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REVIEW

Ambient assisted living technology-mediated interventions for older people and their informal carers in the context of healthy ageing: A scoping review

Maria Y. Nilsson | Stefan Andersson | Lennart Magnusson | Elizabeth Hanson

Department of Health and Caring Sciences, Swedish Family Care Competence Centre, Linnaeus University, Kalmar, Sweden

Correspondence
Maria Nilsson, Swedish Family Care Competence Centre, Department of Health and Caring Sciences, Linnaeus University, 39182 Kalmar, Sweden.
Email: maria.y.nilsson@lnu.se

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Abstract

Background and aims: There is a growing demand for health and social care services to provide technology-mediated interventions that promote the health and well-being of older people with health or care needs and of their informal carers. The objectives of this study were to scope and review the nature and extent of prior intervention studies involving ambient assisted living technology-mediated interventions for older people and their informal carers, and how and in what ways (if any) the goals and aims of these interventions reflected the domains of the World Health Organization framework for healthy ageing.

Methods: We conducted a scoping review. Data were collected between June and October 2018 with an updated search in October 2020. A total of 85 articles were eligible for inclusion.

Results: Nine categories described the aims and content of the included studies. The healthy ageing domain "Ability to meet basic needs" was mirrored in four categories, whereas "Ability to contribute to society" was not addressed at all.

Conclusion: The ways in which domains of healthy ageing are mirrored suggest that there is an emphasis on individual factors and individual responsibility, and a lack of attention given to broader, environmental factors affecting healthy ageing. Only a few of the studies used a dyadic approach when assessing health outcomes concerning older people and their informal carers.

KEYWORDS

aged, aged 80 and over, ambient assisted living technology, caregivers, health services for the aged, healthy aging

1 | INTRODUCTION

Globally, there is a growing demand for the provision of health and social care services to older people (ie, 65 years and older,[1]) with health or care needs and their informal carers via the use of technology-mediated interventions to enhance their health and well-being.[2,3] More older people are benefitting from increased longevity as both life expectancy and healthy life expectancy (HALE) have increased by over 8% globally between 2000 and 2016.[4] However, there is an increased risk of developing long-lasting health or care needs due to the ageing process, social isolation, chronic illness, or disability. When experiencing such needs older people may rely on care and support from informal

carers, that is, a person who provides (usually) unpaid care outside a professional or formal framework.[5] The term "informal carer," often used in Europe is synonymous with the North American term "family caregiver."[6]

Within the OECD countries, approximately 13% of people aged 50 and over report providing informal care at least once a week. The proportion of people aged 50 and over providing informal care is close to 20% in the Czech Republic, Austria, Belgium, the United Kingdom, France, and Germany, and less than 10% in Portugal, Sweden, Poland, the United States, Ireland, and Greece.[7]

Without support, informal caring can adversely affect the carer's health and well-being.[8] The caregiving relationship is, by definition, made up of two people, a dyad.[9] Previous research indicates the importance of including both members of the dyad in interventions to promote their health and well-being.[10] In this study, this is referred to as a dyadic approach.

Older people and their informal carers are, to an increasing extent, offered support through ambient assisted living (AAL) technology-mediated interventions. AAL technologies are defined as information and communication technologies (ICT), stand-alone assistive devices, and smart home technologies which enable individuals to stay active longer, remain socially connected and live independently into old age.[11] Examples from the literature are fall detectors, activity recognition systems, mobile and wearable sensors, intelligent houses, cameras, robots designed for company and service, ICT-solutions for support, health-care or social contacts.[12,13]

Previous reviews in the field have been based on type of technology or type of disease. Gagnon-Roy et al[14] identified four types of technology for people with dementia, namely: monitoring technology, tracking technology, smart homes, and cognitive orthoses. Dietlein et al[15] focused on gaming technology for people with dementia, stating that the overall effectiveness of these games is unclear. Zhang and Kaufman[16] pointed to inconsistency in the evidence regarding the actual impact of gaming for older people. Robbins et al[17] provided a more comprehensive review of the field using the concept of active ageing and digital elements as inclusion criteria for the research under review.

