang Data, VIP, SinoMed, and China National Knowledge Infrastructure (CNKI), and used combinations of medical subject heading (MeSH) terms and keywords; the retrieval strategy was tailored for each database.

For older adults, a combination of the words ‘aged’ OR ‘aging adult’ OR ‘elder* ’ OR ‘old people’ OR ‘old person* ’ OR ‘old population’ OR ‘old adult* ’ OR ‘old men’ OR ‘old women’

OR ‘older people’ OR ‘older person* ’ OR ‘older men’ OR ‘older women’ OR ‘older population’ OR ‘older adult* ’ OR ‘senior* ’ OR ‘senile’ OR ‘aged’ [Mesh] were used.

For artificial intelligence, a combination of the words ‘intelligent’ OR ‘artificial intelligence’ OR ‘AI’ OR ‘Artificial Intelligence’ [Mesh] was used.

In the second step, we searched for grey literature using Google Scholar. The third step involved a manual search of the reference lists of the identified studies and relevant reviews.

2.3. Study selection

The inclusion criteria were as follows: older participants (⩾60 years); various types of artificial intelligence including robots, applications, or those self-labelled as AI-related tools which perform tasks such as speech recognition, learning, visual perception, mathematical computing, reasoning, problem-solving, decision-making, and translation of language; articles published in English or Chinese; randomised controlled trials, pilot studies, pre-post trials, quasi-experiments, case reports, cross-over trials, observational studies, qualitative studies, and mixed-method studies.

The exclusion criteria were: research results that only included satisfaction or acceptability; technical reports of AI devices and publications related to surgical assistive equipment; reviews, dissertations, study protocols, trial registrations, conference abstracts, editorials, and letters.

Three authors independently screened titles and abstracts to identify eligible studies. The full texts of these studies were assessed based on the inclusion criteria. Discrepancies were resolved by discussion among the authors. We did not perform a standardised appraisal of the included studies since the field of AI in elderly healthcare is in its infancy, and many of the studies are small-scale exploratory studies. Nonetheless, they offer insights into what is currently being researched, and the potential of AI in elderly healthcare.

2.4. Charting the data

Data were extracted from eligible literature for the final analysis by two authors, and differences were resolved by discussion.

2.5. Collating, summarizing and reporting the results

The results were reported in a structured narrative synthesis. The application of AI technologies and the roles played in elderly healthcare were grouped thematically. Additionally, countries, participants, settings, and study designs were mapped, and trends in publication numbers were analysed.

3. Results and discussion

3.1. Literature search

The detailed study selection process is shown in Fig. 1. We initially used Endnote to identify 50,548 articles and removed 7056 duplicates as well as 43,044 articles based on title and abstract. A further 441 articles were excluded from full-text analysis because they did not conform to the inclusion criteria. Seven additional publications were included after a manual search of other resources. Finally, a total of 105 studies were included in this scoping review.

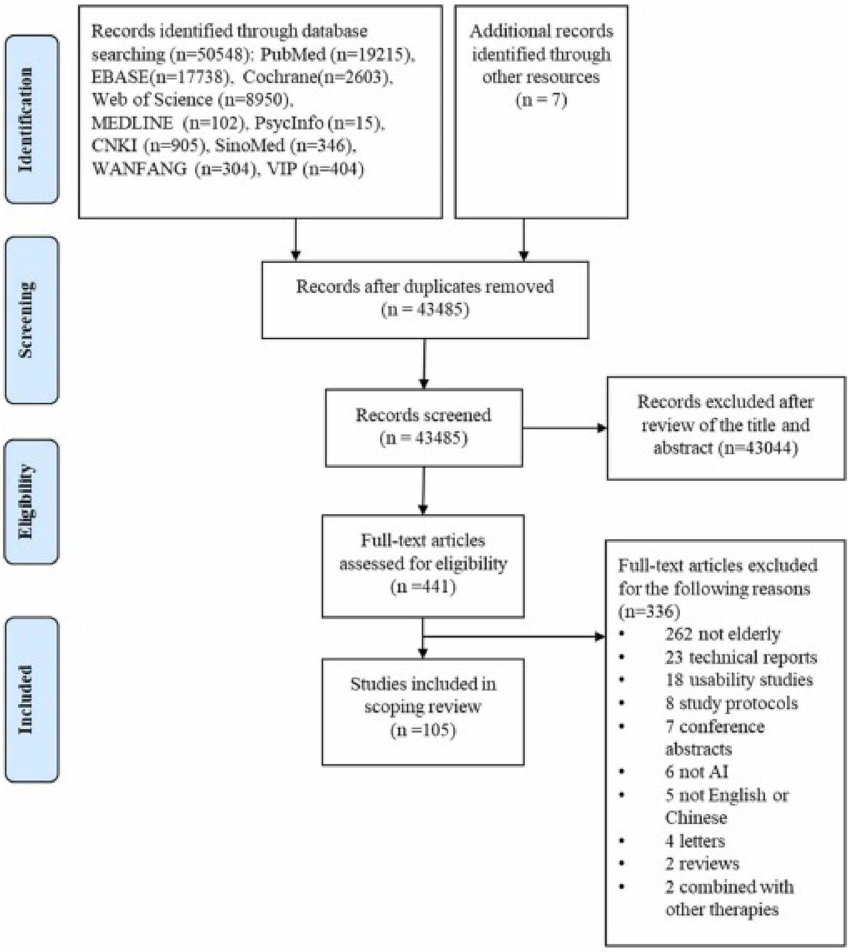

Fig. 1. PRISMA flow chart of the selection process.

3.2. Characteristics of the included studies

There were 105 eligible studies published in English or Chinese according to the inclusion criteria, and the number of articles generally increased over time, except for a decline in 2018 (Fig. 2a–b). They were conducted in 20 countries, with more than half of the studies being from European countries and the United States (Fig. 2c–d). The study designs were diverse, and randomised controlled trials accounted for the largest proportion accounting for nearly one-third of all studies (Fig. 2e). With respect to the setting, 35.0 % were conducted in hospitals, 20.8 % in homes, and 44.2 % of the studies were carried out in various facilities (Fig. 2f). Participants included older adults with no reported illness, cognitive impairment, stroke, Parkinson's disease, frailty, fracture, knee arthroplasty, chronic myelopathy, or depression (Fig. 2g). The characteristics of the included studies are presented in Appendix Table 1.

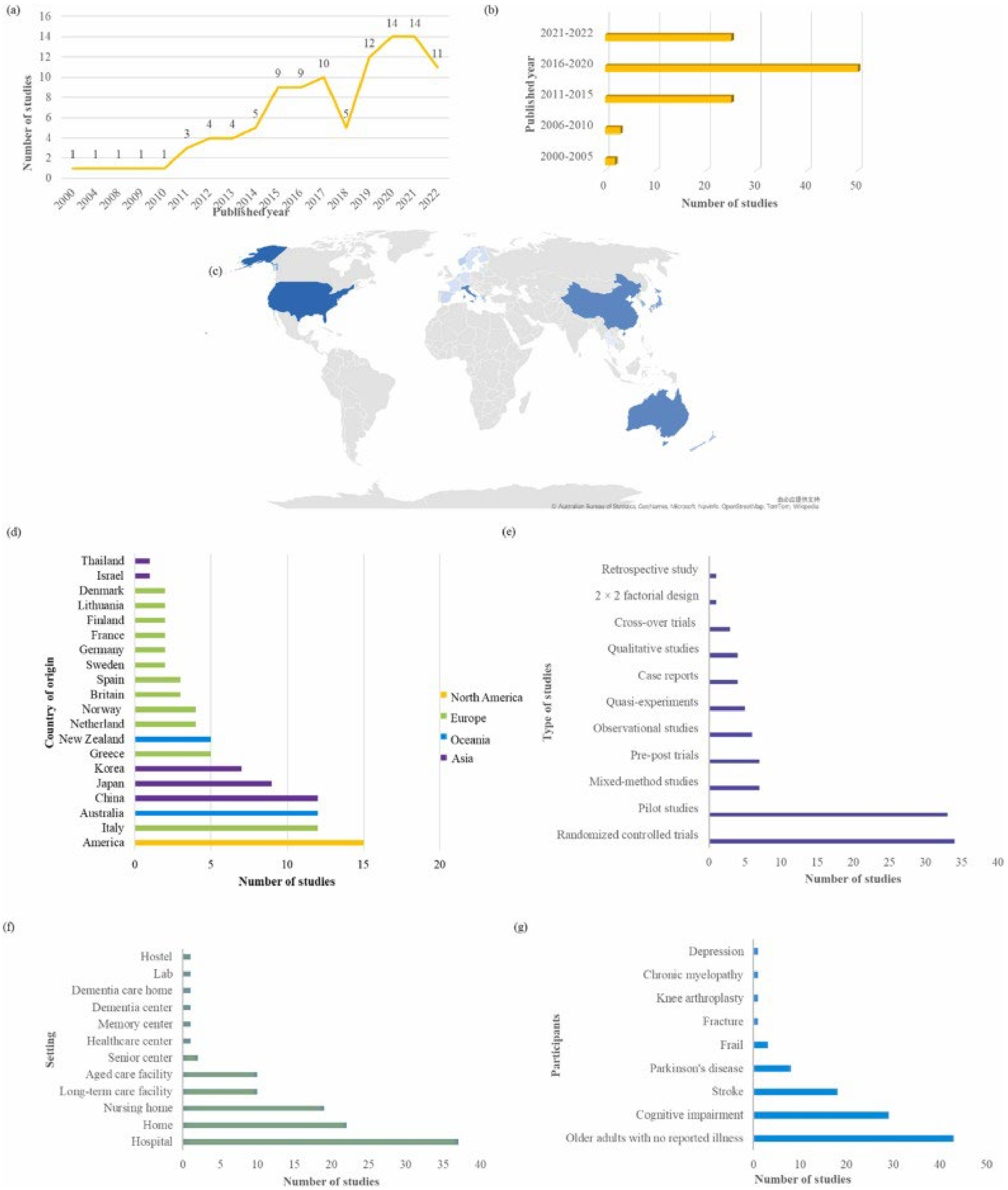

Fig. 2. (a) Number of studies by published year, (b) Increase in the number of studies on AI technologies by period of published year, (c–d) Number of studies by country of origin, (e)

Number of studies by type of study, (f) Number of studies by setting, (g) Number of studies by participants.

3.3. What kinds of AI are employed in the elderly healthcare?

To answer the question of what AI technologies are being currently employed to support older adults, a figure was drawn summarising the various types of technologies used in the literature (Fig. 3). Among these AI devices, robots were most employed (44.8 %), followed by exoskeleton devices (33.3 %), intelligent homes (12.4 %), AI-enabled health smart applications and wearables (6.7 %), voice-activated devices (1.9 %), and virtual reality (1.0 %).

