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Artificial intelligence and robotics for older adults with healthy aging: a systematic review

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Abstract

Background: The demand for effective aged care solutions increases as the global aging population increases. Traditional care models are increasingly being tested by the number of older adults who need support, especially those with chronic diseases or cognitive decline.

Research aim: This systematic review aims to examine the role of artificial intelligence (AI) and robotics in supporting healthy aging in older adults, focusing on motor function, cognitive function, quality of life, and self-efficacy outcomes.

Methods: Using the PRISMA methodology, we analyzed 25 studies published between 2014 and 2024, retrieved from PubMed, Scopus, and EBSCO databases. This review included randomized controlled trials (RCTs).

Results: The results showed that AI and robotic interventions, especially those targeting motor skills rehabilitation and cognitive function, showed promising improvements in older patients. Robotics, such as robotic exoskeletons and assistive robots, have been shown to improve motor skills, gait, and posture, and support cognitive stimulation. However, barriers such as digital literacy, affordability, and ethical concerns about privacy and autonomy remain significant challenges. Despite these limitations, AI and robotics represent a transformational solution to meet the growing needs of eldercare, reduce caregiver burden, and improve health outcomes.

Conclusion: Future research should address these barriers and explore culturally tailored robotic assistance models. Integrating artificial intelligence and robotics into elder care can improve the quality of life for older adults and support healthy aging at home or in a residence.

Keywords: artificial intelligence; healthy aging; older adults; robotic

Introduction

The world's population is aging at an unprecedented rate, with projections indicating that by 2050, over 16% of the global population will be aged 65 years or older (Padeiro et al., 2022). This demographic shift presents significant challenges for healthcare systems, social welfare programs, and caregivers, as aging is often associated with chronic diseases, cognitive decline, and reduced mobility (Grinin et al., 2023; Gürsu, 2022; Hani et al., 2024; Seshadri et al., 2022; Silab et al., 2024). Traditional caregiving models struggle to meet the increasing demand for elderly care, prompting the search for innovative, technology-driven solutions that can enhance the quality of life and independence of older adults (Koç, 2023; Wang et al., 2024). Among these, artificial intelligence (AI) and robotics have emerged as transformative tools with the potential to revolutionize elderly care and promote healthy aging (Ji et al., 2025).

Artificial intelligence and robotics offer various applications to support aging populations, including health monitoring (Cantone et al., 2023; Ho, 2020) and rehabilitation assistance for cognitive stimulation and social engagement (Nasr et al., 2020; Rong et al., 2022). AI-powered systems can analyze medical data, predict health risks, and provide personalized healthcare recommendations (Apriyanto et al., 2024; Fosch-Villaronga et al., 2021; Hirushit et al., 2024; Sharma et al., 2024; Singh et al., 2024), while robots can assist with daily activities, such as mobility support and companionship (Cavazos et al., 2024; Gandhi & Goyal, 2020; Lou et al., 2023). Integrating these technologies into elderly care is gaining momentum, with promising results in reducing caregiver burden and improving health outcomes. However, despite their potential, the widespread adoption of AI and robotics remains limited due to ethical concerns, technological barriers, and varying acceptance levels among older adults and healthcare providers (Dubbaka & Sankar, 2024).

One of the key challenges in integrating AI and robotics into elderly care is ensuring its usabil-

ity, accessibility, and cultural adaptability. Many older people face difficulties interacting with technology, and factors such as digital literacy, affordability, and ethical considerations - such as privacy and autonomy—must be addressed. Furthermore, concerns regarding the emotional and psychological impact of robotic companionship and the potential replacement of human caregivers require careful examination. Addressing these challenges is crucial for maximizing the benefits of AI and robotics while ensuring that they complement rather than replace human caregiving (Babu & Joseph, 2025; Cantone et al., 2023; Dubbaka & Sankar, 2024; Htet et al., 2024).

Given these opportunities and challenges, this study aims to systematically review the existing literature on the use of AI and robotics in elderly care, specifically to promote healthy aging, including the effectiveness of robotics for motor function, cognitive function, quality of life, and self-efficacy outcomes. By synthesizing findings from multiple studies, this review seeks to provide a comprehensive understanding of the effectiveness, limitations, and future directions of AI and robotic applications in elderly care. Therefore, the research question of the review is "What is the role and effectiveness of artificial intelligence (AI) and robotics in supporting healthy aging among older adults?"

Methods

The methodology of the systematic review and database search was guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Systematic Reviews (Page et al., 2021). PRISMA can help readers develop a greater understanding of terminology, core concepts, and key items to report for Systematic Reviews.

Data sources and the search strategy

The databases used to provide a comprehensive overview of this topic are PubMed, Scopus, and EBSCO, in which the literature is published in the English language. The literature published during the ten years from January 2014 to December 2024 was reviewed to ensure the authenticity and reliability of the resource data. The search strategy for this scoping review was performed using the PICO (Population, Intervention, Comparison/Control, Outcome) framework for critical appraisal. The PICO concept was introduced in 1995 by Richardson et al. to break down clinical questions into searchable keywords (Schiavenato & Chu, 2021). It can help researchers form a question that focuses on the most important issue for a patient, problem, or population. It helps to identify key terms to use in a search for evidence and select results that directly relate to the situation. The research question will be the foundation for him to guide the researcher and find the most relevant information or data from previous studies. In this study, we formulated the following: population (P): older adults with >60 years; intervention (I): robotically assisted in any condition designed to support health, functional ability, or well-being in older adults, comparison; (C): group control with usual care or any intervention not performed in the intervention group; and outcome (O): motor function, cognitive function, tool used in the relevant article, and efficacy.

Keywords in this study included terms related to robotic assistance and older adults. The search terms were as follows: robotic assistance and older adults. The terms related to robotic assistance, namely "robotic assistance", "robotic technology", were used as search terms. Subsequently, all search terms related to older adults included 'older adults', 'Elderly frail', 'Frail elders', aged, "Frail Elder", "Frail Older Adults", "Adult, Frail Older", "Adults, Frail Older", "Frail Older Adult", "Older Adult, Frail', 'Older Adults, Frail", "frail elderly". The search keyword combined with Boolean operators (AND/OR), truncation, and wildcards are embedded together namely 'robotic assistance' OR robotic Technology" AND 'older adults' OR "Elderly Frail" OR "Frail Elders" OR aged, 'Frail Elder' OR "Frail Older Adults" OR 'Adult, Frail Older' OR Adults, Frail Older" OR 'Frail Older Adult' OR 'Older Adult, Frail' OR 'Older Adult, Frail' OR "Older Adults, Frail" OR 'Frail elderly' OR 'Frail elderly'. This study included only randomized controlled trials (RCTs) evaluating care-related robotic, with its population being older adults =>60 years, and older people.

Study selection criteria

Research literature that meets the following inclusion and exclusion criteria. The inclusion criteria include 1) the articles were in English and full text; 2) the research published between 2014-2024; 3) the subject of the respondent in the articles is human; 4) the research respondents were older adults aged >= 60 years; 5) the articles focusing on robotic assistance or robotic technology and older adults; and 6) original articles. The exclusion criteria were as follows: 1) research in the form of reviews, books, letters to the editor, abstracts of speeches, master's theses, Ph.D. dissertations, and conference presentations; 2) research articles that only expressed opinions without concrete data or material support; and 3) research articles in which robots assisted in the surgical process.

Screening
Following the database search, all references were imported into Rayyan (AI-Powered Systematic Review Management Platform) to help researchers complete literature and systematic reviews. Researchers (IS and MSP) identified and removed duplicates, and all researchers reviewed and screened the data until full-text screening. Any differences between the reviewers regarding the inclusion or exclusion of articles for the full-text review were discussed. All results were verified by the corresponding researcher (SI). The reasons for excluding studies at the full-text review stage were recorded. Study selection, screening, and reasons for exclusion at the full-text review stage are reported in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram (*Figure 1*).