AAL technology-mediated interventions are promoted to enhance the health and well-being of older people and their informal carers. However, health and well-being are concepts that, throughout history, have held a variety of meanings.[18] In this study, we use the framework of "healthy ageing" presented by the World Health Organization (WHO) in the first *World report on ageing and health*.[1] The framework offers a holistic view of ageing and health, capturing the complex dynamics of internal determinants, socioeconomic factors, and broader environmental determinants of health.[1] This framework differs from the biomedical perspective, which tends to reduce the ageing process to a process of decline.[19] According to the WHO[1] framework, it is possible to have a health condition and still enjoy good health. Rather than regarding healthy ageing as a threshold state of functioning, it should be seen as a process relevant for all older people regardless of chronic illness or disability.[20] Previous work at EU-level has mainly focused on active ageing and prolonged working life, with the risk of over-emphasizing activity as a reflection of middle-age perspectives and thereby making it potentially coercive to older people.[21]

Healthy ageing is defined as the process of developing and maintaining functional ability that enables well-being in older age. Functional ability is made up of intrinsic capacity (all physical and mental capacities a person can draw on) and environmental characteristics.[1] Healthy ageing is based on a life-course perspective, starting at birth, and considers the exposures, opportunities and barriers encountered and the resources a person comes across throughout their life.[1] The framework has a rights-based approach founded on international human rights law. The goal is to build and maintain one's functional ability. Functional ability can be divided into *five key domains*. These are (a) the ability to meet basic needs, (b) the ability to learn, grow, and make decisions, (c) the ability to be mobile, (d) the ability to build and maintain relationships, and (e) the ability to contribute. By optimizing functional ability within the five key domains, which are strongly interconnected, older people are enabled to do the things they value.[22]

Since its publication, the WHO[1] framework has emerged as an important conceptualization of healthy ageing. In 2020, the 73rd World Health Assembly endorsed the proposal for a Decade of Healthy ageing (2020-2030). This review contributes to the current knowledge around the promotion and maintenance of healthy ageing among older people and their informal carers supported by the rapidly emerging field of technology-mediated interventions. We adopt a dual focus on older people and their informal carers, recognizing the importance of both perspectives. To the best of our knowledge, there is currently a lack of review studies offering a theoretical perspective on interventions using AAL technology and how they mirror a healthy ageing for older people and their informal carers.

The primary aim of this scoping review is to describe the nature and extent of empirical studies concerned with AAL technology-mediated interventions for older people and their informal carers. The review was guided by the following questions:

1. What types of AAL technology-based interventions for older people with health or care needs and their informal carers currently exist within the empirical literature?
2. In what contexts and how (if at all) have these interventions been implemented and assessed for health outcomes among older people and their informal carers?
3. In what ways (if any) and to what extent (if at all) do the aims/goals of these interventions mirror the five domains of functional ability within the WHO's healthy ageing framework?

2 | METHODS

This review follows Arksey and O'Malley's six-step framework[2] and the PRISMA Extension for Scoping Reviews (PRISMA-ScR).[23] The first step was *Identifying research questions*, as outlined above. The second step was *Identifying relevant studies*. To identify empirical studies that

addressed the central research questions, the search strategy was based on four clusters: (a) AAL-technology, (b) Chronic conditions, (c) Older people, and (d) Informal carers (Table 1).

We combined the clusters with Boolean operators AND and OR to identify studies with a dual focus on older people and carers combined or with a single focus on older people. In a similar way, we searched both with and without the cluster for chronic conditions to ensure that we captured studies focusing on broader health or care needs as well, not only limited to the presence of chronic disease. Five electronic databases were searched: PubMed, CINAHL, Web of Science, PsychInfo, and Scopus. A further 17 scientific journals were hand-searched via Browzine. The searches were conducted between June and October 2018 and updated in November 2020.

The third step was *study selection*. To be included in the review, studies needed to be published within the last 8 years to capture recent empirical literature and be written in English. Studies including older participants aged ≥65 with health or care needs were included. Studies were also included when 85% or more of the participants were within the set age, or where it was possible to extract results for participants aged ≥65. For studies where no age inclusion criteria and no given age range of the participant were described, inclusion was based on participants' mean age and SD.