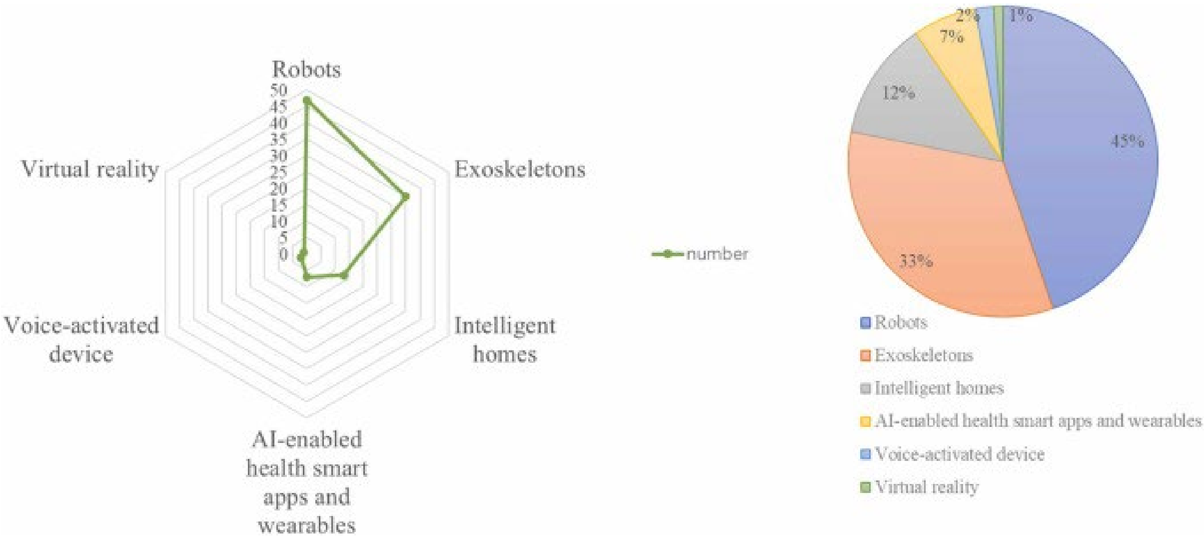

Fig. 3. Types of AI technologies employed in elderly healthcare.

The vast majority of robots were socially assistive (92.0 %) (Feil-Seifer and Matarić, 2005) with assistance provided to human users through social interaction. They were divided into humanoid and pet robots based on their appearance. The humanoid robots employed varied among the included studies. They were mostly used by older adults with no reported illness which accounted for 60.0 %, followed by those with cognitive impairment (40.0 %). Japan, the Netherlands, Norway, and Britain had the most research on the application of humanoid robots

(53.3 %). In terms of pet robots, many studies applied PARO in elderly healthcare, accounting for 80.6 %. Paro is a robotic baby harp seal designed as a therapeutic tool that has been used in hospitals and care facilities in approximately 30 countries (Yu et al., 2015). It was commonly used in older adults with cognitive impairment, accounting for 51.6 %, and the top two countries that employed it were Australia and the United States.

Exoskeletons employed in the studies mainly involved upper and lower limb exoskeletons, based on the body part to which they were applied. The proportions of the upper and lower extremity exoskeletons were close to half, occupying 45.5 % and 54.5 %, respectively. In terms of countries, Italy was the country that used exoskeletons most (34.4 %). Regarding the population, those using upper extremity exoskeletons most were older stroke patients (86.7 %). Similar use prevalence was reported for lower extremity exoskeleton application used among patients with Parkinson's disease, stroke, and older adults with no reported illnesses.

Intelligent homes, AI-enabled health smart applications and wearables, voice-activated devices, and virtual reality accounted for a smaller proportion, and most of these studies were feasibility articles and the countries where they were applied were scattered. It is worth noting that the population which used these devices was mainly older adults with no reported illnesses.

3.4. What are the roles of AI in elderly healthcare?

Five roles for AI technologies in elderly healthcare were identified: rehabilitation therapists, emotional supporters, social facilitators, supervisors, and cognitive promoters. Detailed information on their roles in elderly healthcare is presented in Table 1.

Table 1. Roles of AI technologies in elderly healthcare.

AI type	**AI device**	**Role**				
Empty Cell	Empty Cell	**Rehabilitation therapist**	**Emotional supporter**	**Social facilitator**	**Supervisor**	**Cognitive promoter**
Robots	Paro	✓	✓	✓		✓
	Kabochan	✓	✓			✓
	NAO		✓	✓		✓
	Sil-Bot		✓			✓
	AIBO		✓			
	Temi		✓			
	Robotic pets		✓			
	Pepper		✓	✓		✓
	MARIO			✓		
	Qoobo		✓	✓		✓
	Sota		✓	✓		
	ZORA			✓		
	Evondos				✓	
	Dinsow Mini® robot	✓				
	HOTAR	✓				
	PaPeRo i robot	✓				

	Giraff		✓	✓		
	Jack and Sophie			✓		
	An unknown humanoid robot		✓			
Exoskeleton devices	Lokomat	✓				✓
	GEAR	✓				
	BEAR	✓				
	Bi-Manu-Track	✓				
	Amadeo	✓				
	Gait-Trainer GT1	✓				
	IronHand	✓				
	Gloreha	✓				
	Armeo Spring	✓				
	Hunova	✓				
	Hybrid Assistive Limb	✓				
	Stride assistance system	✓				

	Gait Enhancing Mechatronic System	✓				
	BrightArm	✓	✓			
	Whole arm manipulator	✓				
	RE6116	✓				
	NeReBot	✓				
	L-exos	✓				
	InMotion2 robotic system	✓				
	Mixed reality rehabilitation system	✓				
	MIT-MANUS	✓				
	HAL robot suit	✓				
	Walkbot	✓	✓			
	Soft robotic intervention system	✓				

	Robotic rollator	✓				✓
	Tymo® system	✓				
Intelligent homes	HomeSense				✓	
	Dem@Care				✓	
	Sensing system				✓	
	Intelligent Sensor System				✓	
	Intelligent Monitoring Technology	✓			✓	✓
	An outdoor monitoring system				✓	
	Personalized Health-Monitoring System				✓	
	Smart home				✓	
	Intelligent home medical system				✓	
	"Internet + Smart		✓			

	Bed” health management system (IPBS)					
	Smart home technology		✓			
	eNightLog				✓	
AI-enabled health smart applications and wearables	MeMo					✓
	SSP-App			✓		
	EncephaLog	✓				
	PDMonitor				✓	
	AmbIGeM				✓	
	Online Conversational Skills Coach			✓		
	LONG-REMI		✓			
Virtual reality	Virtual reality	✓				✓
Voice-activated devices	Amazon Echo		✓	✓	✓	

3.4.1. Rehabilitation therapist

Forty-eight selected articles indicated that AI technologies can function as a rehabilitation therapist. Rehabilitation in older adults included the recovery of upper and lower extremity functions (Adomavičienė et al., 2019, Bernocchi et al., 2018, Calabrò et al., 2019, Carda et al., 2012, Cho and Song, 2015, Daunoraviciene et al., 2018, Duff et al., 2010, Franceschini et al., 2020, Frisoli et al., 2011, Hirano et al., 2017, Jansons et al., 2022, Kotani et al., 2020, Kubota et al., 2019, Maranesi et al., 2022, Masiero et al., 2011, Ogata et al., 2017, Ozaki et al., 2017, Picelli et al., 2014, Rabin et al., 2012, Radder et al., 2019, Shimada et al., 2009, Taveggia et al., 2016, Ustinova et al., 2011, Volpe et al., 2000, Wallard et al., 2015), amelioration of hemispatial neglect (Karner et al., 2019, Park, 2021), promotion of sleep quality and daily living activities (Koumpouros et al., 2020, Mizuno et al., 2021, Moyle et al., 2018, Pu et al., 2021), improvement of athletic ability including gait and balance (Feng, 2021, Lee et al., 2017, Netz et al., 2021, Spina et al., 2021, Yun et al., 2021), prevention of falls (Hu et al., 2021, Maneeprom et al., 2019), and relief from pain (Petersen et al., 2017, Pu et al., 2020a, Pu et al., 2020b). Research has shown that effective rehabilitation emphasises helping older adults acquire the ability to successfully complete functional tasks while relearning premorbid movement patterns (Duff et al., 2010). AI technology can not only provide objective rehabilitation training quantitatively but also record detailed data and graphics and provide real-time feedback of the movement and evaluation parameters, which is helpful for improving the rehabilitation effect and efficiency (Nam et al., 2017). In addition, interacting with AI technologies can produce an analgesic effect by limiting the availability of cognitive resources of attention system for pain perception (Pu et al., 2020b).

3.4.2. Emotional supporter

AI technologies acted as emotional supporter in the 34 selected articles. During the intervention, older adults had positive experiences and showed improvement in mood with AI technologies, including greater frequency of laughter, more positive facial expressions, alleviated psychological distress, decreased agitation, alleviated anxiety and depression, reduced loneliness, increased feelings of interest and pleasure, and improved mental well-being and quality of life (Aggar et al., 2022, Banks et al., 2008, Bemelmans et al., 2015, Chen et al., 2022, Chen et al., 2020b, Follmann et al., 2021, Gustafsson et al., 2015, Han et al., 2022, Hudson et al., 2020, Jøranson et al., 2016b, Liang et al., 2017, Libin and Cohen-Mansfield, 2004, Moyle et al., 2013, Moyle et al., 2019, Moyle et al., 2017, Nebot et al., 2022, O'Brien et al., 2019, Papadopoulos et al., 2022, Petersen et al., 2017, Pu et al., 2020a, Robinson et al., 2013, Thodberg et al., 2016a, Torta et al., 2014). On the one hand, AI technologies provided fun, friendly, and attractive entertainment, motivating and comforting people when they felt ill or in a negative mood (Robinson et al., 2013). On the other hand, AI technologies were able to improve the mood of participants by humanising AI technology based on personal experiences and increasing social interaction and companionship (Chen et al., 2020b). Therefore, older adults experienced a more meaningful life as AI blended into their daily routine.