Risk of bias of the study
The methodology of all studies included was evaluated using version 2 of the Cochrane risk-of-bias tool (RoB-2) for randomized trials. This tool examined five areas: the randomization process, deviations from the intended intervention, missing outcome data, outcome measurement, and the reporting of results. The risk of bias was categorized as low, unclear, or high. A study was excluded if two domains of RoB-2 were identified as having a risk of bias. Two authors independently conducted the risk-of-bias assessment for the included studies. Any discrepancies that emerged during this process were resolved through mutual agreement under the supervision of a second author.

Data extraction and synthesis
The next stage after searching for research articles was to perform data extraction and synthesis, which is illustrated in the form of tables in the Microsoft Excel program. The extracted data included the first author, year of publication, study objective, study location, study design, study setting, study sample, study population, age, measurement, intervention, and outcome. The included research results were summarized using descriptive syntheses that show the characteristics of the included studies and the situation of robotic assistance for older adults in *Table 1*.

Results

Characteristics of articles
The identification process in three databases (PubMed, Scopus, and EBSCO) resulted in 134.451 articles. After removing duplication and applying the limitation, including articles published in 2014-2024, human subject area, original study, and English articles, 1754 were processed for screening. When reading the title, there were 1655 articles irrelevant to the type of study and not suitable for the context. In addition, 28 papers whose abstracts were not about robotics and older adults were excluded. In addition to the screening, approximately 41 articles were excluded from the review due to the inaccessibility of full-text articles, and five papers did not have an RCT design. In the final stage, this study included 25 eligible articles for further analysis. Similar data were categorized and discussed among the authors to generate the topic of the implementation of robotic assistance in older adults. The total number of subjects in this review was 1687 people, including patients with stroke, dementia, spinal cord injury (SCI), and Parkinson's disease.

Most of the studies involved patients with stroke (72%) and measured upper limb function (72%). Implementing robotic assistance for older adults mainly involved training or rehabilitation, which lasted approximately 20-120 minutes per session. The frequency of using robotic assistance was 2-7 times per week, and the duration of intervention was approximately 2 -12 weeks.

Risk of bias of study
In accordance with Version 2 of the Cochrane RoB-2 assessment, the included studies were determined to exhibit a low risk of bias. None of the studies were excluded due to breaches in the five RoB-2 domains. Nonetheless, a concern was noted regarding deviations from the intended intervention, especially concerning the blinding of participants, which could potentially introduce bias in most of the studies analyzed (*Figure 2*).

Robotic-assisted therapy rehabilitation improves motor function interdependence
The use of robotics to enhance motor function is divided into robotic assistance for the upper and lower limbs. For the upper limb region, robotics was applied to train the finger, hand movement, shoulder rotation, and general hand function in daily life (Orihuela-Espina et al., 2016; Park et al., 2021; Rowe et al., 2017; Susanto et al., 2015). Upper limb motor function was trained using various robotic assistance or artificial intelligence, depending on the severity of the patient's impairment and focus area. The fingers were trained using a hand skeleton robot and serious games (Rowe et al., 2017; Susanto et al., 2015). In random order, the hand skeleton robot was placed on the patient's hand to perform maximum flexion and extension of each digit individually for 3 seconds (Susanto et al., 2015). Musical games, such as playing guitar, could be added to the finger exercise program for an hour each day (Rowe et al., 2017).

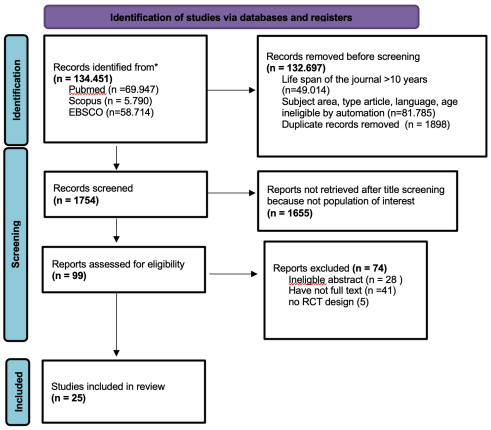


Figure 1. PRISMA flow diagram illustrating the study selection process, including the number of records identified, screened, excluded, and included at each stage of the review.

Six studies investigated the effect of robotic-assisted therapy on lower limb function (Castelli et al., 2023; Kang et al., 2021; Kayabinar et al., 2021; Park et al., 2021; J.-H. Shin et al., 2024; Yu et al., 2021). These studies showed that there were an improvement of body posture, gait, and walking for the lower limb regio. Robot gait training with and without virtual reality increased gait, mobility, balance and functional independence (Kayabinar et al., 2021; Yu et al., 2021). An exercise with robot improved the walking posture and preventing to fall among older people (J.-H. Shin et al., 2024).

Robotic-assisted therapy rehabilitation improves cognitive function and interdependence

Three studies reported that robotic-assisted therapy rehabilitation improves cognitive function interdependence (Castelli et al., 2023; Gryfe et al., 2022; Park et al., 2021). Robotic assisted therapy (Hunova) showed improved executive functions, information processing, attention, and discrimination of multiple stimuli, which performed a specific rehabilitation program for 12 sessions (Castelli et al., 2023). Robotics also had a significantly higher post-intervention improvement in cognitive function ($t = 4.707$, $p < 0.001$) in patients with mild cognitive impairment during the COVID-19 Pandemic. The last study also showed that robotic assisted significapost strokeed the memory and learning domain of the SCOPA-COG (P=0.014).

Quality of life and self-efficacy outcomes

Three studies showed that rehabilipost strokeobotic-assisted therapy improves quality of life and self-efficacy (Y.-W. Chen et al., 2023; Kayabinar et al., 2021; Rowe et al., 2017). Robotic-assisted therapy can improve self-efficacy in stroke and self-efficacy in daily living after stroke (Y.-W. Chen et al., 2023). Robot gait training also improved fall self-efficacy scores among patients with chronic stroke (Kayabinar et al., 2021). Robotic assistance to train fingers can improve the self-efficacy with respect to their ability to perform the box and blocks Test (BBT) significantly over time, with a p-value of ($P = 0.014$) (Rowe et al., 2017) . Home-based robot-based rehabilitation therapy also increased the quality of life of stroke patients. Improvement in quality of life (SSQOL) with a significant increase of 17.2 points at week 24 ($p < 0.05$) (Aguirre-Ollinger et al., 2024).