While the scoping review method itself allowed for the inclusion of grey literature, a decision was made to only include published articles that assessed health outcomes for the older care recipient her/himself as well as for both the older care recipient and his/her informal carer. Studies that solely included health outcomes for informal carers of older people were excluded to delimit the scope. With regard to the method for selecting health outcomes, the authors referred to Wilson and Cleary's conceptual model which includes five core levels to capture the interrelationships between biomedical outcomes and societal factors for health.[24] According to their model, health outcomes can be divided into (a) *biological and physiological factors*, (b) *physical*, *psychosocial*, *emotional*, *and psychological symptoms*, (c) *various domains of functioning*, (d) *subjective ratings of general health*, and (e) *overall quality of life* (QoL). This review included all studies that assessed health outcomes as defined by Wilson and Cleary.[24] Finally, articles were excluded if the technology was solely a working tool for professional staff in the context of a hospital or specialist care settings (Figure 1).

The fourth step, *charting the data*, was conducted using a descriptive-analytical framework[25] for collecting the following information: author, year of publication and place, participants, age-range and setting, intervention content and aims, methodology employed, outcome measures employed and for whom (older person or older person and informal carer), and summary of important results. The results were discussed and continuously updated in an iterative process.

The fifth step, *collating*, *summarizing*, and *reporting results*, comprised three phases. In the first phase, each study was labeled and categorized based on the purpose of the intervention. The labels were scrutinized, so the process was not linear, but went back and forth between label and category in discussion with the co-authors. This

TABLE 1 Search clusters and search terms

AAL-technology	Older people	Chronic disease	Informal carer
assistive technology OR e-health OR m-health OR assistive robot* OR service robot* OR telecare OR telemedicine OR health information technology OR internet health intervention OR gerontechnology OR welfare technology OR telehealth OR AI OR the internet of medical things OR app OR applications OR GPS OR electronic tracking OR medicine dispensing robot* OR medicine dispenser OR smartphone OR device use OR communication technology OR ICT OR health technology assessment OR web-based healthcare robot* OR smart home OR location device OR tracking device OR ambient assisted living OR voice assistant OR virtual reality oR augmented reality OR telemonitoring OR reminder systems OR mobile health OR self-help device	older person OR older patient OR elderly OR aging in place OR senior citizen OR senior person OR senior patient OR aging society OR older user OR aging OR aged OR aging population OR geriatric	Dementia OR chronic disease OR heart failure OR Chronic obstructive pulmonary disease OR Diabetes Mellitus type II OR chronic illness OR longstanding chronic illness OR stroke OR chronic conditions OR long-term condition OR cognitive impairment OR cancer	working carer OR unpaid carer OR family care support OR family carer OR municipal care OR family caregiver OR caregiver OR home care OR next of kin OR carer OR informal carer

Note: Limits: NOT review*, protocol*, willingness to use. Dates: January 1, 2013 to September 30, 2018; updated to include October 1, 2018 to October 31, 2020. Age: ≥65. Language: English.