3.4.3. Social facilitator

AI technologies acted as social facilitators in the connection between older adults and their friends, families, or health professionals in 24 selected articles. Participants showed a significant improvement in their communication and interaction skills, as demonstrated by greater verbal communication and eye contact (Ali et al., 2021, Blindheim et al., 2022, Boumans et al., 2019, Chen et al., 2022, Chu et al., 2017, Hsu et al., 2021, Jøranson et al., 2016a, Kolstad et al., 2020, Lin et al., 2022, Melkas et al., 2020, Moyle et al., 2014, Robinson et al., 2016, Šabanović et al., 2013, Sung et al., 2015, Takayanagi et al., 2014, Thodberg et al., 2016b). When interacting with AI technologies, they addressed it as an agent and responded by greeting, smiling, cuddling, petting, grooming, and talking with them (Hudson et al., 2020, Robinson et al., 2016, Sung et al., 2015). AI technologies have been integrated with the delivery of services, such as songs, games, and stories with emotive expressions and gestures, to provide sensory enrichment and positive social engagement (Chu et al., 2017). Thus, they could stimulate conversation, functioning as an icebreaker to start conversations in activities, and strengthening social ties of older adults with other people (Chen et al., 2020b, Robinson et al., 2013).

3.4.4. Supervisor

AI technologies acted as supervisors in 15 selected articles. In general, AI technologies allowed the monitoring of participants and provided objective and continuous observations that promote autonomy and uphold better health (Chan et al., 2009, Suryadevara et al., 2013). They monitored location, presence, activity intensity, sleep patterns, mood, social interaction, medication use, physiological indicators, and vital signs (blood pressure, blood glucose, heart rate, calories, and steps) from environmental and wearable sensors, smart devices, and appliances (Ahmed, 2015, Cheung et al., 2022, Lazarou et al., 2016, Lazarou et al., 2019, Obayashi and Masuyama, 2020, Rantanen et al., 2017, Rantz et al., 2017, Suryadevara et al., 2013, Tsamis et al., 2021, Valero et al., 2014, VandeWeerd et al., 2020, Visvanathan et al., 2021, Wang et al., 2016, Wang, 2022). After collecting sensor data and performing data analysis to detect behavioural changes, they provide feedback, recommendations, reminders, and alarm messages based on individual health-related parameters (Ahmed, 2015, Lazarou et al., 2016, Lazarou et al., 2019, Obayashi and Masuyama, 2020, Rantanen et al., 2017, Rantz et al., 2017, Suryadevara et al., 2013, Tsamis et al., 2021, Valero et al., 2014, VandeWeerd et al., 2020, Visvanathan et al., 2021, Wang et al., 2016). In addition, this reliable and updated information enabled clinicians to make better decisions with a comprehensive image of older adults and to track progress (Lazarou et al., 2016, Suryadevara et al., 2013, Tsamis et al., 2021, Visvanathan et al., 2021).

3.4.5. Cognitive promoter

AI technologies provided cognitive training to older adults in 10 articles. Cognitive training is considered a promising option for slowing the cognitive decline in older adults and for improving cognition and behavioural symptoms in people with cognitive impairment (Butler et al., 2018, Ge et al., 2018, Hill et al., 2017). AI technologies allowed older adults to experience a complex series of cognitive, physical, and psychological activities with consequent enhancement of cognitive function, such as imitating motion, performing mental arithmetic for a monetary problem, and walking on a square board after memorising the given motion path (Park et al., 2021). Based on the results of several cognitive assessment scales, they were found to have a positive impact on improving overall cognition function, attention, ability of abstract thinking, judgement component of executive function, language production, and verbal, working and short-term memory, based on the results from several cognitive assessment scales (Calabrò et al., 2015, Hsieh et al., 2019, Park et al., 2021, Robert et al., 2020, Tanaka et al., 2012). Moreover, behavioural symptoms involving apathy, irritability, and lability decreased after the intervention (Valentí Soler et al., 2015).

In addition, 34 randomised controlled studies were included in this review. It is worth noting that by applying AI technologies, 25 studies showed a more significant effect on older adults than by usual care or traditional therapy, demonstrating the potential to meet care needs of older adults and address the challenges of aging. These significant effects include various aspects, such as rehabilitation of body function (Calabrò et al., 2019, Daunoraviciene et al., 2018, Karner et al., 2019, Park et al., 2020, Park, 2021, Picelli et al., 2012, Radder et al., 2019, Spina et al., 2021, Taveggia et al., 2016, Wang, 2022), improvement of cognitive function (Park et al., 2021, Robert et al., 2020), prolongation of sleep time (Moyle et al., 2018, Pu et al., 2021), promotion of positive expressions and interaction skills (Ali et al., 2021, Liang et al., 2017), improvement of quality of life (Han et al., 2022, Jøranson et al., 2016b, Papadopoulos et al., 2022), growth of interest and pleasure (Moyle et al., 2017, Tanaka et al., 2012), and reduction of pain and loneliness (Petersen et al., 2017, Pu et al., 2020b, Robinson et al., 2013). Moreover, combining AI technologies and usual care also had a more significant outcome in the rehabilitation of upper limb function than usual care alone (Volpe et al., 2000). In addition, five studies reported that both AI-based elderly healthcare and usual care had positive results without significant differences between the experimental and control groups in limb function and loneliness (Banks et al., 2008, Carda et al., 2012, Chen et al., 2020a, Franceschini et al., 2020, Masiero et al., 2011). Two other studies showed that traditional therapy or usual care had a greater impact on sleep time and in maintaining attention than AI-based elderly healthcare (Thodberg et al., 2016a, Thodberg et al., 2016b).

3.5. Key considerations

This review has provided answers to the most fundamental questions in the advancement of AI technologies in elderly healthcare: what kinds of AI are employed and what are their roles of AI in elderly healthcare? To answer these questions, we have conducted a comprehensive review by exploring a broad scope of studies in the application of emerging AI technologies in elderly healthcare to provide. AI technologies employed in elderly healthcare can be broadly divided into six types: robots, exoskeleton devices, intelligent homes, AI-enabled health smart applications and wearables, voice-activated devices, and virtual reality. Five roles for AI technologies in elderly healthcare were identified according to their function: rehabilitation therapists, emotional supporters, social facilitators, supervisors, and cognitive promoters. Additionally, the impact of AI technologies on elderly healthcare is promising and AI technologies are capable of satisfying the unmet care needs of older adults, demonstrating great potential in its further development in this area. The advancements in AI technologies are expected to open the prospect of reshaping elderly healthcare.

To the best of our knowledge, this is the first scoping review of AI in elderly healthcare. Our review contributes to the existing literature by providing a comprehensive overview of AI technologies in elderly healthcare through an exhaustive literature search. Previous studies have focused on a particular type of AI technologies in elderly healthcare or examined a specific function of AI technologies such as rehabilitation (Abdi et al., 2018, Koh et al., 2021, Tanioka, 2019), without considering the current application of AI technologies in elderly healthcare as a whole. Besides, previous studies have found that socially assistive robots and robotic pets displayed positive effects in elderly healthcare (Abdi et al., 2018, Koh et al., 2021), but these results need to be investigated further due to methodological issues with the included articles. Our study extends the findings of the previous studies by not only analysing the types of AI technologies and the roles they perform in elderly healthcare, but also analysing the outcomes of the included randomised controlled trials. The majority of AI technologies showed significant effects in different aspects of elderly healthcare, demonstrating the great potential of AI technologies in this field.

As the current applications show, AI technologies are not only increasing in number but also in variety, and thus play various roles in elderly healthcare. Previous AI devices were typically bulky, heavy, unattractive, and focused on a single domain, such as surveillance or physical rehabilitation through tracking, remote monitoring, alarm prompting, and repetitive actions (Ienca et al., 2017, Volpe et al., 2000, Young and Ferris, 2017). Currently, AI technologies combine more advanced algorithms and machine learning to precisely meet users' multiple needs, including companionship, communication, social interaction, entertainment, and cognitive training (Ienca et al., 2017). They are designed to be safer, more user-friendly, and more pleasing in appearance, making them more accessible to older adults (Hu et al., 2021). Current AI technologies emphasise holistic care for older adults and empower them by maintaining the integrity of physical function, promoting autonomy and successful completion of daily activities, and increasing psychosocial support (Abdi et al., 2020, Pu et al., 2019). This review found 15 AI devices which are currently employed that could serve more than one role in elderly healthcare. This emerging holistic trend has the potential to achieve better outcomes than earlier trends in technology-assisted elderly healthcare.

Of all the studies included, only 43 (40.6 %) did not include older adults with a specific disease, which implies the potential benefits of AI on preventive health. Physical and mental health may be compromised as people live longer, and adverse living conditions/events increase with age (e.g., chronic diseases, functional limitations, and disabilities) (Maresova et al., 2019). There is an urgent need for more practical and professional care to assist older adults with disease guidance or rehabilitation. Often, this care relies mainly on family caregivers and long-term facility resources (Hsieh et al., 2022, Kulpa et al., 2021). However, caring for older adults with illness is challenging and stressful, and their needs may not adequately met, placing a heavy burden on caregivers (Adolfo et al., 2022). In addition, some caregivers lack the core competencies to recognise the symptoms and needs of patients (Adolfo et al., 2022). Thus, AI technological innovation has become an important breakthrough in the dilemma of elderly healthcare (Abdi et al., 2020).

The 20 countries included in this review face the problem of an aging population, especially the European countries. They encounter formidable healthcare challenges brought about by aging, which is the propulsion for technological innovation to support elderly healthcare (United Nations Population Fund, 2021). In addition, among the included countries, 18 were developed countries with advanced AI technologies that attach great importance to the development of new technologies, not only issuing relevant policies but also increasing capital investment in the AI industry (European Commission, 2021, GOV.UK, 2021, United States government, 2021). As a result, these countries are taking the lead in applying AI technologies to elderly healthcare with promising results. It is worth noting that no African countries were included in this review. The absence of African countries is probably due to entrenched poverty and inadequate governmental attention to the needs of older adults (Adamek et al., 2022). Therefore, reducing inequality in the development of AI technologies between regions and allowing older adults to enjoy the convenience of emerging technologies is a problem that needs to be solved in the future.

In the included studies, the same AI devices produced different results, indicating that many factors influence their effect when they are used in practice. First, it is important to introduce AI devices appropriately, considering their acceptance by older adults (Wu et al., 2014). Second, some of the main barriers that could influence technology adoption by older adults include a lack of confidence in their digital skills and a lack of understanding of the positive impact it might have on their quality of life (Bian et al., 2021, Radder et al., 2019). For better adoption and positive outcomes, relevant training prior to intervention is indispensable for older adults. Finally, the different stages of disease and the duration, intensity, pattern, or site of intervention (e.g., group or individual, hospital, home, or institution) may affect the results (Leng et al., 2019). Therefore, it would be best to develop formal guidelines that could establish a framework for AI projects, harmonise AI technology development, facilitate the process of technology transfer, and develop an intervention schedule that includes the frequency and duration of each session and the duration of the entire process.