Tools measurement used

The current study has evaluated the use of robots and artificial intelligence using various measurement tools to assess the effectiveness of robotic interventions, especially in medical rehabilitation. The evaluation of the thirty studies was analyzed, generally focused on aspects of motor function, cognitive function, quality of life, and self-efficacy outcomes. Thirteen studies include the Fugl-Meyer assessment (FMA) to assess motor function recovery after robotic therapy (Y.-W. Chen et al., 2023; Kang et al., 2021; Keeling et al., 2021; Majeed et al., 2020; Morelli et al., 2023; Norouzi-Gheidari et al., 2021; Orihuela-Espina et al., 2016; Rosenthal et al., 2019; Rowe et al., 2017; Rozevink et al., 2021; Susanto et al., 2015; Yu et al., 2021). The Action Research Arm Test (ARAT) assesses upper extremity motor ability (Aguirre-Ollinger et al., 2024; Keeling et al., 2021; Rodgers et al., 2019; Rozevink et al., 2021; Susanto et al., 2015), and the Wolf Motor Function Test (WMFT) assesses upper extremity motor ability by measuring the performance time (WMFT-Time) and functional ability rating scale (WMFT-FAS) in the required tasks (Y.-W. Chen et al., 2023; Hsieh et al., 2016; Rozevink et al., 2021; Susanto et al., 2015), the Timed Up & Go (TUG) to measure the progress of balance, sit-to-stand, and walking (Castelli et al., 2023; J.-H. Shin et al., 2024; Yu et al., 2021), and the Modified Ashworth Scale (MAS) to assess sensorimotor and clinical measures of hemiparetic limb spasticity of shoulder adductors, elbow flexors, wrist and finger flexor (Aguirre-Ollinger et al., 2024; Gorman et al., 2016; Rosenthal et al., 2019). The most widely used instruments to evaluate independence in carrying out daily living activities are the Functional Independence Measure-FIM (Hirano et al., 2024; Hsieh et al., 2016; Kayabinar et al., 2021; Keeling et al., 2021) and the Functional Ambulation Category (FAC), which are used to measure the patient's walking ability after training with a robot (Castelli et al., 2023; Kayabinar et al., 2021).

Table 1. Summary of included study

No	Author (Year) and Title	Study setting/ design/ population	Intervention	Results
1	Yen-Wei Chen, Kuan-Yi Li, Chu-Hsu Lin, Pei-Hsuan Hung, Hui-Tzu Lai & Ching-Yi Wu (2023). The effect of sequential combination of mirror therapy and robot-assisted therapy on motor function, daily function, and self-efficacy after stroke.	The study setting in medical centres in Taiwan. The study was single-blind randomized controlled trial, with 43 patients with chronic stroke survivors	All patient received interventions for 60 min/session, 3 sessions/week for 6 consecutive weeks. In MR group, each intervention consisted of 20 min of mirror therapy, followed by 40 min of robot-assisted therapy. In SMR group, each intervention consisted of 20 min of sham mirror therapy, followed by 40 min of robot-assisted therapy. Mirror therapy protocol (MR group) - a mirror was placed in the patient midsagittal plane to create a visual illusion of a paretic limb by using the mirror reflection of the non-paretic arm.	1. WMFT-FAS, there was no statistically significant interaction between groups and intervention ($p = 0.60$). 2. NEADL showed no statistically significant interaction effect between group and intervention ($p = 0.92$). Patients in both groups significantly improved their independence in daily activities, and the improvements were not significantly different between the two groups. 3. SSEQ showed no statistically significant interaction effect between group and intervention ($p = 0.84$). Then researcher conducted pairwise comparisons to examine the differences between baseline and post-intervention for each group and found significant improvements in SSEQ scores from baseline to post-intervention in MR group, $t(18) = 2.35$, $p = 0.03$, and no significant differences were found in SMR group, $t(17) = 2.08$, $p = 0.053$. For the DLSES showed no statistically significant interaction effect between group and intervention ($p = 0.21$). Then they conducted pairwise comparisons to examine the differences between baseline and post-intervention for each group. Significant improvements in DLSES scores was found from baseline to post-intervention in MR group, $t(18) = 2.37$, $p = 0.03$, and no significant differences were found in SMR group, $t(17) = 1.62$, $p = 0.12$.
2	Büşra Kayabinar , İpek Alemdaroğlu-Gürbüz, Öznur Yilmaz (2021) The effects of virtual reality augmented robot-assisted gait training on dual-task performance and functional measures in chronic stroke: a randomized controlled single-blind trial.	Inpatient rehabilitation centre. The study was a randomized controlled single-blind trial	The patients in the study group participated in VR-RAGT for six weeks, two days a week, for a total of 12 sessions. RAGT was performed with RoboGait. A hip and knee support exoskeleton gait robot that was programmed to move individuals' lower extremities on a treadmill along a predefined trajectory	1.FGA, RMI, BBS, and FIM total scores within the groups; significant improvements were determined after the treatment in all test scores in both groups ($P<0.05$). 2.FES-I the significant improvement was determined only in the control group ($P<0.05$).
3	Helen Rodgers, Helen Bosomworth, Hermano I Krebs, Frederike van Wijck, Denise Howel, Nina Wilson, Lydia Aird, Natasha Alvarado, Sreeman Andole, David L Cohen, Jesse Dawson, Cristina Fernandez-Garcia, Tracy Finch, Gary A Ford, Richard Francis, Steven Hogg, Niall Hughes, Christopher I Price, Laura Ternent, Duncan L Turner, Luke Vale, Scott Wilkes, Lisa Shaw (2019) Robot assisted training for the upper limb after stroke (RATULS): a multicentre randomised controlled trial.	Four National Health Service (NHS) centres in the UK Study design was a multicentre randomised controlled trial	Robot-assisted training and EULT programmes were delivered at the same frequency and duration: 45 min of face-to-face therapy, three times per week for 12 weeks. The same therapists and therapy assistants delivered both interventions at each centre. The robot-assisted training programme integrated training with all three modules of the MIT-Manus robotic gym (shoulder–elbow module, wrist module, hand module integrated on to the shoulder–elbow module).	Robot-assisted training (adjusted odds ratio [aOR] 1·17 [98·3% CI 0·70–1·96]) and EULT (aOR 1·51 [0·90–2·51]) did not improve upper limb function; the effects of robot-assisted training did not differ from EULT (aOR 0·78 [0·48–1·27]).
4	L. Castelli, C. Iacovelli, C. Loreti, A.M. Malizia, I. Barone Ricciardelli, A. Tomaino, A. Fusco, L. Biscotti, L. Padua, S. Giovannini (2023) Robotic-assisted rehabilitation for balance in stroke patients (ROAR-S): effects of cognitive, motor and functional outcomes.	The study setting was in a post-acute rehabilitation unit in Italy The design of the study used a single-blind, noninferiority, randomized, interventional, control group study.	Hunova group (HuG), which performed a specific rehabilitation program for balance using Hunova for 12 sessions in addition to conventional rehabilitation, and the control group (CoG), which performed only conventional rehabilitation	The assessment of cognitive performance, the intra-group analysis showed a statistically significant improvement between T0 and T1 in most of the scales for both groups, with the exception of the TMT ($p=0.182$) for HuG and the SDMT ($p=0.173$) and TMT ($p=0.862$) for CoG.
5	J. F. Alingh, B. M. Fleerkotte, B. E. Groen, J. S. Rietman, V. Weerdesteyn, E. H. F. van Asseldonk, A. C. H. Geurts and J. H. Buurke (2021) Effect of assist-as-needed robotic gait training on the gait pattern post stroke: a randomized controlled trial.	Study setting was in Sint Maartenskliniek, Nijmegen; Roessingh Center for Rehabilitation, Enschede) in Netherland A randomized controlled trial was used in the study design	Functional Ambulation Categories 3–5) and randomly assigned to six weeks of AANmDOF (assist-as-needed' multiple degrees of freedom) robotic (combination of training in LOPES-II and conventional gait training) or conventional gait training.	WEXT did not significantly differ ($p = 0.263$), These Time effects did not differ between groups (Group × Time interactions, $p \geq 0.152$).