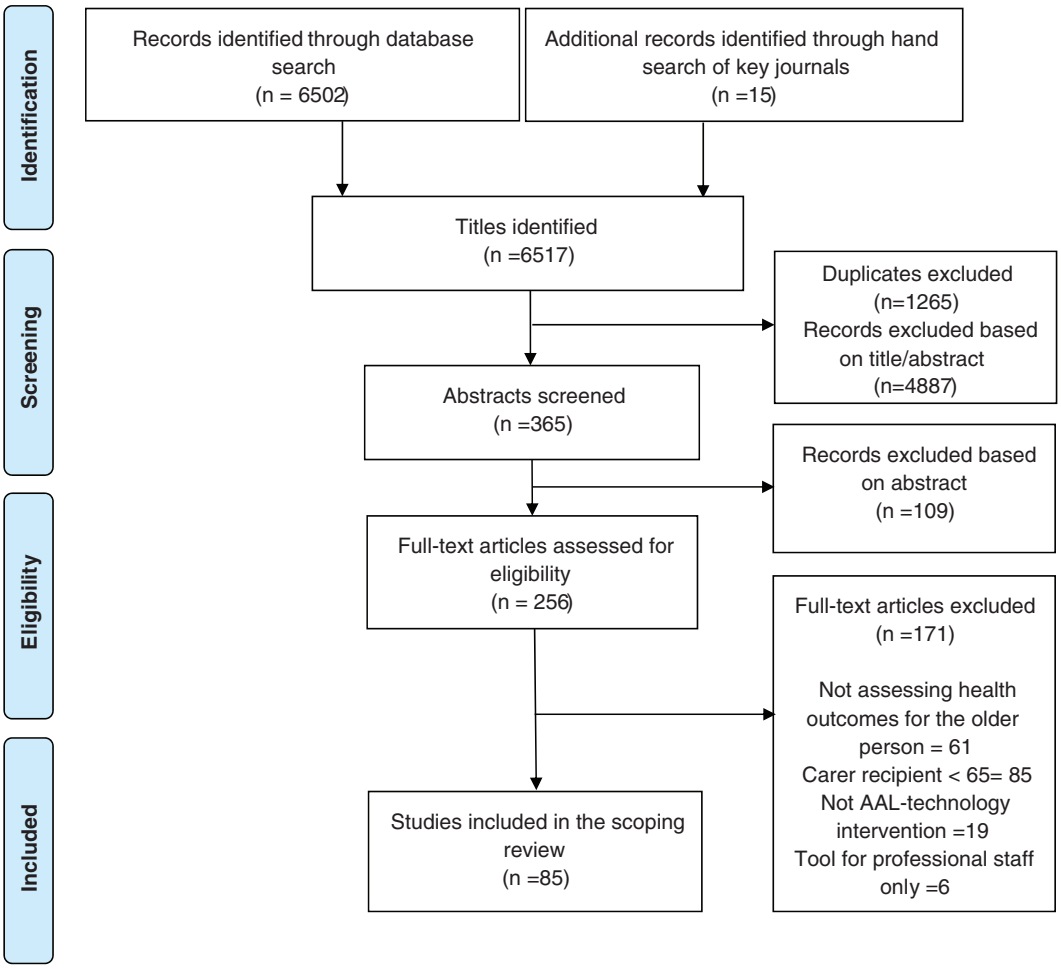

FIGURE 1 PRISMA flow diagram of identification, screening, eligibility assessment, and inclusion of studies

process generated a map, contributing to the understanding of the current breadth and depth of the field. In the second phase of analysis, the five domains of functional ability were used as a critical lens to analyse if and how the categories corresponded to the WHO[1] framework for healthy ageing. The aims and goals of the interventions were compared to the definitions and core concepts of the domains. In the final phase, the studies were analyzed to identify if and to what extent (if at all) a dyadic approach was present in the design and/or implementation of the included intervention studies.

3 | PROTOCOL AND REGISTRATION

This study had no pre-published or registered protocol before commencement.

4 | RESULTS

A total of 85 studies were included, 36% (n = 31) from Europe, 32% (n = 27) from North America, 18% (n = 15) from Asia, 9% (n = 8) from Oceania, 4% (n = 3) from South America, and 1% (n = 1) were cross-national. In the ensuing results section, first, the core categories of interventions are presented (research questions I and II). Second, the results concerning the extent to which (if at all) these core categories of interventions reflect the domains of functionality within the WHO[1] framework for healthy ageing are reported (research question III).

4.1 | Categories of interventions

The analysis resulted in nine categories of interventions, describing the characteristics and goals of the interventions. See Table 2, and for more details of included intervention studies; Supporting Information.

4.2 | Exercise to improve physical fitness

18% (n = 15) of the studies described interventions promoting physical fitness among older participants.[26-40] The interventions were aimed at preventing falls or further decline among older people due to frailty, sarcopenia, multiple chronic conditions, or cancer by means of improving balance, strength, and physical capacity. The interventions used gaming technology with motion capture cameras,[28,29,31-38]

TABLE 2 Intervention categories and included intervention studies, assessing health outcomes, and inclusion of informal carers