Some AI devices, including Paro and Lokomat, are very mature for commercialisation and have been applied in many countries, regions, and institutions (Bemelmans et al., 2015, Calabrò et al., 2015, Jøranson et al., 2016a, Sung et al., 2015, Wallard et al., 2015). However, there are still many emerging devices that are currently under research, yet they have not been introduced into the market (Cinini et al., 2021, Cruz et al., 2018, Rincon et al., 2019). At present, the actual application of AI technologies is disproportionate to the developed equipment, and a large number of AI devices have not been translated into clinical applications. As these AI technologies lack clinical validation, health professionals and institutions may be reluctant to introduce them to elderly healthcare (Ienca et al., 2017). Therefore, future research should focus on applying the developed AI equipment in clinical practice to bridge the gap between theory and practice. In addition, only 32.4% of the included studies were randomized controlled trials, and 31.4% of the studies focused on the technical evaluation, exploration, usability, or feasibility of AI technologies, suggesting that many technologies for older adults are still in the early stages of development. This indicates that larger studies are required on the role and effectiveness of AI technologies in elderly healthcare.

3.6. Limitations

This study has two limitations. First, this review only included Chinese and English studies, which may have led to an incomplete synthesis of data given that some related articles were published in other languages. Second, although the diversity of included studies is a strength of this review, it also indicates that it included more heterogeneous studies; specific recommendations for particular populations cannot be drawn from this review without further research.

4. Conclusions

It was found that there are a wide variety of AI-based devices currently employed in the elderly healthcare. The results showed that the roles played by AI technologies in older adults were multiple, and the effect of AI technologies on elderly healthcare is promising. AI technologies are capable of satisfying the unmet care needs of older adults, demonstrating great potential in elderly healthcare. More well-designed randomised controlled trials are needed in the future to validate the roles of AI technologies in elderly healthcare.

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CRediT authorship contribution statement

Bingxin Ma: Methodology, Writing – original draft. Jin Yang: Methodology, Writing – original draft. Frances Kam Yuet WONG: Writing – review & editing. Arkers Kwan Ching Wong: Writing – review & editing. Tingting Ma: Validation. Jianan Meng: Validation. Yue Zhao: Conceptualization, Methodology, Writing – review & editing. Yaogang Wang: Conceptualization, Methodology, Writing – review & editing. Qi Lu: Conceptualization, Methodology, Writing – review & editing.

Conflict of interest

None.

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Appendix

Table 1 The characteristics of included studies

Study(year) Country	AI Device	Participants	Study design	Intervention	Comparison	Frequency/ duration/sessions	Follow-up	Indicators	Outcomes
B.T. Volpe et al. (2000) America	MIT-MA-NUS	Stroke(n=56)	RCT	Standard poststroke multidisciplinary rehabilitation + robotic training	Standard poststroke multidisciplinary rehabilitation +exposure to the robotic device without training	1h/d, 5 d/w at least 25 sessions	/	FM-SEC/FM-WH/MP/MS-SE/MS-WH	Robot-delivered training enhanced the motor performance and functional outcome of the exercised shoulder and elbow. The robot-treated group also demonstrated improved functional outcome. When added to standard multidisciplinary rehabilitation, robotics provides novel therapeutic strategies that focus on impairment reduction and improved motor performance
Xinyao Hu et al. (2021) China	Soft robotic intervention system	Older adults(n=24)	Pilot study	Walk on a treadmill under no soft robotic intervention, inactive soft robotic intervention, and active soft robotic intervention	/	/	/	Gait variability	Soft robotic intervention could reduce step length variability for elderly people with medium-high fall risks
Hwang-Jae Lee et al. (2017) Korea	Gait Enhancing Mechatronic System (GEMS)	Older adults(n=30)	Pre-post trial	Overground gait at comfortable speed under three different conditions: free gait without robot assistance, robot-assisted gait with zero torque (RAG-Z), and full robot-assisted gait (RAG)	/	/	/	Spatio-temporal parameters/Muscle activation patterns	In the RAG condition, participants demonstrated improved gait function, decreased muscle effort, and reduced metabolic cost

Dong-Seok Kim et al. (2018) Korea	GEMS	Older adults(n=15)	Pilot study	Free ascent without the GEMS (NoGEMS) and robot-assist ascent with the GEMS(GEMS)	/	/	/	Metabolic energy expenditure	GEMS was helpful for reducing cardiopulmonary metabolic energy expenditure during stair climbing in elderly adults
Margaret Duff et al. (2010) America	Mixed reality rehabilitation system	Stroke(n=3)	Pilot study	Training with mixed reality rehabilitation system	/	75 minutes each, 6 sessions over 2 weeks	/	Goal completion/ speed/trajectory/ accuracy/velocity profile/range of joint angles/joint coordination/ compensatory shoulder/torso movements	Significant improvements in the movement parameters included faster and smoother reaches, increased joint coordination and reduced compensatory use of the torso and shoulder
Yiannis Koumpouros et al. (2020) Greece	Robotic rollator	Frail older adults (n=30)	Pilot study	Assist participants with navigating in a trail	/	/	/	Success rate/task completion time/stopping time/walking trajectories/gait parameters	The provided directional audio cues led to smoother walking paths and better orientation

Giovanni Taveggia et al. (2016) Italy	Lokomat	Stroke(n=28)	RCT	Robot-assisted gait training	Usual gait training	5 sessions a week for 5 weeks	Baseline 5 weeks 3 months	6MWT/TWT/FIM/SF-36/Tinetti scale	Both treatments were effective in the improvement of gait performances, but a significant improvement in functional independence in the experimental group
Antonio Frisoli et al. (2011) Italy	L-exos	Stroke(n=2)	Pilot study	Robot-assisted training	/	6 weeks	/	FM/MAS/BAT/task time/position/joint error/resistance torques	Overall spasticity is decreased and FMA is increased
Rocco Salvatore Calabrò et al. (2019) Italy	Amadeo	Stroke(n=50)	RCT	Amadeo hand training	Occupational therapist-guided conventional hand training	45 minutes each, 5 times/w, for 8 consecutive weeks, 40 sessions	/	FMAUE/9HPT/TRCoh/MEP/SAI	The experiment group presented improvements in FMAUE, 9HPT, TRCoh and SAI greater than control group
Alessandro Picelli et al. (2012) Italy	Gait-Trainer GT1	Parkinson's disease(n=34)	RCT	Robot-assisted gait training	Physical training	40 minutes each, 12 sessions, 3 d/w, for 4 consecutive weeks	Baseline 4 weeks 8 weeks	BBS/Nutt/ABC/TUG/10MWT/UPDRS	A significant improvement was found after treatment on the BBS and Nutt in favor of the experiment group compared to control group. All improvements were maintained at the1-month follow-up evaluation
Masaaki Tanaka et al. (2012) Japan	Kabochan	Elderly women living alone(n=34)	RCT	Living with a communication robot	Living with a control robot	8 weeks	/	MMSE/Cognistat/VAS/GDS-15/TMIG-IC/APG/saliva cortisol level	The MMSE score, judgement, and verbal memory function were improved, the saliva cortisol level was decreased, nocturnal sleeping hours tended to increase, and difficulty in maintaining sleep tended to decrease with the communication robot, the

									proportions of the participants in whom effects on attenuation of fatigue, enhancement of motivation, and healing could be recognized were higher in the communication robot group relative to the control group
Elvira Maranesi et al. (2022) Italy	Tymo® system	Parkinson's disease(n=16)	Pilot study	Accept traditional therapy and technological treatment with a robotic system	/	30 min of traditional therapy and 20 min of technological treatment, 2 sessions/w, for 5 weeks	/	Balance	Statistical analysis reveals a significant effect on balance performance after intervention
Wendy Moyle et al. (2018) Australia	Paro	Dementia(n=175)	RCT	PARO intervention	Plush toy intervention; Usual care	15 minutes each, 3 times/w for 10 weeks	Baseline 5 weeks 10 weeks 15 weeks	Day- and nighttime motor activity and sleep	After 10 weeks, the PARO group showed a greater reduction in daytime step count than usual care, and in nighttime step count and daytime physical activity compared with the plush toy group. At post-intervention, the PARO group showed a greater reduction in daytime step count than the plush toy group, and at nighttime compared with both the plush toy group and the usual-care group. The PARO group also had a greater reduction in nighttime physical activity than the usual-care group

Seo Jung Yun et al. (2021) Korea	Walkbot	Parkinson's disease(n=11)	Pilot study	Robot-assisted gait training	/	45 minutes each, 3 d/w, for 4 consecutive weeks	Baseline 4 weeks (TI) 8 weeks (T2)	10MWT/BBS /KFES	A significant change over time only in single-task gait speed of the 10MWT, but not in dual-task gait speed, dual-task interferences and KFES. Cognitive dual-task interference significantly increased at T1, but not at T2. No significant changes were observed for physical dual-task interference at T1 and T2. Single-task gait speed of the 10MWT was significantly increased at T1, but not at T2. There were no significant changes in the dual-task gait speed of 10MWT. A significant improvement was observed in BBS at T1 and T2
KSENIA USTINOVA et al. (2011) America	Lokomat	Parkinson's disease(n=1)	Case report	Robot-assisted gait training	/	6 sessions	/	UPDRS	Gait speed, stride length and foot clearance increased, the time required to complete a 180° turn and the latency of gait initiation reduced. Improvements were observed in motivation, bradykinesia, rigidity, freezing, leg agility, gait and posture
Jumpei Mizuno et al. (2021) Japan	PaPeRo i robot	Older adults living alone(n=14)	Pre-post trial	Robot support	/	4 weeks	/	Daily activities/MMSE/ COGNISTAT	Faster wake-up times, reduced sleep duration, and increased amount of activity in the daytime
Stefania SPINA et al. (2021) Italy	Hunova	Parkinson's disease(n=22)	RCT	Robotic balance training	Conventional balance training	45 min/session, 5 times/week, 20 treatments	Baseline 4 weeks 8 weeks	MBT/BBS/10 MWT/5TSTS/ PDQ-39	Primary outcome measures in patients in both the experimental and control groups improved significantly after the balance treatment. The experimental group performed significantly better than the control

									group at both post-intervention and follow-up evaluation in the primary outcomes. No significant differences between groups were found in secondary outcome
Natthawadee Maneeprom et al. (2019) Thailand	Dinsow Mini® robot	Older adults(n=64)	Quasi-experiment	Received a small robot-installed fall prevention software, personal coaching, and handbook	Received only handbook	6 months	Baseline 3 months 6 months	BI/TUG/BBS/ fall prevention questionnaire/number of exercises	There was a statistically significant improvement in knowledge at 6th month in both groups and the intervention group showed faster increase in knowledge than the control group at 3rd month. The intervention group showed a statistically significant higher number of exercises than the control group at 3rd and 6th month. There was no statistically significant difference on TUG and BBS scores between the two groups at baseline, 3rd, and 6th month. The intervention group showed a statistically significant improvement in TUG and BBS at 6th month post-intervention
Susanne Karner et al. (2019) Germany	Paro	Stroke(n=39)	RCT	Exposed to PARO	Read to aloud	3 times/w for 2 weeks	Baseline (T0) 2 weeks (T1) 4 weeks (T2)	cancellation test/LBT/ SINGER	Improvement of hemineglect at T1 and T2 was significantly higher in the PARO group compared to the control group
Hiroyuki Shimada et al. (2009) Japan	Stride assistance system	Older women(n=15)	Pre-post trial	Robotic walking exercise	/	90 min/session, 2 times/w, 3 months	/	FDG	Walking speed was improved and FDG uptake by the gluteus minimus, gluteus medius and rectus femoris, and pelvic muscles were reduced