6	Satoshi Hirano, Eiichi Saitoh, Daisuke Imoto, Takuma Ii, Tetsuya Tsunoda and Yohei Otaka (2024) Effects of robot-assisted gait training using the Welwalk on gait independence for individuals with hemiparetic stroke: an assessor-blinded, multicentre randomized controlled trial.	Recruited from Convalescent rehabilitation wards hospitals in Japan. The study was a multicenter randomized controlled trial.	RAGT (Robot-assisted gait training) using the Welwalk combined with conventional physical therapy (Welwalk group) or conventional physical therapy alone (control group). The intervention period for the two groups was 4 weeks, and the rehabilitation program was provided for up to 180 min/day, including physical therapy for 80 min/day and occupational and speech therapy for up to 100 min/day.	For the FAS (full analysis set), the numbers of participants who achieved gait independence in the Welwalk and control PPS (The per-protocol set), the numbers of participants who achieved gait independence in the Welwalk and in the control group with no significant difference between the groups for FAS (full analysis set) and PPS (The per-protocol set) ($p = 0.648$).
7	Alexa B. Keeling, Mark Piitz, Jennifer A. Semrau, Michael D. Hill, Stephen H. Scott and Sean P. Dukelow (2021) Robot enhanced stroke therapy optimizes rehabilitation (RESTORE): a pilot study.	Recruited from Foothills Medical Center and Dr. Vernon Fanning Care Center in Calgary, Alberta, Canada A pilot study clinical controlled trial	Participants received either an hour per day of robotic rehabilitation plus standard of care, or standard of care. Standard of care therapy included an average of approximately 45 min of Occupational Therapy and 45 min of Physical Therapy per day. For individuals in the robotic therapy group, the intervention occurred for 1 h/day for 10 days over two weeks and consisted of the nine robotic rehabilitation tasks.	Increase noted for the FMA UE (Fugl-Meyer Assessment of Upper Extremity), a 10-point increase in ARAT (Action Research Arm Test), and a 16-point increase in FIM. For the control group, no significant changes were found for the FMA UE or the ARAT, with only a 2.5-point and 2-point increase noted in.
8	Yazan Abdel Majeed, Saria Awadalla and James L. Patton (2020) Effects of robot viscous forces on arm movements in chronic stroke survivors: a randomized crossover study	Recruited from Clinical Neuroscience Research Registry of the Shirley Ryan AbilityLab in Chicago. The study was a randomized crossover study.	One of eight possible targets was displayed at random for each center-out reach. Patient then returned to the home position and the next target was displayed.	Negative viscosity produced significant speed increases during early exposure that persisted through late expo-sure ($p < 0.0004$), Movement error increased significantly during early exposure to negative viscosity ($p = 0.004$,Movement distance showed behaviour similar to movement error where negative viscosity resulted in worse performance during exposure ($p < 0.0001$)
9	Samantha G. Rozevink, Corry K. van der Sluis, Ainara Garzo, Thierry Keller and Juha M. Hijmans (2021) HoMEcare aRm rehabiLItatioN (MERLIN): telerehabilitation using an unactuated device based on serious games improves the upper limb function in chronic stroke.	Rehabilitation centers: University Medical Center Groningen (UMCG) and Rehabilitation Friesland, Netherlands. A repeated measures within subject design, where the participant was their own control (control clinical Trial).	Patients trained task specific serious games for three hours per week during six weeks using an unactuated version of a robotic device. The first measurement (T0) and the WMFT and ARAT were assessed subsequently. After six weeks, the participants were assessed again (T1). During the period between T0-T1 the participants did not receive any arm/hand training and it was considered as control period.	WMFT improved significantly with 3.8 points ($p = .006$), which is also clinically relevant. No significant changes in quality of life were observed. Patients were overall satisfied with the usability of the device. Comfort and the robustness of the system need further improvements.
10	Evan A Susanto, Raymond KY Tong, Corinna Ockenfeld, and Newmen SK Ho (2015) Efficacy of robot-assisted fingers training in chronic stroke survivors: a pilot randomized-controlled trial.	The study was a pilot randomized-controlled trial in a hospital in China.	Participants were randomized into 2 groups: (1) the robot-assisted (robot) group and (2) the non-assisted (control) group, with a 1:1 ratio, by random number generator. Participants underwent a total of 20 one-hour sessions of robot-assisted finger training. The training intensity was set at 3 to 5 times a week with all 20 sessions to be completed within 5 consecutive weeks.	Intergroup comparisons showed significantly better WMFT-FT scores and time improvements post-training (with $p = 0.017$) in the robot group. No significant difference between the two groups was present in any clinical scores 6 months after training.
11	Deng Yu, Zhang Yang, Liu Lei, Ni Chaoming, Wu Ming (2021) Robot-Assisted Gait Training Plan for Patients in Poststroke Recovery Period: A Single Blind Randomized Controlled Trial.	Hospital of University of Science and Technology of China. The study was a Single Blind Randomized Controlled Trial.	85 patients were randomly assigned to one of two treatment groups, with 31 patients in withdrawal before treatment. The training program comprised 14 2-hour sessions, for 2 consecutive weeks. Patients allocated to the robot-assisted gait training group were treated using the Gait Training and Evaluation System A3 from NX (robotic gait training (RT) group, n = 27).	In the time-space parameter analysis of gait, the two groups exhibited no significant changes in time parameters, but the RT $P < 0.05$). After training, FMA scores (20.22 ± 2.68) of the PT group and FMA scores (25.89 ± 4.6) of the RT group were significant. In the Timed Up and Go test, FMA scores of the PT group (22.43 ± 3.95) were significant, whereas those in the RT group (21.31 ± 4.92) were not.
12	Eun-A Park, Ae-Ri Jung, Kyoung-A Lee (2021) The Humanoid Robot Sil-Bot in a Cognitive Training Program for Community-Dwelling Elderly People with Mild Cognitive Impairment during the COVID-19 Pandemic: A Randomized Controlled Trial.	S-City Dementia Center in Gyeonggi-do, Republic of Korea. The study was a Randomized controlled study.	Participants were first randomized into two groups. One group consisted of 90 participants who would receive cognitive training and 45 who would not receive any training (NI/control group). The mental training group was randomly divided into two groups, 45 who received traditional cognitive training (TCT) and 45 who received robot-assisted cognitive training (RACT). The training for both groups consisted of a daily 60 min session, twice a week for six weeks. The humanoid robot, Sil-bot (Robocare, Seongnam, Korea) was used in the RACT group. Participants in the robot group responded to instructions using an individual smart pad, except for three programs for which the robots	RACT participants had significantly greater post-intervention improvement in cognitive function ($t = 4.707$, $p < 0.001$), memory ($t = -2.282$, $p = 0.007$), executive function ($t = 4.610$, $p < 0.001$), and depression ($t = -3.307$, $p = 0.004$). TCT participants had greater post-intervention improvement in memory ($t = -6.671$, $p < 0.001$) and executive function ($t = 5.393$, $p < 0.001$).