Intervention categories	Number of articles	Studies assessing health outcomes for the older participants only	Inclusion of informal carers	
			Studies including informal carers to varying extents	Studies in which also informal carers were assessed for health outcomes
Exercise to improve physical fitness	15	(n = 12)[28-39]	(n = 2)[40,41]	42
Activities for social engagement, comfort, or well-being	15	(n = 9)[43,44,45,46,47,48,49,50,51]	(n = 5)[52,53,54], Van der[55,56]	57
Support for daily needs and activities	14	(n = 7)[58,59,60,61,62,63,64]	(n = 2)[65,66]	(n = 5)[67-70,71]
Monitoring symptoms for self-care	11	(n = 5)[72,73,74,75,76]	(n = 5)[77,78,79,80,81]	82
Education to support self-efficacy and social inclusion	8	(n = 6)[83,84,85,86,87,88]	(n = 2)[89,90]	
Training and maintenance of cognitive ability	8	(n = 5)[91,92,93,94,95]	(n = 2)[96,97]	98
Supervision for increased safety	7	(n = 2)[99,100]	(n = 2)[101,102]	(n = 3)[103-105]
Exercise to regain physical functions	5	(n = 5)[106,107,108,109,110]		
Receiving therapy from a distance	2	111	112	
	Total: 85	Total: 52	Total: 21	Total: 12

virtual reality software[39] a web-based platform,[30] telehealth and videoconference[26,40] an app on a tablet,[27] and robot-mediated exercise.[36]

The studies lasted from 4 weeks to 12 months. All but one study[39] used a quantitative design. Of these, seven were RCTs.[29-32,34-36] One study used strong control, that is, comparing the intervention to group-based exercise[35] whilst Hong et al[30] and Gomes et al[29] provided education and guidance to all participants but did not offer actual exercise to the control group. Jorgensen[32] used insoles as a placebo treatment and Lauzé et al[34] compared intervention to the regular routine. All of the studies except McEwen et al[39] and Lafaro et al[40] showed improvements when assessing balance and strength, thereby potentially reducing the risk of falling. McEwen et al[39] included family members in interviews in order to include their views on changes regarding physical activity and daily life activities of their older relatives. Chao et al[28] suggested that volunteer family or friends might lead the exercise due to limited resources.

Only Lafaro et al[40] assessed health outcomes for informal carers, showing gradual improvement in distress levels.

4.3 | Activities for social engagement, comfort or well-being

18% (n = 15) offered interventions focusing on activities for social engagement, entertainment or comfort ([41-52,54,55]; Van der[53]). The interventions aimed at increasing older people's QoL through encouraging communication and offering positive experiences and thereby relieving and managing psychogeriatric symptoms such as behavioral and psychological symptoms in dementia (BPSD) or depression.

Interventions used robotic pets,[41,43,45,48-50] social robots,[44] tablets for apps or videos,[46,47,54] videoconferences (Van der[53]), virtual reality technology,[42,51,52] and light therapy.[55]

Study duration was 4 months or shorter, except Chu et al[44] who followed up after 5 years. Five studies used mixed methods,[42,43,50-52] the others were quantitative of which three were RCTs.[45,48,49] In the study by Van der Ploeg et al,[53] families provided comfort via videoconference. Gustafsson et al[50] and Moyle et al[51] interviewed family members concerning perceived effects for the older person during the intervention.

Main outcome measures among older participants within this category were indicative of improved well-being,[44,46] alternatively stable or enhanced QoL derived from positive social engagement,[43,50] increased comfort and reductions in the use of psychoactive and pain medications,[49] fewer neuropsychiatric symptoms such as decreased agitation ([47,54]; Van der[53]), less anxiety,[41] reduced levels of apathy,[42,52] and enhanced sleep.[55] Vahia et al[54] highlighted the scope for using tablets for video chats with family members as a non-pharmacological intervention.

In 7% (n = 1) of the studies in this category, informal carers were also assessed for health outcomes. Sekiguchi et al[55] assessed the burden of care and found a decrease in five of 17 cases.