Chanhee Park et al. (2020) Korea	Walkbot	Stroke(n=14)	RCT	Walkbot locomotor training	Conventional locomotor training	7 d/w, over 2 weeks	/	BBS/FAC/HR /BRPE/BDI-II/ABC	The experiment group showed superior effects on FAC, HR, BRPE, BDI-II, and ABC scale compared to control group, but not on BBS
Kristina Daunoraviciene et al. (2018) Lithuania	Armeo Spring	Stroke(n=34)	RCT	Robot-assisted training	Conventional therapy	30 min/d in 10 sessions	/	FIM/FMA/HAD1/HAM-A/ACE-R/ROM assessment of the shoulder, elbow and wrist/MAS	The experiment group showed a statistically significant improvement in upper extremity motor function compared to the control group. The calculated treatment effect in the both groups was meaningful for shoulder and elbow kinematic parameters
L. Wallard et al. (2015) France	Lokomat	Stroke(n=10)	Pre-post trial	Robotic gait rehabilitation	/	4 sessions/w during5 weeks	/	Gait analysis	A significant improvement in walking speed, step length, single and double support time and knee kinematics
Naoya Kotani et al. (2020) Japan	Hybrid Assistive Limb	Total knee arthroplasty(n=22)	Pilot study	Robot-assisted knee flexion exercise	conventional physical therapy	5-10 min and 10-15 min in the experiment group and control group respectively	5 days 10 days 6 months	ROM/ muscle strength /VAS	Both groups showed significant improvement between postoperative days 5 and 10 in all outcome measures. Improvements in active ROM, passive ROM, muscle strength, and pain were significantly greater in the experiment group than in the control group. Long-term outcomes were also significantly better in the experiment group
Bob Radder et al. (2019) the Netherlands	IronHand	Older adults with self-perceived decline	RCT	Assistive or therapeutic ironHand use	Received no additional exercise or treatment	4 weeks	/	Maximal pinch grip	Scores on the BBT and JTHFT improved in both groups. The therapeutic group showed improvements in unsupported handgrip

		of hand function(n=91)						test/BBT/JTHFT	strength and pinch strength after 4 weeks. No significant correlations were found between changes in performance and assistive or therapeutic ironHand use
Palmira Bernocchi et al. (2018) Italy	Gloreha	Stroke(n=21)	Pilot study	Intensive hand training using the Gloreha Lite glove	/	2 months	/	VAS/Ashworth spasticity index/ circumference of forearm, wrist and fingers/MI/NHPT/Grip test	The MI, NHPT and Grip test improved significantly compared to baseline, but VAS score, Ashworth spasticity index and hand edema did not change significantly.
Lihui Pu et al. (2020) Australia	Paro	Dementia(n=22)	Mixed-method study	PARO intervention	Usual care	30 minutes each, 5 d/w, 6 weeks	/	/	Residents with dementia expressed positive attitudes towards the use of PARO and acknowledged the therapeutic benefits of PARO on mood improvement and relaxation for pain relief
Aušra Adomaviˇciene et al. (2019) Lithuania	Armeo Spring	Stroke(n=42)	RCT	Conventional programs + the Armeo Spring robot-assisted trainer	Conventional programs + Kinect-based system	45 min/d, 10 sessions	/	FIM/FMA-UE/MAS/Hand grip strength/HTT/BBT/ROM/MMSE/ACE-R/HAD2	Both groups had a positive effect and significantly recovered post-strokes functional level in self-care, upper limb motor ability (dexterity and movements, grip strength, kinematic data), visual constructive abilities (attention, memory, visuospatial abilities, and complex commands) and decreased anxiety level

Bryan A. Rabin et al. (2012) America	BrightArm	Stroke(n=5)	Pilot study	BrightArm upper extremity rehabilitation	/	3 sessions/w, 6 weeks,18 sessions	Baseline 6 weeks 12 weeks	Shoulder strength/grasp strength/finger pinch strength/shoulder and elbow active range of motion/JTHFT/FMA-UE/BDI-II/NAB/HVLT-R/BVMT-R	Significant improvements in active range of shoulder movement, shoulder strength, grasp strength, and ability to focus. Several participants demonstrated substantially higher arm function and less-depressed
Ioulietta Lazarou et al. (2019) Greece	Intelligent Monitoring Technology	Older adults with cognitive impairment(n=18)	Observational study	System installed at home	Received tailored interventions; Neither had a system installed nor received interventions	4-12 months	/	/	The experiment group showed statistically significant improvement in cognitive function, compared to control groups. Moreover, experiment group has shown improvement in sleep quality and daily activity
Yael Netz et al. (2021) Israel	EncephaLog	Older adults(n=52)	Pilot study	Personalized exercise programs delivered via smartphone	/	5 times/w for 6 weeks	/	Static balance/dynamic balance/strength of upper and lower extremities/range of motion in upper and lower body	Significant improvement was observed for strength/flexibility for upper/lower body and balance

Hayley Robinson et al. (2015) New Zealand	Paro	Older adults(n=17)	Pilot study	Interact with the robot	/	10 minutes	/	Systolic and diastolic blood pressure/heart rate	Systolic and diastolic blood pressure changed significantly over time as did heart rate. Diastolic blood pressure increased significantly after Paro was withdrawn
Kunihiro Ogata et al. (2017) Britain	HOTAR	Hemiplegia(n=2)	Pilot study	Rehabilitation using an upper limb training system	/	2 times/w for 3 weeks	/	CCI/MFT	The movement skills and motor function of the upper limb improved using the proposed training method
Alessandro Picelli et al. (2014) Italy	Bi-Manu-Track	Parkinson's disease(n=10)	Pilot study	Robot-assisted arm training	/	45 minutes each, 10 sessions, 5 d/w, for 2 weeks	Baseline 2 weeks 4 weeks	FM/NHPT/UPDRS	A significant improvement was found in the NHPT and the upper limb section of the FM. Findings were confirmed at the 2-week follow-up evaluation only for the nine-hole peg test. No significant improvement was found in UPDRS at both post-treatment and follow-up evaluations
Ki Hun Cho et al. (2015) Korea	Whole arm manipulator	Stroke(n=10)	Pre-post trial	Robot-assisted reach training	/	40 min/d, 2 times/w, for 4 weeks	/	Movement velocity/ARAT	Upper extremity kinematic performance and functional movement showed improvement after two weeks and four weeks of training compared to baseline
Stefano Carda et al. (2012) Italy	Lokomat	Parkinson's disease(n=30)	RCT	Robotic gait training	Conventional treadmill training	30 minutes each,3 d/w for 4 weeks	Baseline 1 month 3 months 6 months	6MWT	At the 6-month follow-up, both groups had improved significantly in the primary outcome measure, but no significant differences were found between groups
Lihui Pu et al. (2021) Australia	Paro	Dementia(n=41)	RCT	PARO intervention	Usual care	30 min/d, for 6 weeks	/	Sleep/motor activity	At week one, PARO group had a greater increase in the night sleep period. At week six, PARO group showed a greater increase in daytime wakefulness and a greater

									reduction in daytime sleep. No significant results were found for motor activity
Lihui Pu et al. (2020) Australia	Paro	Demen-tia(n=43)	RCT	PARO intervention	Usual care	30 minutes sessions, 5 d/w for 6 weeks	/	PAINAD/CMAI/CSDD/RAID/MQS-III	PARO group had a significantly lowered level of observed pain and used fewer pro re nata medications than those in usual care. There were no significant differences in staff-rated pain, agitation, anxiety, and depression, nor regularly scheduled medications between intervention and control group
Chih-Chin Hsieh et al. (2019) China	Virtual reality	Older Adults with Cognitive Impair-ment(n=60)	Quasi-experiment	Virtual reality-based Tai Chi exercise	No exercise or specific behavioral management training	60minute sessions, 2 times/w, for 24 weeks	/	CASI/6MWT/30s arm curl test/30s STS/FR/TUG/the chair sit-and-reach test/drop ruler test/5m gait speed/GDS	Significant interaction effects in the 6min walk test, 30s sit-to-stand test, functional reach, 5m gait speed and abstract thinking and judgment
Jin-Hyuck Park (2021) Korea	Amadeo	Stroke(n=24)	RCT	Robot-assisted left-hand training	Conventional treatments for neglect symptoms	20 sessions for 4 weeks	/	LBT/the Albert test/CBS	Improvements in the LBT, the Albert test and the CBS were found in experiment group and improvements in the LBT and the CBS were found in control group. Experiment group showed a significantly greater gain in all outcome measures compared to control group