No	Author (Year) and Title	Study setting/ design/ population	Intervention	Results
			detected and evaluated the participants' motion (Galaxy Tab 10.1, Samsung Electronics, Seoul, Korea). Sil-bot can display various facial expressions and emotions based on humanoid–robot interaction (HRI) technology.	
13	Jin-Hyuck Park, PhD, OT (2021) The effects of robot-assisted left-hand training on hemi spatial neglect in older patients with chronic stroke.	Recruited from a rehabilitation hospital in South Korea. The study was a pilot and randomized controlled trial.	The Experimental Group (EG) performed 20 sessions (five days a week for four weeks) of robot-assisted hand training using the Amadeo Robotic device (Trymotion GmbH, Graz, Austria). The end-effector-based Amadeo Robot has five degrees of freedom and provides the motion of one or all five fingers through a passive rotational joint placed between the fingertip and an entity moves laterally (the thumb has two passive rotational joints). All five translational degrees of freedom are independent and almost entirely cover the fingers' workspace. The interface between the human hand and the machine is achieved via elastic bands or plasters and the wrist is restrained from movement by a Velcro strap.	EG showed significant improvements in the hemispatial neglect (P<.001) and the Albert test (P<.01) whereas there were significant improvements in the hemispatial neglect (P<.01) but not in the Albert test (P>.05) in the control group. Both groups showed a significant improvement in the neglect symptoms (EG: P<.001; CG: P<.05). On the other hand, there was a statistically significant difference in changes in the neglect symptom (P<.001; η2=0.569)
14	Felipe Orihuela-Espina PhD, Giovana Femat Roldán MD, Israel Sánchez-Villavicencio MD, Lorena Palafox MSc, Ronald Leder PhD, Luis Enrique Sucar PhD, Jorge Hernández-Franco PhD (2015) Robot training for hand motor recovery in subacute stroke patients: A randomized controlled trial.	Recruited from Neurologic Rehabilitation Unit of the National Institute of Neurology and Neurosurgery (INNN) in Mexico City. The study was a randomized controlled trial.	All patients attended therapy five times a week until they completed 40 sessions of treatment. The first four sessions were shorter and lasted approximately 40 min. After that, therapy sessions lasted about 1 h (w60 m) with rest periods according to the ability of each patient. Experimental groups received treatments, whether occupational or robotic, under the supervision of an occupational therapist e LP. The control group received classical occupational therapy.	Fugl-Meyer score indicated a significant advantage for the hand training with the robot (FMA hand: WRS: W ¼ 8, p <0.01), whilst the Motricity index suggested a greater improvement (size effect) in hand prehension for RT (Robotic therapy) with respect to OT (Occupational therapy) but failed to reach significance (MI prehension: W ¼ 17.5, p ¼ 0.080).
15	Peter H. Gorman, William Scott, Henry York, Melita Theyagaraj Naomi Price-Miller, Jean McQuaid, Megan Eyvazzadeh, Frederick M. Ivey, Richard F. Macko (2014) Robotically assisted treadmill exercise training for improving peak fitness in chronic motor incomplete spinal cord injury: A randomized controlled trial.	Outpatient SCI clinics at an academically- affiliated bed rehabilitation hospital center (UMROI) and an academically affiliated outpatient Department of Veterans Affairs SCI clinic (VAMC), America. The study was a pilot prospective randomized, controlled clinical trial	RABWSTT was performed using the Lokomat®robotic treadmill training device that had a continuously variable weight suspension system installed. CMISCI patients were randomized to RABWSTT or a home stretching program (HSP) three times per week for three months. Those in the home stretching group were crossed over to three months of RABWSTT following completion of the initial three-month phase.	The RABWSTT group improved peak VO2 by 12.3% during robotic treadmill walking (20.2 ± 7.4 to 22.7 ± 7.5 ml/kg/min, P = 0.018), compared to a non-significant 3.9% within group change observed in HSP controls (P = 0.37). Neither group displayed a significant change in peak VO2 during arm cycle ergometry (RABWSTT, 8.5% (P = 0.25); HSP, 1.76% (P = 0.72)). A repeated measures analysis showed statistically significant differences between treatments for peak VO2 during both robotic treadmill walking (P = 0.002) and arm cycle ergometry (P = 0.001)
16	Jang-hoon Shin, Naeun Byeon, Heeju Yu, Geonhyang Yun, Hyunjin Kim, Hye-Kang Park, Dongwoo Kim, Hwang-Jae Lee, Wan-hee Lee (2024) Clinical effects of walking exercise program for older adults applied with an exercise assist robot (Bot Fit): A randomized controlled trial	The study was a randomized controlled trial with a two-group parallel design in Silver town in Yongin-si, Gyeonggi-, Korea.	Respondents performed IWE in assist mode while wearing Bot Fit (an exercise assist robot) for the first 3 weeks, and then performed IWE in resist mode for 3 weeks.	There was a significant difference in the pelvic tilt significantly increased after six weeks of exercise (P < 0.05). The waist-to-hip ratio was significantly lower after six weeks of exercise using Bot Fiit than walking exercise withour Bot Fit (P < 0.05)
17	Yu-wei Hsieh, Rong-jiuan Liing, Keh-chung Lin, Ching-yi Wu, Tsan-hon Liou , Jui-chi Lin and Jen-wen Hung (2016). Sequencing bilateral robot-assisted arm therapy and constraint-induced therapy improves reach to press and trunk kinematics in patients with stroke	The study was conducted in a clinical setting, specifically within two hospitals in Taiwan. The study was a Randomized controlled trial designed.	Respondents received a combination of RT and modified constraint-induced therapy (mCIT). Each group underwent 20 therapy sessions, lasting between 90 to 105 minutes per day, five days a week for four weeks. Specifically, the RT + mCIT group received 10 sessions of RT in the first two weeks, followed by 10 sessions of mCIT in the subsequent two weeks. The Bi-Manu-Track device was utilized during RT sessions to facilitate bilateral practice of wrist and forearm movements	The Index PV (Peak Velocity) in the RT + mCIT group was significantly smaller than in the RT group, with a p-value of **0.02**. the combination therapy (RT + mCIT) led to improved motor control strategies during the reaching task. Patients who received RT+ mCIT and RT alone had different aspects of benefits on motor control strategies. RT + mCIT uniquely improved motor control strategies of the affected limb and enhanced independence in instrumental ADL. RT improved force generation at movement initiation. A combination of RT and mCIT contributes to improve motor control strategies, motor function, and functional independence of instrumental ADL for patients with stroke
18	Chancee Park, Mooyeon Oh-Park, Amy Bialek, Kathleen Friel, Dylan Edwards, Joshua Sung H. You (2021) Abnormal synergistic gait mitigation in acute stroke using an innovative ankle–knee–hip interlimb humanoid robot: A preliminary randomized controlled trial	The study was a preliminary randomized controlled trial. Setting: Burke Rehabilitation Hospital, located in New York, United States	The study involved two groups: the Interlimb Coordinated Training combined with Conventional physical therapy (ICT-C) group and the Conventional Physical Therapy and Gait training (CPT-G) group. ICT-C Group: Patients in the ICT-C group underwent a 60-minute session of conventional physical therapy followed by 30 minutes of robot-assisted training using the innovative ankle-knee-hip interlimb robot (ICT).	The results indicated that the mean post-intervention knee joint angle in the ICT-C group was significantly higher than the mean pre-intervention knee joint angle, Post-ICT Knee Joint Angle: Mean (M) = 26.69, Standard Deviation (SD) = 1.10, Pre-ICT Knee Joint Angle: Mean (M) = 22.42, Standard Deviation (SD) = 0.61. The statistical analysis using paired t-tests yielded a t-value of t(9) = −14.59, with a p-value of P = 0.00.
19	Cheon Ji Kang, Min Ho Chun, Junekyung Lee, Ji Yeon Lee (2021) Effects of robot (SUBAR)-assisted gait training in patients with chronic stroke Randomized controlled trial	Asan Medical Center, which is a tertiary hospital located in South Korea Design: a prospective randomized controlled trial.	Intervention group received physiotherapy treatment using a ground walking exoskeletal robot (SUBAR) for 10 sessions about 30 minutes per session in 3 weeks. SUBAR is a robot that assists the patient's ankle, knee, and hip movement. Each participant started a gait speed of 0,5 up to 2,5 km/h and a step lenght of 20 to 50 cm by adjusting in 1 cm. The joystick is used to give direction step between right and lef. Control group received conventional physiotherapy program.	In the SUBAR group, MAS and step length were significantly improved between pre- and posttreatment measurements (Mean ± SD: 1.1 ± 1.6 and 5.5 ± 7.6, P = .019 and .016, respectively). The SUBAR group improved the stride length and step length of the affected limb but not significantly. The BBS improved more in the control group than in the SUBAR group. There were no other differences between the SUBAR group and the control group
20	Justin B Rowe, Vicky Chan, Morgan L. Ingemanson, (2017) Robotic Assistance for Training Finger Movement Using a Hebbian Model: A Randomized Controlled Trial	The study setting was at the University of California, Irvine, involving patients with a chronic stroke and moderate hemiparesis. A randomized controlled trial, was used in this study	Patients (n = 30) with a chronic stroke and moderate hemiparesis (average Box and Blocks Test 32 ± 18 and upper extremity Fugl-Meyer score 46 ± 12) actively moved their index and middle fingers to targets to play a musical game similar to Guitar Hero 3 h/wk. for 3 weeks. The patients were randomized to receive high assistance (causing 82% success at hitting targets) or low assistance (55% success). Participants performed ~8000 movements during training sessions.	Both groups started with similar capabilities in terms of finger movement as measured by the Box and Blocks Test (BBT). Over the 3 weeks of therapy, the average number of movements attempted by the high-assistance group was 7994 ± 1101, while the low-assistance group attempted 7930 ± 723. The statistical analysis showed no significant difference between the two groups, with a p value of P = .86. **Success Rates**: The average success rates for the high-assistance and low-assistance groups were significantly different, with the high-assistance group achieving 81.6% ± 7.2% and the low-assistance group achieving 55.1% ± 6.9%. The p value for this comparison was P < .001, indicating a highly significant difference in success rates between the two groups. **Self-Efficacy**: The self-efficacy of participants regarding their ability to perform the BBT improved significantly over time, with a p value of P = .014. However, there was no significant interaction between time and group, with a p value of P = .58. Motivation: **Motivation levels** were significantly higher in the high-assistance group, with a p value of P < .001. Additionally, motivation increased significantly over time for all participants, with a p value of P = .027
21	Yu-wei Hsieh; Keh-chung Lin; Ching-yi Wu; Tsai-yu Shih; Ming-wei Li & Chia-ling Chen (2018) Comparison of proximal versus distal upper-limb robotic rehabilitation on motor performance after stroke: a cluster controlled trial	Several hospitals in Taiwan included Chang Gung Memorial Hospital, Buddhist Taipei TzuChi General Hospital, Cathay General Hospital, Cheng Hsin General Hospital, and Taipei Hospital, Ministry of Health and Welfare. The study design used a cluster-controlled trial.	The study compared three different interventions for upper-limb rehabilitation in stroke patients: Proximal-Emphasized Interactive Motor Therapy (P-IMT), Distal-Emphasized Interactive Motor Therapy (D-IMT), Conventional Therapy (CT). Patient in P-IMT received 3 series of 320 assisted clockwise repetitions as adaptive movement and 4 series of 16 unassisted clockwise repetitions as record movements within 40 to 50 minutes. Patient in D-IMT performed wrist movement during clock games and forearm pronation/supination during the point-to-point game. Each session, patient was asked to complete 1024 repetitions of wrist and forearm movement within 40-50 minutes. Robot provided assistance when patient could not finish target in clock game and point to point game. Patient in CT protocol received 45 minutes of conventional rehabilitation including passive or active range of motion, gross motor,	There were statistically significant differences and large effect sizes on pre post intervention score of the distal FMA, total MRC, and distal MRS in P-IMT (2.13;0.07;0,07), D-IMT (3.00;0.61;0.55) and CT group (1.17;0.36;0.17) (p=0.02 to 0.04). D-IMT group show statistically significant better progress than CT group on distal FMA (p=0.03) and distal MRC (p=0.04). However, P-IMT and CT group were not statically significant different. D-IMT group had most improvement of motor function and muscle strength in the distal part of upper limb among three groups. D-IMT group had greater improvement in MAL-QOM than P-IMT group (p=0,05).