4.4 | Support for daily needs and activities

16% (n = 14) of the studies aimed to support basic daily needs and functions such as nutrition, mobility, medication intake, self-care, and hearing.[56-69] The technology used consisted of motion sensors,[63] medication dispensers,[66,67] hearing aids,[56,57] and tablet or mobile apps,[58,65,68] robots,[59,61] a scooter,[60] a smart walker,[62] and electric light wires.[64]

The studies were from 3 weeks to 4 years in duration. Three studies were case reports,[57,66,67] one RCT[69] and one qualitative.[61] Results reported were an increase in medication adherence[58,66,67] and improvements or maintenance in activity performance and participation among older participants.[59,60,62,65,69] For the studies focusing on hearing impairment, McInerney and Walden[57] reported positive results with fewer communication breakdowns among the older participants, while in the study by Jupiter,[56] the older participants disliked or simply forgot to use the technology. Tchalla et al[64] showed a reduction in the prevalence of indoor falls, while Pripfl et al[61] did not show any changes according to the "Falls efficacy scale" as a result of the low usability of the technology. Informal carers took an active role in assisting the older care recipients in the use of the technology in the study by Lindhardt and Nielsen.[68]

Dupuy et al[63] assessed the burden for *professional caregivers* and found that the burden increased more during the study period for the control group compared to the technology-equipped group. Dupuy et al[63] considered the technology to have a greater potential for informal carers. In their research, Tchalla et al[64] and Obayashi et al[59] considered that the interventions had the potential to relieve stress for informal carers.

But the researchers did not assess carer burden as an outcome. Health outcomes were assessed for informal carers in 36% (n = 5) of the interventions. Carer burden was found to decrease in three studies.[65-67] In Lindhardt and Nielsen,[68] informal carers reported a reduction in worry and relief from tasks, both of which improved their relationship with their next-of-kin. Mortenson et al[69] reported how burden decreased for informal carers in the identified activity perceived as problematic, but this did not extend to their overall burden.

4.5 | Monitoring symptoms for self-care

13% (n = 11) of the studies reported interventions aimed at increasing the knowledge and self-management skills of older people living with chronic diseases and thereby helping to decrease the use of health-care resources and improve QoL among older people.[70-80] Interventions offered comprised programs of symptom monitoring and testing devices for collecting and sending data to health-care professionals. The assessment was received through various channels, some combining several channels in different phases.

The channels used were videoconference[77,78,80] telephone[70,75] a digital health diary[73] apps with text[71] or message functions.[74,79] Some of the programs generated automatic feedback and risk assessment via algorithms,[71,72] whilst in others, data were audited directly by health care staff.[70,77,79,80]

The studies ranged from 3 months to 3 years in duration. One study included qualitative results,[71] all others were quantitative, of which five were RCTs.[70,74,75,77,79] In the controlled studies, the control group received care according to the usual routine with face-to-face meetings with health-care staff. In Dario et al's[75] study, relatives were contacted following alarms triggered by blood glucose levels among older participants. In Nouryan et al[77] and Shah et al,[78] informal carers assisted and received feedback on the health status of their older care recipient. Villani et al[79] provided health-related information to both the older person and their informal carer, and in Maresca et al,[76] a neuropsychologist provided support for both patient and caregiver.

Results showed an overall decrease in the use of health-care by older participants.[70,75,78,79] Nouryan et al[79] described no difference in the use of health-care but reported improved outcomes of QoL among the older subjects. Maresca et al[76] reported improvements in emotional status and hematochemical values, Persson et al[73] showed significant improvement in general HRQoL, while Dario et al[75] reported no clinical significance in the improvement of older participants' QoL. Sun et al[74] reported improved levels of blood glucose for the participants. Göransson et al[71] described an increase in self-care ability, but later a decrease in sense of security at follow up compared to at the end of intervention.

9% (n = 1) of the studies also assessed health outcomes for informal carers of older participants. De Cola et al[80] reported a significant reduction in the Caregiver Burden Inventory.

4.6 | Education to support self-efficacy and social inclusion

9% (n = 8) of the included studies described interventions framed around education, digital and health literacy, promoting social inclusion, healthy lifestyle and self-efficacy for managing chronic disease among older people.[81-88] The interventions used teleconference,[81] videoconference,[88] software programs for PC,[83,86,87] web-based programs,[84,85] and digital tracking tools.[82] The interventions lasted from 6 weeks to 22 months. The designs were all quantitative apart from Mullins et al,[85] who used mixed methods. Czaja et al[83] and Ferreira et al[87] conducted RCTs.