Xiuping Han et al. (2022) China	"Internet + Smart Bed" health management system (IPBS)	Elderly with chronic diseases(n=150)	RCT	Accepted the IPBS	Routine examination and daily health risk management	15 months	/	Quality of life	In the intervention group, after using the IPBS, all scores of quality of life were better than those before use, and the differences were statistically significant. In the control group, there were no statistically significant differences before and after observation
P. Jansons et al. (2022) Australia	Amazon Alexa	Older adults(n=15)	Pilot study	Accept home-based muscle strengthening, weight-bearing impact and balance exercises delivered using Amazon Alexa	/	12 weeks	/	European Quality of Life Scale/30 second sit-to-stand test	Outcomes did not significantly change across the 12-week follow-up
Satoshi Hirano et al. (2017) Japan	GEAR	Hemiplegia(n=1)	Case report	Exercise with the GEAR	Gait exercise using conventional orthosis	5 d/w, 40 min/d, for 4 weeks	/	FIM-walk	Improvement efficiency of FIM-walk
Sandra Petersen et al. (2017) America	Paro	Dementia(n=61)	RCT	Interacte with the PARO	Standard activity program	20 minutes sessions, 3 times/w for 3 months	/	RAID/CSDD/GDS/GSR/medication utilization/pulse rate/pulse oximetry	Compared to control group, RAID, CSDD, GSR, and pulse oximetry were increased in the treatment group, while pulse rate, pain medication, and psychoactive medication use were decreased. The difference between groups was consistent throughout the 12-week study for pulse oximetry and pulse rate, while GSR had several weeks when changes were similar between groups
Kenichi Ozaki et al. (2017) Japan	BEAR	Frail older adults(n=27)	Cross-over trial without a washout term	Training with BEAR	Conventional balance training	twice a week for 6 weeks	/	Preferred and maximal gait	Robotic exercise achieved significant improvements for tandem gait speed, functional reach test, timed up-and-go test and

								speeds/tandem gait speeds/TUG/FRT functional base of support/COP/muscle strength of the lower extremities	muscle strength of the lower extremities compared with conventional exercise
Marco Franceschini et al. (2020) Italy	InMotion2 robotic system	Stroke(n=48)	RCT	Upper limb robot-assisted therapy	Traditional physical therapy	30 sessions (45 minutes each, 5 d/w for 6 weeks)	Baseline 6 weeks 6 months	FM-UL/pROM/MAS-S/MAS-E	At T1, significant gain of FM-UL in both groups, while significant improvement in MAS-S, MAS-E, and pROM were found in experiment group only. At T2, significant increase in MAS-S were revealed only in control group. In FM-UL, pROM and MAS-E the improvements obtained at the end of treatment seem to be maintained at 6 months follow-up in both groups
Stefano Masiero et al. (2011) Italy	NeReBot	Stroke(n=21)	RCT	NeReBot training	Conventional functional rehabilitation	120 minutes, 5 d/w for 5 weeks	Baseline 5 weeks 3 months	MRC/FM/m-FIM/MAS/FAT/BBT/Tolerability of treatment	Robot patients achieved similar reductions in motor impairment and enhancements in paretic upper-limb function to those gained by patients in a control group
Shigeki Kubota et al. (2019) Japan	HAL robot suit	Chronic myelopathy(n=1)	Case report	Wearable robot treatment	/	once every 2 weeks for 10 sessions	/	10-m walk test/2-minute walk test	Improvements were observed in gait speed, step length, and cadence and improvements

									in walking ability were maintained after the wearable robot treatment for 6 months
Yuning Feng et al. (2021) China	RE6116	Fracture(n=95)	Quasi-experiment	Physical occupational therapy + robot-assisted therapy	Physical occupational therapy + weight loss walking rehabilitation training	30 minutes each, 5 times/w for 15 weeks	/	Bipedal stride time/3 m straight pace/3 m straight stride length/BBS	The experiment group had greater improvements in all measures compared to control group and the interaction between training and time in both groups was statistically significant
Amy Liang et al. (2017) New Zealand	Paro	Dementia(n=30)	RCT	PARO intervention	Standard care	30 minutes sessions, 2-3 times/w for 6 weeks at care center; had Paro at home for 6 weeks	/	NPI-Q/CSDD/CMAI-SF/blood pressure/salivary cortisol	Paro significantly improved facial expressions and communication with staff at the day care centers and care recipients with less cognitive impairment responded significantly better to Paro. There were no significant differences in care recipient dementia symptoms, nor physiological measures between the intervention and control group
Shu-Chuan Chen et al. (2020) China	Paro	Older adults with depression(n=20)	Mixed-method study	PARO intervention	/	24 h, 7 d/w, for 8 weeks	/	GDS-SF/UCLA-3/WHO-QOL-OLD	Statistically significant changes in decreasing depression and loneliness and improving quality of life over time were identified and increased social interaction with other people
Marian R. Banks et al. (2008) America	AIBO	Older adults(n=38)	RCT	Either AIBO or a living dog visit	No animal-assisted therapy	weekly visits lasting 30 minutes for 8 weeks	/	UCLA-3/MLAPS	Both the Dog and AIBO groups had statistically significant improvements in their levels of loneliness

Nina JØRANSON et al. (2016) Norway	Paro	Dementia(n=60)	RCT	PARO intervention	Usual care	30 minutes each, twice a week over 12 weeks	Baseline 12 weeks 6 months	BARS/CDR/ QUALID	Stable quality of life in the intervention group compared with a decrease in control group and intervention group used significantly less psychotropic medication compared with control group after end of intervention
Wendy Moyle et al. (2014) Australia	Giraff	Dementia(n=5)	Mixed-method study	Participated in a discussion via the Giraff robot	/	a minimum of 6 times over a 6-week period	/	Emotional response and engagement via video recordings	Residents showed a general state of positive emotions across the calls with a high level of engagement and a minimal level of negative emotions and the Giraff robot offered the opportunity to reduce social isolation
Geoffrey W. Lane et al. (2016) America	Paro	Older adults(n=23)	Pilot study	PARO intervention	/	one and a half year	/	Behavioral observations	Increased observed positive affective and behavioral indicators, with concomitant decreases observed in negative affective and behavioral indicators
Roger Bemelmans et al. (2015) The Netherlands	Paro	Dementia(n=71)	Quasi-experiment	PARO intervention	Daily care activities	4 months	/	IPPA/mood scale	All interventions combined show a significant effect. Paro in daily intramural psychogeriatric care practice can increase the quality of care and the quality of life for the elderly
Elena Torta et al. (2014) The Netherlands	Humanoid robot	Older adults(n=8)	Pilot study	Robot intervention	/	2 sessions over a 2-week period; 8 sessions over a 3-month period	/	ANX/PAD/PS /SP/PEOU	Participants might engage in an emotional relationship with the robot, but that perceived enjoyment might decrease over time

Wendy Moyle et al. (2013) Australia	Paro	Dementia(n=18)	Cross-over trial	PARO intervention	Reading	45 minutes each, 3 times/w, for 5 weeks	/	QOL-AD/RAID/AES/GDS/ AES/OERS	PARO had a moderate to large positive influence on participants' quality of life compared to the reading group. The PARO intervention group had higher pleasure scores when compared to the reading group
Nina JØRANSON et al. (2016) Norway	Paro	Dementia(n=30)	Observational study	PARO intervention	/	30 minutes each, twice a week during 12 weeks	/	Behaviors observations	"Observing Paro" was observed more often in participants with mild to moderate dementia, while the variable "Observing other things" occurred more in the group of severe dementia. "Smile/laughter toward other participants" showed an increase, and "Conversations with Paro on the lap" showed a decrease during the intervention period
Markus KOLSTAD et al. (2020) Norway	Paro/Pepper/Qoobo	Nursing facilities(n=3)	Qualitative study	Robot intervention	/	/	/	/	Results pointed out user satisfaction, adjusted purpose, therapeutic and entertaining effects after robot intervention
Kari Blindheim et al. (2022) Norway	Pepper	Dementia(n=3)	Qualitative study	Robot intervention	/	/	/	/	Residents report that they enjoyed interactions with the social robot, highlighting opportunities for novel types of activities and action that differed from the daily routine
Kazuko Obayashi et al. (2020) Japan	Sota/monitoring sensors	Older adults(n=2)	Pilot study	Sota used with a sensing system supported by cloud robotics, in caring for elderly people	/	4 days	/	Conversations/smiles/movement	Robots can stimulate elderly people to communicate more with others. Appropriate vocalization by communicative robots may prevent the deterioration of quality of life in elderly individuals

Andreas Follmann et al. (2021) Germany	Temi	Older adults(n=70)	Pilot study	Virtual encounters by robot	Non-contact or any other contact	/	/	Loneliness score	In the hospital, loneliness decreased significantly among patients for whom the robot was used to provide contact. In the nursing homes, no demonstrable effect could be achieved
Janella Hudson et al. (2020) America	Robotic pet	Older adults(n=20)	Qualitative study	Interact with a robotic pet	/	/	/	/	Robotic pets may be an effective solution for alleviating loneliness in older adults
Meritxell Valentí Soler et al. (2015) Spain	Paro/NAO	In the nursing home, dementia(n=101) (Phase 1), n=110 (Phase 2) In the day care center, dementia(n=20) (Phase 1), n=17 (Phase 2)	Pilot study	In the nursing home, CONTROL, PARO and NAO (Phase 1) and CONTROL, PARO, and DOG (Phase 2). In the day care center, all patients received therapy with NAO (Phase 1) and PARO (Phase 2).	Usual standardized care	30–40 min each, 2 d/w during 3 months	/	GDS/sMMSE /MMSE/NPI/ APADEM-NH/AI/ QUALID	In the nursing home, (Phase 1) patients in the robot groups showed an improvement in apathy; patients in NAO group showed a decline in cognition; the robot groups showed no significant changes between them; (Phase 2) QUALID scores increased in the PARO group. In the day care center, (Phase 1) improvement in the NPI irritability and the NPI total score; (Phase 2) no differences were observed at follow-up
Chris Papadopoulos et al. (2022) Britain	Pepper	Older adults(n=33)	RCT	A fully culturally Pepper robot intervention	Control Group 1: a more limited version Control Group 2: Care As Usual	6 sessions, each session lasted for up to 3 h, 18 h across 2 weeks	/	SF-36/ULS-8/CCATool-Robotics	The difference in SF-36 between experimental group and care as usual over time was significant, as was the comparison between any robot used and care as usual. There were no significant changes in SF-36 physical health subscales. ULS-8 loneliness scores slightly improved among experimental and control group1 participants

									compared to care as usual participants, but this was not significant
Eun-A Park et al. (2021) Korea	Sil-Bot	Older adults without cognitive impairment(n=135)	RCT	Robot-assisted cognitive training	Traditional cognitive training or without anything training	60 minutes each, 12 times, twice a week for 6 weeks	/	MMSE-DS/SMCQ/CERAD-K/GDSSF-K	Robotic training had significantly greater post-intervention improvement in cognitive function, memory, executive function, and depression. Traditional cognitive training participants had greater post-intervention improvement in memory and executive function
Hayley Robinson et al. (2013) New Zealand	Paro	Older adults(n=40)	RCT	Robot intervention	Normal activities	twice a week for an hour over 12 weeks	/	QoL-AD/GDS/UCLA-3	In comparison with the control group, residents who interacted with the robot had significant decreases in loneliness over the period of the trial. Both the resident dog and the seal robot made an impact on the social environment in comparison to when neither was present. Residents talked to and touched the robot significantly more than the resident dog. A greater number of residents were involved in discussion about the robot in comparison with the resident dog and conversation about the robot occurred more