No	Author (Year) and Title	Study setting/ design/ population	Intervention	Results
			object manipulation and fine motor training and muscle strengthening. All patient in each group received 40 to 45 minutes functional task practice following training session.	
22	Peter Feys; Karin Coninx; Lore Kerkhofs;Tom De Weyer; Veronik Truyens; Anneleen Maris; and Ilse Lamers (2015) Robot-supported upper limb training in a virtual learning environment: a pilot randomized controlled trial in persons with MS (Multiple Sclerosis)	The Rehabilitation and MS Centre Overpelt in Belgium. Participants were either hospitalized at this centre or attended rehabilitation sessions on an ambulant basis, meaning they lived in the community and visited the centre for therapy purposes. A randomized controlled trial (RCT) was used in the study.	Robot training was provided about 30 minutes each session, 3 session per week for 8 consecutive weeks. Participants were trained in a chair or a wheelchair, their hand was placed in a gimbal and move freely following different training activity related to upper limb function. Virtual training environment was applied alongside robot assistance to evaluate arm movement. The virtual training environment used therapeutic training based. Each training was started with basic exercise followed by multiple skill combination that designed personalized based on participant interview. Last part of each training session, participant did a serious games designed to incorporated simultaneous training of multiple skill components combined with cognitive distractors and challenges. Pre and post-test were done in week 1 and week 8.	There were no statistically significant differences between control and intervention group after training (p>0.05). A near threshold significant difference (p = 0.048) was found between both groups for the MAL amount of use and the total MAL. For intervention group, there was improvement for overall velocity during reaching, lifting and transporting, and thus reduced movement duration statistically significant for all skill components (p<0.05)
23	Calabrò RS, Naro A, Russo M, Milardi D, Leo A, Filoni S, Trinchera A, Bramanti P (2017) Is two better than one? Muscle vibration plus robotic rehabilitation to improve upper limb spasticity and function: A pilot randomized controlled trial	A pilot randomized controlled trial with a double-blind and parallel-group study design. Setting: at Neurorobotic Rehabilitation Laboratory of the IRCCS Centro Neurolesi "Bonino-Pulejo" in Messina, Italy	Patient underwent to 40 training session with Armeo power, an hour persession for 5 times a week in 8 consecutive weeks. Armeo-Power was a robotic rehabilitation that focused in arm and shoulder movement. Group A (intervention group) received the combination of mucle vibration and Armeo-Power training. Group B (control group) received only rehabilitation using Armeo-Power training.	Patients receiving combination of muscle vibration and robotic training show a statiscally significant of reduction spasticity score (p=0,007, d=0.6), Hmax/Mmax ration (p<0,001, d=0.7), and increased short intracortical inhibition (p<0,001, d=0,7). The combination group compared to only robotic training group had greater improvement of upper limb function (p=0,007, d=0,4). There was a significant correlation between reduction spasticity score and increased short intracortical inhibition to agonist spastic muscle (p=0,004)
24	Pearl GryfE, Andrew sEXtoN, Chris a. McGibboN (2022) Using gait robotics to improve symptoms of Parkinson's disease: an open-label, pilot randomized controlled trial	Open-label, parallel, pilot randomized controlled trial study design conducted in a neurorehabilitation clinic in a large urban centre at Canada, involving patients with Parkinson disease.	Patients in the Exo and Nxo groups engaged in an 8-week program that included aerobic, strength, and functional mobility exercises. These sessions were conducted twice a week at the clinic, with staff not involved in the interventions present to ensure unbiased support	Forty participated in the trial (Exo, N.=13; Nxo, N.=14; Con, N.=13). Significant improvement in the Memory & Learning domain of the SCOPA-COG (P=0.014) and 6MwT (P=0.008) were detected for the Exo group compared to the Nxo and/or Con group. No other statistically significant between-groups effects were found. There was no serious or unanticipated adverse events
25	Sandra Petersena, Susan Houstonb , Huanying Qinc , Corey Tagued and Jill Studley (2017) The Utilization of Robotic Pets in Dementia Care	Randomized Block Design involving five urban secure dementia units.	Intervention Group: patients in the intervention group received treatment with the PARO robotic pet. This involved sessions three times a week, each lasting 20 minutes, over a period of three months. The sessions were conducted in the activity room of assisted living memory care units, where six residents were seated around a table with the PARO pet placed in the centre to encourage interaction	61 patients, with 77% females, average 83.4 years in age, were randomized into control and treatment groups. Compared to the 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 changes in GSR, pulse oximetry, and pulse rate over time were plotted for both groups. 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.