Health outcomes among older participants included decreased fatigue,[81] improved well-being and physical and mental health[82-84,86,88] decrease in loneliness[85] but no effect on depressive symptoms.[88] There were indications of improvements in QoL.[87] Tsai et al[88] included family bi-weekly appointments for a videoconference with the older person. Upton et al[86] suggested that the technology should be introduced to family members encouraging videocalls. None of the studies assessed health outcomes for the older participants' informal carers.

4.7 | Training and maintenance of cognitive ability

9% (n = 8) of included studies described interventions aiming to improve or preserve cognitive skills and functions and reduce depressive symptoms among older people.[89-96] The interventions used mobile, web-based or virtual reality gaming software,[89-92,95] wearable and monitoring sensors,[94] a web-based app,[93] and an exercise robot.[96] The system in Lazarou et al[94] also included a caregiver interface for sharing information. The studies lasted up to 4 months. Half of the studies were RCTs.[89,91-93]

Health outcomes among older participants were improvement in depression and Mini-Mental State Examination (MMSE) scores,[89] in ADL functioning and sleep[94] global cognition and executive functioning[90] and in executive functioning and verbal memory.[91] In the study conducted by Merilampi et al,[95] no significant improvements in older participants' cognitive skills were shown. However, there were improvements in general well-being and recreation. Merilampi et al[95] also discussed the potential for the intervention to increase social interaction with family members. Calabrò et al[96] showed a significant improvement in the attention process and executive functioning among older participants. In Robert et al,[93] there were indications of steady results in cognitive performance, suggesting less or slowed deterioration. Park et al[92] showed improvements in memory, but otherwise, no differences compared to the control group who used a conventional computer-based training program. 13% (n = 1) assessed health outcomes for older participants' informal carers. Calabrò et al[96] reported a decrease in caregiver burden post-intervention.

4.8 | Supervision for increased safety

8% (n = 7) of included studies described interventions aiming to increase safety and prevent further decline of older participants through surveillance systems and active or passive alarm devices.[97-103] These interventions were mediated through video cameras,[97,101] passive monitors and sensors,[98,99,102] wearable or built-in alarms, and digital tracking devices.[100,103]

Interventions lasted from 2 months up to 1 year. Two studies were qualitative[101,103] while the others used various quantitative methods, none of them being RCT. Rohne et al[100] discussed the possibility that relatives could be alarm recipients and, as a result, there would be a potential for increased contact between older participants and their informal carers and thereby a reduced need for formal sources of care. The relatives in the study wanted to be included but did not want to be responsible 24 hours a day. Finch et al[99] described families or friends being contacted when the alarm-center discovered a need for a further check-up. Results showed a decrease in falls rates,[97] a reduction in the use of health-care,[99] and a feeling of safety for the older person and their informal carer.[100,101,103]

43% (n = 3) also reported health outcomes for informal carers. Lexis et al[102] assessed the burden on informal carers, (only 16 informal carers responded out of a total of 53 carer participants) and results pointed to a significant reduction in burden. Akerlind et al[101] and Watson et al[103] reported qualitative outcomes in favor of the mental health and well-being of the informal carers.

4.9 | Exercise to regain physical functions

6% (n = 5) of the studies described interventions for rehabilitation after a stroke among older participants, which aimed at improving the function of the arms and hands, from sitting to standing, or gait training.[104-108] The technology included exoskeletons,[105,106] motion sensors and virtual reality[104] or smartphones with motion sensors,[107] and robot-assisted therapy.[108]

The study designs were case reports, one of which was a case control study.[105] Informal carers were not involved in any assistance capacity to aid compliance with using the rehabilitation technology. Outcomes for the older subjects showed improvements in controlling movements and strength. None of the studies included secondary health outcomes for the informal carer.

4.10 | Receiving therapy from a distance

Interventions offering treatment for dementia or post-traumatic stress disorder (PTSD) symptoms among older people made up the smallest category, constituting only 2% (n = 2) of the included studies. The interventions were mediated through videoconference.[109,110] Kim et al[110] included informal carers as participants in the meetings. Both studies were quantitative cohort studies.