Karen THOD-BERG et al. (2016) Denmark	Paro	Older adults(n=100)	RCT	PARO visit	Either dog or a soft toy cat visit	10 minutes each, 2 times/w for 6 weeks	/	MMSE/GDS/ GBS/CAM	Sleep duration increased in the third week when accompanied by a dog rather than the robot or soft toy cat. No effects were found in the sixth week or after the visit period had ended. Visit type had no effect on weight, body mass index, GDS, GBS, or MMSE. Furthermore, a decrease in the GDS during the experimental period, whereas cognitive impairment worsened
Alexander Libin et al. (2004) America	Robocat	Dementia(n=9)	Pilot study	Interact with robocat or plush toy cat	/	10 minutes each, one session per day	/	Lawton's Modified Behavior Stream/ABMI	Interacting with the cats was linked with decreased agitation and increased pleasure and interest
Wendy Moyle et al. (2017) Australia	Paro	Dementia(n=415)	RCT	PARO intervention	Interact with plush toy or usual care	15 minutes each, 3 times/w for 10 weeks	Baseline 1 week 5 weeks 10 weeks 15 weeks	CMAI-SF	Participants in the PARO group were more verbally and visually engaged than participants in plush toy. Both PARO and plush toy had significantly greater reduced neutral affect compared with usual care, whilst PARO was more effective than usual care in improving pleasure and agitation. When measured using the CMAI-SF, there was no difference between groups
Christine Gustafsson et al. (2015) Sweden	Robotic cat	Dementia(n=4)	Mixed-method study	Robot intervention	/	7 weeks	Baseline-3 weeks intervention-7 weeks follow up-2 weeks	QUALID/CMAI	Results indicated less agitated behavior and better quality of life for individuals with dementia. Interviews showed positive effects by providing increased interaction,

									communication, stimulation, relaxation, peace, and comfort to individuals with dementia
Wendy Moyle et al. (2019) Australia	Giraff	Dementia(n=22)	Mixed-method study	Making a video-call involving conversation and manoeuvering of Giraff	/	once	/	Modified-TPI/I-PANAS-S/ODAS/ attitudes and reactions	Participants reported a sense of authenticity, social connection and positive social presence through the experience
Katherine O'Brien et al. (2019) America	Amazon Echo	Older adults(n=125)	Retrospective study	Use Amazon Echo	/	/	/	/	Amazon Echo provided entertainment, companionship, reminders and emergency communication to older adults
Rafayet Ali et al. (2021) America	Online Conversational Skills Coach	Older adults(n=20)	RCT	Web-based communication coach provides automated feedback on eye contact, facial expressivity, speaking volume, and negative content	Education and videos on communication	8 sessions over 4-6 weeks	/	Social skills performance	Participants randomized to experiment group demonstrated statistically and clinically significant improvement in eye contact and facial expressivity
Karen Thodberg et al. (2016) Denmark	Paro	Older adults(n=100)	RCT	PARO visit	Either a dog or a soft toy cat visit	10 minutes each, twice a week, a total of 12 visits	/	MMSE/GBS/ GDS	The dogs and Paro triggered the most interaction compared with the toy cat, in the form of physical contact, eye contact, and verbal communication, but Paro failed to maintain the attention at the same level over time. The higher the cognitive impairment level, the more interaction was directed toward the animal and less toward humans, regardless of visit type

Yi-Chun Lin et al. (2022) America	NAO	Older adults(n=14)	Observational study	Interacted with NAO	/	3 weeks for 6 sessions	/	Interaction	Individuals demonstrated high levels of both human-human interaction and human-robot interaction, but the activity influenced the type of interaction. Engagement measures (visual, verbal, behavioral) also varied by type of activity
Kazue Takayanagi et al. (2014) Japan	Paro	Dementia(n=30)	Observational study	Interacted with either PARO or a lion toy	/	15 min	/	Behaviors observations	Subjects talked more frequently, showed more positive changes in emotional expression and laughed more frequently with PARO than with Lion. Subjects in mild/moderate dementia even showed more negative emotional expressions with Lion than with PARO. Furthermore, subjects in severe dementia showed more active interaction with PARO. For subjects in mild/moderate dementia, frequencies of touching and stroking, frequencies of talking to staff member, and frequencies of talking initiated by staff member were significantly higher with Lion than with PARO
Roel Boumans et al. (2019) The Netherlands	PEPPER	Older adults(n=42)	Cross-over trial	Robot–patient interactions	Nurse–patient interactions	/	/	Interaction time/similarity of the data/the percentage of robot interactions	Social robots may effectively in interviewing older adults

								completed autonomously	
Mei-Tai Chu et al. (2017) Australia	Jack and Sophie	Dementia(n=139)	Observational study	Robot intervention	/	4-6 hours, two times	/	Behavioral reactions	Social robots can improve the engagement and quality of care for people suffering from dementia
Ke Chen et al. (2020) China	Kabochan	Dementia(n=103)	RCT	Kabochan intervention	Usual standardized care	32 weeks	/	NPI-Q/GDS/MoCA/MBI/ QoL-AD	When Kabochan was removed in the withdrawal phase (weeks 17-24), the neuropsychiatric symptoms became more severe at week 24 for the intervention group, although the effect size was small to moderate. No statistical between-group differences were found in other health outcomes
Àngela Nebot et al. (2022) Spain	LONG-REMI	Older adults without Cognitive Impairment (n = 21) Older adults with Cognitive Impairment (n = 21)	Pilot study	LONG-REMI intervention	/	30 min/w sessions were held for 4 consecutive weeks	/	PANAS	High frequency of positive emotions increased in the participants at the end of the intervention, while the low frequencies of negative emotions were maintained at the end of the intervention
Eva Barrett et al. (2019) Britain	MARIO	Dementia(n=10)	Pre-post trial	Engagement in music, news, reminiscence, games, and calendar applications via robot	/	3 times/w, 12 sessions for 4 weeks	/	QoL-AD/ CSDD/ MSPSS	Participants spent more time socially engaged. No statistically significant differences were found in quality of life, depression and perceived social support

Huei-Chuan Sung et al. (2015) China	Paro	Older adults(n=16)	Pilot study	Robot-assisted therapy	/	30 minutes each, twice a week for 4 weeks	/	ACIS-C/Activity Participation Scale	Participants' communication and interaction skills and activity participation were significantly improved after receiving 4-week robot-assisted therapy
Selma Šabanović et al. (2013) America	Paro	Dementia(n=10)	Observational study	Interact with PARO	/	7 weekly sessions	/	Behavioural interactions	PARO provides indirect benefits for users by increasing their activity in particular modalities of social interaction, including visual, verbal, and physical interaction, PARO's positive effects on older adults' activity levels show steady growth over the duration of our study
Hayley Robinson et al. (2016) New Zealand	Paro	Older adults(n=40)	Mixed-method study	Interact with PARO	Usual standardized care	2 sessions a week over 12 weeks	/	Behavioral interactions	Residents engaged on an emotional level with Paro and enjoyed sharing, interacting with and talking about Paro
Shu-Chuan Chen et al. (2022) China	Paro	Older adults(n=26)	Qualitative study	Interact with PARO	/	60 m/session, 3 sessions/w for 8 weeks	/	/	Paro might provide the value of companionship and improve interpersonal relationships for older adults
Helina Melkas et al. (2020) Finland	ZORA	Older adults(n=60)	Pilot study	Care-robot implementation	/	27 sessions, 10 weeks	/	Behaviors observations and interviews	Care-robots like Zora have impacts on interaction and activity for clients and their presence stimulated the clients into exercising and interacting
Pei-Ti et al. (2021) China	SSP-App	Older adults(n=107)	Quasi-experiment	Took part in an SSP-App program	Did not participate in any experimental treatment program	Week 4 (T1) Week 12 (T2)	/	GDS-SF/Emotional and Social Support	At T1, effects were observed in social participation intention only. However, at T2, effects were observed in both social participation intention and social participation behavior

								Scale/SPI/SPB	
Christian Werner et al. (2018) Greece	Robotic rollator	Frail older adults with cognitively impaired(n=20), not cognitively impaired(n=22)	2 × 2 factorial design	Complete a two-section navigation path with robotic rollator with activated navigation system	Complete a two-section navigation path with robotic rollator without activated navigation system	/	/	Success rate/completion and stopping time/number of stops/walking distance/gait speed	Significant interactions between navigation assistance and cognitive status for both sections, such that robotic rollator-assisted navigation reduced the completion time (both sections), stopping time (section 1), and number of stops (section 2) in the cognitively impaired but not in the not cognitively impaired group. On section 2, robotic rollator-assisted navigation led to a reduced stopping time and walking distance in the total group
Philippe Robert et al. (2020) France	MeMo	Older adults with cognitive impairment(n=46)	RCT	Using MeMo	Not using MeMo	4 sessions/w, 12 weeks	Baseline 12 week 24 weeks	MMSE/IQCODE/FCSRT/TMTA/Stroop test/DSST/FAB/NPI	There were significant differences in attention and apathy comparing the active MeMo and nonactive MeMo. A significant increase in apathy in the nonactive MeMo with time interaction
Rocco Salvatore Calabro et al. (2015) Italy	Lokomat	Dementia(n=1)	Case report	Traditional cognitive training + intensive gait robotic rehabilitation	/	5 session/weekly for 4 weeks	/	MMSE/AM/TMT-A/TMT-B/TMT-BA/SRT/TCD/BPRS/ FAB /HRS-D/ADL/IADL	Significant improvement in the motor and cognitive function