Discussion

Healthy aging is the main goal in elderly care, improving their quality of life and independence (Esmaeilzadeh & Maddah, 2024; Jones & Noppeney, 2021). Although healthy aging is the overarching goal in elderly care, the current body of robotics research predominantly reflects disease-specific rehabilitation contexts, particularly post-stroke recovery. It is crucial to remember, nevertheless, that the majority of the existing research on robots for older persons is focused on post-stroke rehabilitation settings. Therefore, rather than promoting ageing at the population level, the definition of "healthy ageing" in this review is based primarily on functional recovery and independent restoration. Artificial intelligence (AI) and robotics technology development offer innovative solutions to support the rehabilitation of the elderly. This review aims to evaluate the effectiveness of robotics in improving motor function, cognition, quality of life, and self-efficacy in older adults. Based on 25 analysed studies, the findings showed that robotics effectively improves motor skills, cognitive function, and quality of life in elderly patients, especially in rehabilitation of the upper and lower extremities. In addition, significant improvements in self-efficacy and daily independence were also observed. However, there are limitations related to the duration, frequency, and type of technology used in this intervention.

In this review, all of the included studies were randomized controlled trials (RCTs), which represented 100% of all articles analyzed. RCTs have high methodological strength in assessing the effectiveness of robotic interventions, as they allow for more objective comparisons between intervention and control groups (Kaul et al., 2022). The diversity of the patient populations studied also provides broader insights into the application of robotics for various medical conditions, such as stroke, dementia, spinal cord injury (SCI), and Parkinson's disease. This diversity is important to assess how these findings can be generalized to different types of elderly patients with different conditions (Littell, 2024; Long et al., 2024). However, the prevalence of stroke populations indicates that the evidence base is still mostly disease-specific, which would restrict extrapolation to older persons living in the community who do not have acute neurological problems.

Regarding the measurement of the outcomes of using robotics, most studies focused on the recovery of motor function, especially in rehabilitating the upper and lower limbs, as well as improving cognitive function and quality of life. The measurements used included standard test tools such as the Fugl-Meyer Assessment (FMA) and Timed Up & Go (TUG), which showed significant improvements in patients' motor skills and balance. The duration of robotic intervention in these studies varied from 2 to 12 weeks, with a therapy frequency ranging from 2–7 times a week. Therapy generally focuses on rehabilitating motor function, both for the up-

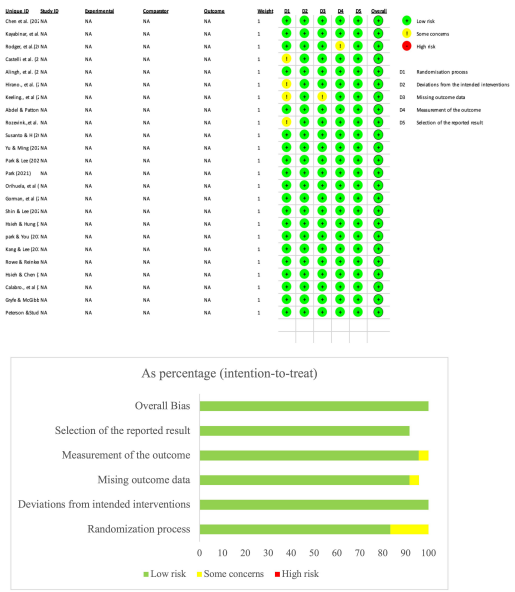


Figure 2. Risk of bias assessment of included studies using version 2 of the Cochrane risk-of-bias tool (RoB-2) for randomized trials. This tool examined five areas: the randomization process, deviations from the intended intervention, missing outcome data, outcome measurement, and the reporting of results. Green indicates low risk of bias, yellow indicates some concerns, and red indicates high risk of bias.

per limbs (such as hands and fingers) and lower limbs (such as posture and walking), as well as cognitive training to improve executive function and memory. These findings align with previous research showing the potential for robotic rehabilitation to aid motor function recovery after stroke (Coskunsu et al., 2022; Zhang et al., 2024). These findings suggest that robotic interventions can significantly impact elderly patients, although the duration and frequency of interventions must be tailored to the patient's condition for optimal outcomes (Obayashi et al., 2020; Philipp et al., 2019).

Robotic interventions for the rehabilitation of motor function in older adults have shown significant results, especially in the upper and lower extremities, although there is variation in technology and patient response (Castelli et al., 2023; Kayabinar et al., 2021). Soft robotic gloves are effective for patients with low recovery potential, such as spinal cord injury (SCI). Similarly, hand-skeleton robots and virtual reality are more successful in patients with high recovery potential (Hsieh et al., 2018). However, differences in the duration and frequency of therapy, which vary from 2 to 7 times per week for 2 to 12 weeks, affect long-term outcomes (Yu et al., 2021). Lower limb rehabilitation, especially in walking training, has shown positive results in improving balance and walking ability in stroke patients, with findings consistent with the study by Kayabinar et al. (2021). However, the main gap lies in the lack of long-term studies to assess the effectiveness of robotic therapy, mainly related to the varying standards of therapy protocols and limitations in relevant long-term studies.

This review also showed that robotic-assisted therapy significantly positively affects cognitive function in older adults, with the most pronounced improvements in executive function, attention, and memory. The three analysed studies showed that this therapy can improve information processing abilities, attention to stimuli, and decision-making skills in patients with mild cognitive impairment (MCI) and other neurodegenerative conditions. Improvements in these cognitive domains are important because MCI is often an early sign of dementia, so robotic therapy can serve as an early intervention to slow the progression of cognitive impairment. Cognitive disorders in older people occur after 3 months of an attack. The presence of this cognitive disorder will interfere with the daily activities of older adults. Furthermore, in other cases, this disorder can cause falls in older adults (Diraco et al., 2022). Three studies reported that robotic-assisted therapy rehabilitation improves cognitive function interdependence (Castelli et al., 2023; Gryfe et al., 2022; Park et al., 2021). Robotic-assisted therapy also improves executive functions, speed of information processing, attention, and discrimination of multiple stimuli (Castelli et al., 2023). The involvement of cognitive components is related to the adaptation of the brain system. Brain reserve is still considered a protective factor for many neurodegenerative pathologies that can remain dormant due to size and neural networks, as in threshold theory (Castelli et al., 2023). The last study also showed that robotic-assisted learning significantly improves memory and learning. Interventions that aim to improve or maintain cognitive functioning may have better chances of delaying nursing home admission, especially for those who show signs of cognitive impairment (Gochoo et al., 2020; Vogan et al., 2020). In other words, these findings suggest that robotic therapy is beneficial for motor recovery and improving the quality of life and functional independence of elderly patients, who are often hampered by cognitive impairment.