Liang-Hung Wang et al. (2016) China	An outdoor monitoring system	Older adults(n=4000)	Pilot study	/	/	/	/	Behaviors observations	The successful detection time can be improved by 38% based on 4,000 samples, thereby increasing rescue opportunities for elderly patients
Renuka Visvanathan et al. (2021) Australia	AmbIGeM	Older adults(n=3240)	Pilot study	Patients wore a cotton singlet with an encased wearable Bluetooth Low Energy sensor device with integrated triaxial accelerometer and gyroscope sensors	Best practice consistent with the Australian falls prevention guidelines	103 weeks	/	Falls rate/the proportion of fallers/the injurious falls rate	There was no significant difference between intervention and control relating to the falls rate, proportion of fallers, and injurious falls rate. In a post hoc analysis, falls and injurious falls rate were reduced in the Geriatric Evaluation and Management Unit wards when the intervention period was compared to the control period
C VandeWeerd et al. (2020) America	HomeSense	Older adults(n=21)	Pilot study	Have home sensing system installed	/	19 participants with 6 months and 15 participants have crossed the 1-year threshold	/	/	Homesense offers the potential to monitor older adults within their own homes, facilitating supportive environments that bolster the healthy, safe and independent aging plan preferred by older adults
Miguel Ángel Valero et al. (2014) Spain	Smart home	The UPM Accessible Digital Home and MetalTIC house	Pilot study	Smart home	/	/	/	/	Monitor personal and environmental data at a smart home in a private way and promote independent living for elderly people
KONSTANTINOS I. TSAMIS et al. (2021) Greece	PDMonitor	Parkinson's disease(n=2)	Pilot study	Patients wore PDMonitor	/	2 days	/	Motor symptoms	With the use of PDMonitor, physicians had access to an objective assessment of the patient's motor symptoms as those manifested in his daily home environment and managed

									to reach a final diagnosis and make the right treatment decisions
N.K. Suryadevara et al. (2013) New Zealand	Intelligent system	Older adults(n=4)	Pilot study	Have intelligent system installed	/	10 weeks	/	/	An effective technique has been presented for analysis of data to monitor the daily activities of the elderly
Marilyn Rantz et al. (2017) America	Intelligent Sensor System	Older adults(n=172)	RCT	Using sensor data to detect early signs of illness or functional decline	Usual health assessment methods	experiment group: 350.56 days; control group: 382.39 days	/	SF-12/GDS/MMSE/ADL/IADL/gait speed/FAP/hand grips	Elders can benefit from early detection and recognition of small changes in health conditions and get help early
Pekka Rantanen et al. (2017) Finland	Evondos	Older adults(n=44)	Pilot study	Care with Evondos	/	26.9 days	/	On-time dispensing/missed doses	The device delivered and patients retrieved medicine sachets for 99% of the alerts
Ioulietta Lazarou et al. (2016) Greece	Dem@Care	Older adults with cognitive impairment(n=4)	Mixed-method study	Have Dem@Care installed	/	4 months	/	MMSE/MoCA/CDR/RBMT/NPI/FDS/GDS/HDRS/FUCAS/PSS/BAI/TMT-B/BDI/IADL/ROCF/AVLT/TEA	Improvement was detected from the beginning to the end of the trial for all participants in neuropsychological assessment. Detecting abnormalities via the system, such as REM sleep, has proved to be critical to assess current status, drive interventions, and evaluate improvements in a reliable manner

Mobyen Uddin AHMED (2015) Sweden	Personalized health-monitoring system	Older adults(n=6)	Pilot study	Have personalized health-monitoring system installed	/	8 weeks	/	/	The system is acceptable since the feedback; recommendation and alarm messages are personalized and differ from the general messages
Qiong Wang (2022) China	Intelligent home medical system	Dementia(n=64)	RCT	Have intelligent medical care system installed	routine family care	6 months	/	ADL/nursing satisfaction/the accidents during care	ADL score in the intervention group was lower than that in the control group both 3 months and 6 months after care, and the total incidence of accidents in the intervention group was higher than that in the control group
Christina Aggar et al. (2022) Australia	Smart home technology	Older adults(n=60)	Pre-post trial	Completed a personalized Smart Home technology program	/	12 weeks	/	Personal Well-being Index	Participants' quality of life significantly increased after Smart Home use
James Chung-Wai Cheung et al. (2022) China	eNightLog	Older adults(n=26)	Pilot study	Have eNightLog systems installed	/	3 months	/	/	eNightLog system was validated with excellent performance and showed only 3 false alarms out of 2762 bed-exiting events over three months. The system revealed its capability of performing wandering surveillance in a practical environment and of potentially replacing existing products such as pressure sensors

Abbreviation: RCT, Randomized Controlled Trials; h, hour; d, day; w, week; min, minute; FM-SEC, Fugl-Meyer scale for shoulder/elbow and coordination; FM-WH, Meyer scale for wrist/hand; MP, Motor Power score; MS-SE, Motor Status score for shoulder and elbow; MS-WH, Motor Status score for wrist and hand; 6MWT, 6-min walk test; TWT, the 10 m walk test; FIM, Functional Independence Measure; SF-36, The Item Short-Form Health Survey physical functioning questionnaire; FM, Fugl-Meyer scale; MAS, Modified Ashworth Scale; BAT, Bimanual Activity Test; FMAUE, Fugl-Meyer Assessment for of Upper Extremity; 9HPT, the Nine-Hole Peg Test; TRCoh, task–related coherence; MEP, motor evoked potential; SAI, short-latency afferent inhibition; BBS, Berg Balance Scale; Nutt, the Nutt's rating; ABC, Activities-Specific Balance Confidence scale; TUG, The Timed Up & Go Test; 10MWT, The Ten-Meter Walk Test; UPDRS, The Unified Parkinson's Disease Rating Scale; MMSE, Mini-Mental State Examination score; VAS, visual analogue scale; GDS-15, The Geriatric Depression Scale-15; TMIG-IC, The

Tokyo Metropolitan Institute of Gerontology Index of Competence; APG, Accelerated plethysmography; KFES, Korean version of the Falls Efficacy Scale; MBT, Mini BESTest; 5TSTS, Five Times Sit to Stand Test; PDQ-39, Parkinson's Disease Questionnaire 39; BI, Barthel Index; LBT, Line Bisection Test; SINGER, Scores of Independence Index for Neurological and Geriatric Rehabilitation test; FDG, fluorodeoxyglucose; FAC, functional ambulation category; HR, heart rate; BRPE, Borg rating of perceived exertion; BDI-II, Beck depression inventory-II; FMA, the Fugl-Meyer Assessment; HAD1, the Hamilton Rating Scale for Depression; HAM-A, the Hamilton Rating Scale for Anxiety; ACE-R, Addenbrooke's Cognitive Examination-Revised; ROM, range of motion; BBT, Box and Blocks test; JTHFT, Jebsen-Taylor Hand Function Test; MI, Motricity Index; NHPT, Nine Hole Peg Test; HTT, Hand Tapping test; ACE-R, Addenbrooke's Cognitive Examination-Revised; HAD2, Hospital Anxiety and Depression Scale; NAB, Neuropsychological Assessment Battery; HVLT-R, Hopkins Verbal Learning Test, Revised; BVMT-R, Brief Visuo-spatial Memory Test, Revised; CCI, Co-Contraction Index; MFT, manual function test; ARAT, Action Research Arm Test; PAINAD, Pain Assessment in Advanced Dementia scale; CMAI, Cohen-Mansfield Agitation Inventory-Short Form; CSDD, Cornell Scale for Depression in Dementia; RAID, Rating Anxiety in Dementia scale; MQS-III, Medication Quantification Scale-III; CASI, Cognitive Abilities Screening Instrument; 30-s STS, 30-s sit-to-stand test; FR, functional reach test; LBT, the line bisection test; CBS, the Catherine Bergego Scale; GDS, Global Deterioration Scale; GSR, galvanic skin response; GDS, Geriatric Depression Scale; GBS, Gottfries-Bråne-Steen Scale; CAM, Confusion Assessment Method; FRT, functional reach test; COP, center of pressure; FM-UL, Upper Limb part of Fugl-Meyer assessment; pROM, total passive Range Of Motion; MAS-S, Modified Ashworth Scale Shoulder; MAS-E, Modified Ashworth Scale Elbow; MRC, Medical Research Council; m-FIM, Motor-Functional Independence Measure; FAT, Frenchay Arm Test; NPI-Q, The Neuropsychiatric Inventory Brief Questionnaire Form; CMAI-SF, The Cohen-Mansfield Agitation Inventory-Short Form; GDS-SF, The Geriatric Depression Scale Short Form; UCLA-3, the UCLA Loneliness Scale Version 3; WHO-QOL-OLD, the World Health Organization Quality of Life Questionnaire for older adults; MLAPS, The Modified Lexington Attachment to Pets Scale; BARS, The Brief Agitation Rating Scale; CDR, Clinical Dementia Rating scale; QUALID, Quality of Life in Late-Stage Dementia scale; IPPA, Individually Prioritized Problems Assessment; MoCA, the Hong Kong Montreal Cognitive Assessment 5-minute Protocol; MBI, the Modified Barthel Index; QoL-AD, Quality of Life–Alzheimer's Disease; MSPSS, Multidimensional Scale of Perceived Social Support; ANX, Almere model Anxiety; PAD, Perceived Adaptability; PS, Perceived Sociability; SP, Social Presence; PEOU, Trust and Perceived Ease of Use; AES, Apathy Evaluation Scale; AWS, Algase Wandering Scale–Nursing Home version; OERS, Observed Emotion Rating Scale; sMMSE, Severe Mini Mental State Examination; NPI, the Neuropsychiatric Inventory; APADEM-NH, the Apathy Scale for Institutionalized Patients with Dementia Nursing Home version; AI, Apathy Inventory; ULS-8, Short Form UCLA Loneliness Scale; CCATool-Robotics, perceptions of robotic cultural competence; MMSE-DS, Mini-Mental State Examination-Dementia Screening; SMCQ, Subjective Memory Complaint Questionnaire; CERAD-K, Korean version of Consortium to Establish a Registry for Alzheimer's Disease; GDSSF-K, Korean Version of The Geriatric Depression Scale Short Form; ABMI, Agitated Behaviors Mapping Instrument; Modified-TPI, Modified-Temple Presence Inventory; I-PANAS-S, International Positive and Negative Affect Schedule; ODAS, Observable Displays of Affect Scale; ACIS-C, Assessment of Communication and Interaction Skills; SPI, Social Participation Intention scale; SPB, Social Participation Behavior scale; IQCODE, Informant Questionnaire on Cognitive Decline in the Elderly; FCSRT, Free and Cued Selective Reminding Test; TMTA, Trial Making Test A; DSST, Digit Symbol Substitution Test; FAB, Frontal Assessment Battery; AM, attention matrices; TMT-B, Trail Making Test; TMT-B-A, Trail Making Test; SRT, story recall test; TCD, test copy of design; BPRS, Brief Psychiatric Rating Scale; HRS-D, Hamilton Rating Scale for Depression; ADL, activities of daily living; IADL, instrumental activities of daily living; FAP, Functional Ambulation Profile; RBMT, Rivermead Behavioral Memory Test; FDS, Functional Rating Scale for Symptoms of Dementia; HDRS, Hamilton Depression Rating Scale; FUCAS, Functional Cognitive Assessment Scale; PSS, Perceived Stress Scale; BAI, Beck Anxiety Inventory; ROCF, Rey–Osterrieth Complex Figure Test; AVLT, Rey Auditory Verbal Learning Test; TEA, Test of Everyday Attention.