This review also confirmed that robotic-based therapy is beneficial for physical rehabilitation and positively impacts the self-confidence and independence of older adults, which is very

important for healthy aging (Sirizi et al., 2024; Zhao et al., 2023). These results mostly represent impairment-oriented outcomes (e.g., motor scores, balancing tests, executive function measures), even though they show significant clinical improvements in structured rehabilitation settings. Less often evaluated were broader areas essential to healthy ageing, like long-term autonomy in naturalistic settings, carer stress, and social engagement. The results showed that robotic-based therapy can improve quality of life and self-efficacy, especially in stroke patients, with a significant impact on older people. Several studies reported a significant improvement in patient quality of life, with SSQOL scores increasing by an average of 17.2 points after 24 weeks of therapy ($p < 0.05$), indicating that this therapy effectively improves the physical and psychosocial well-being of older people. Robotic therapy has also been shown to be effective in increasing the confidence of older adults in performing daily tasks, such as dressing, eating, and walking, which are often challenging for them (Y. Chen et al., 2023; Dilip et al., 2022; M. H. Shin et al., 2022). In addition, it reduces fear of falling, a common problem among older adults, and can hinder their independence (Aguirre-Ollinger et al., 2024; Petersen et al., 2017; Rowe et al., 2017). Significant increase in self-efficacy, where older adults feel more capable of performing daily activities independently, further demonstrates how robotic therapy can help improve the quality of life of older adults, reduce anxiety, and improve their overall well-being.

Twenty-five systematic reviews of the literature in this study used various measurement tools to assess motor function recovery, cognitive improvement, and functional independence in elderly patients undergoing robotic-based therapy. The most widely used measurement tools include the Fugl-Meyer Assessment (FMA), Action Research Arm Test (ARAT), and Wolf Motor Function Test (WMFT), which are effective in evaluating motor function recovery, especially in the upper limbs. Additionally, the Timed Up & Go (TUG) is used to assess balance and walking ability. In contrast, the Functional Independence Measure (FIM) and the Functional Ambulation Category (FAC) assess independence in daily activities. These measurement tools have been shown to be highly reliable in measuring patient progress, and several studies have shown significant improvement in scores after robotic intervention. However, although these measurement tools are helpful, they have several limitations, such as reliance on subjective tests that can be influenced by external factors such as patient motivation or severity of impairment. Moreover, some measurement tools, such as ARAT and WMFT, focus more on motor function, not providing a comprehensive picture of the cognitive and psychosocial aspects that are also important in elderly rehabilitation. Therefore, although this measurement tool is relevant and reliable, its use must be balanced with a more holistic evaluation to fully assess the effectiveness of robotic therapy in older adults (Bevilacqua et al., 2022; Hing Ting et al., 2021; Tobis et al., 2021).

This systematic review has significant strengths, particularly its large sample size, covering 1687 patients from various patient groups and various robotic interventions. Focusing on both motor and cognitive outcomes provides a comprehensive picture of the impact of robotic rehabilitation in older adults, which is an advantage in understanding the breadth of benefits of this therapy. However, there are several limitations in the studies included in this review, such as variations in intervention protocols, including duration, frequency, and technology used, which may affect the consistency of the results (Dubbaka & Sankar, 2024). Furthermore, potential bias in patient selection or reporting, especially in small-scale studies or those with incomplete data, can also affect the validity of findings (Gorard, 2024; Zurita-Cruz & Villasís-Keever, 2021). Another limitation is the limited number of studies evaluating the long-term outcomes of robotic interventions. This highlights the necessity for additional longitudinal research to assess the sustained effectiveness of robotic therapy and its ongoing impact on the independence and quality of life of older patients (Gürsu, 2022; Koç, 2023).

The findings of this review have important implications for clinical practice, particularly in geriatric rehabilitation centers. Robotic-based therapies can complement or even enhance traditional rehabilitation methods by providing a more structured and intensive approach to motor and cognitive rehabilitation (Bevilacqua et al., 2022; Hing Ting et al., 2021; Tobis et al., 2023). Additionally, robotic therapy can be integrated with physical or occupational therapy to provide a more holistic approach to rehabilitation, improving patient recovery in multiple aspects of daily life. However, to optimize robotic therapy, more research is needed to investigate the long-term effects of this therapy on motor and cognitive function and evaluate its integration with other therapies. Research also needs to expand the studied patient population, including those with comorbid conditions, to assess the benefits of robotic therapy in older adults with a more complex range of health problems.

In light of the positive outcomes, the methodological quality of the evidence must be scrutinized. Although the risk-of-bias assessment was clearly presented, the implications of identified methodological concerns warrant deeper consideration. In particular, the lack of participant blinding in many included studies may have inflated the estimates of the outcomes. For example, participants who were aware of receiving a robotics-assisted intervention may have reported greater improvements due to expectation effects or social desirability bias, rather than genuine clinical benefit. This limitation is particularly relevant in rehabilitation robotics research, where outcomes often rely on performance-based or self-reported measures that may be susceptions stroke and placebo effects. As a result, the observed intervention effects may have been overestimated, potentially inflating the reported effectiveness of robotic interventions (Salazar et al., 2025). Similarly, unblinded evaluators may have introduced measurement bias, consciously or unconsciously favoring intervention groups. These factors limit the confidence with which conclusions can be drawn and highlight the need for more rigorously designed trials with appropriate blinding procedures, where feasible, in future trials to strengthen the internal validity of this evidence base (Yonis et al., 2025).

While the included studies primarily address clinical rehabilitation outcomes, a gerontechnology perspective requires broader consideration of user context and deployment environments. For older adults, the effectiveness of AI and robotics is not only determined by clinical efficacy but also by usability, accessibility, and integration into daily life. Home-based technologies must account for ease of use, safety, and caregiver involvement; community settings emphasize social engagement and inclusivity; and institutional environments raise questions of scalability, staff training, and ethical oversight. Addressing these dimensions would enhance the relevance of findings to healthy aging, ensuring that technological innovations are not only clinically effective but also practically implementable in diverse real-world settings.

This review has several limitations that should be acknowledged. First, the majority of included studies focused on stroke survivors, particularly in relation to upper-limb rehabilitation. While this emphasis reflects current research trends in AI- and robotics-assisted rehabilitation, it restricts the generalizability of findings to broader older adult populations. Moreover, important groups such as those living with frailty, dementia, or multimorbidity remain underrepresented, limiting the applicability of conclusions to diverse aging trajectories. This is because, compared to stroke survivors, older adults with frailty or dementia often experience fluctuations in functional capacity, decreased attention, and lower acceptance of technology, which can substantially alter engagement and intervention outcomes. In addition, the predominance of stroke-focused studies may also have influenced the types of outcomes assessed, which were largely performance-based and impairment-oriented, potentially overlooking psychosocial or caregiver-related outcomes that are more relevant in populations with dementia or multimorbidity. Second, heterogeneity in study designs, intervention types, and outcome measures complicates direct comparison across studies. Many trials had small sample sizes and short follow-up periods, which reduces the strength of evidence regarding long-term effectiveness and sustainability. Third, most studies were conducted in controlled or laboratory settings, which may not reflect real-world implementation challenges such as cost, accessibility, cultural acceptance, and ethical considerations. Finally, publication bias may exist, as studies reporting positive outcomes are more likely to be published, potentially skewing the overall evidence base. Therefore, the effectiveness reported in this review may be overestimated when applied to older adults with higher clinical complexity. Future research should expand beyond post-stroke rehabilitation to include older adults with diverse health conditions, employ larger, more diverse samples, and investigate long-term outcomes in real-world settings. Addressing these gaps will be critical to understanding the broader role of AI and robotics in supporting healthy aging.

Final considerations

This review shows that robot-based interventions have the potential for rehabilitation, significantly improving motor and balance. Their use also aimed at improving older adults, including physical health, mental health, and social factors. However, its effectiveness still depends on the population and the type of disorder being treated. Further research with larger clinical trials and cost-benefit analyses is needed to assess the application of robotic technology on a wider scale.

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Ethical considerations
Not applicable.

Conflict of interest
The authors declare no conflict of interest.

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