The PTSD symptoms among older participants decreased significantly, QoL increased, as did self-efficacy.[109] Treatment of dementia symptoms showed no difference in outcomes compared to the control group, suggesting that therapy from a distance worked equally well as face-to-face sessions.[110] None of the studies assessed health outcomes for the informal carers of older participants.

5 | CORRESPONDENCE BETWEEN CATEGORIES OF INTERVENTION AND DOMAINS OF FUNCTIONAL ABILITY ACCORDING TO THE WHO FRAMEWORK

Table 3 presents the correspondence between categories of intervention and domains of functional ability according to the WHO[1] model for healthy ageing.

5.1 | Ability to learn, grow and make decisions

The domain is about being able to learn and apply knowledge, engaging in problem-solving, personal development and having the ability to make choices.[1] The interventions in *Monitoring symptoms for self-care* promoted health literacy and increased participation for the older person and their informal carers through education and platforms for

consultation. The interventions further aimed to increase self-management of chronic disease, thus reflecting this domain. *Education to support self-efficacy* reflected the domain, since the interventions had the explicit aims of educating and enhancing self-efficacy, promoting problem solving and the application of knowledge among older people. Finally, *Training and maintenance of cognitive ability* offered interventions for lifelong learning and growing, despite cognitive impairment.

5.2 | Ability to be mobile

This domain refers to movement in all its forms, powered by one's own body, a vehicle or mobility supported by assistive devices.[1] The categories *Exercise to improve physical fitness* and *Exercise to regain physical function* corresponded with this domain since the interventions focused on improving balance, strength, and muscle control and thereby supporting and improving physical capacity among older people. The outcomes "Timed Up and Go" and "Falls efficacy scale" were recurrent and reflected the focus of the domain in improving the ability to get around. In the category *Support for daily needs and activities*, several interventions reflected the core concept of older people moving around safely and efficiently, with powered scooters or guided by increased lighting. Tchalla et al[64] and Dupuy et al[63] addressed fall prevention as did studies in the category *Supervision for increased safety* by optimizing the environment and the ability for older people to move around safely.

5.3 | Ability to meet basic needs

Ability to meet basic needs means being able to afford an adequate diet, clothing, suitable housing, health care and long-term services, and support to minimize the impact of economic shocks and enjoying security and safety.[1] Interventions in *Supervision for increased safety* were framed around safety for both the older person and their informal carer, using technology to detect whether an older person had fallen or wandered away, for example. The interventions in this category as well as in *Support for daily needs and activities* might contribute to enabling older people to return home after hospital visits, thus avoiding admission to residential care. Therefore, the categories reflect the domain that states that a basic need for older people might be to remain in their homes and communities. The category of *Monitoring symptoms for self-care* reflects the domain in that it allows older people access to specialist health care at home, as exemplified in the work conducted by Persson et al,[73] in a similar way to the two interventions in *Receiving therapy from a distance*, which also allowed access to health care for both the older people and their informal carers.

5.4 | Ability to build and maintain relationships

This domain represents the social network, from family members to more formal relationships within the community.[1] Several interventions in *Education to support self-efficacy and social inclusion* mirror this domain since they focused on interventions affecting isolation and loneliness among older people. In the category *Monitoring symptoms for self-care*, there were groups for elder peer support and it can thus be seen to mirror the domain with regard to how social relationships are viewed as a source of support. *Support for daily needs and activities* reported attempts to decrease isolation and promote communication among older people in two studies[56,57] and Pettersson et al[60] encouraged participation in the wider community.

TABLE 3 Correspondence between categories of interventions and domains of functional ability

Categories of interventions	Ability to learn, grow and make decisions	Ability to be mobile	Ability to meet basic needs	Ability to build and maintain relationships	Ability to contribute
Activities for social engagement, comfort or wellbeing					
Support for daily needs and activities		✓	✓	✓	
Monitoring symptoms for self-care	✓		✓	✓	
Exercise to improve physical fitness		✓			
Supervision for increased safety		✓	✓		
Exercise to regain physical functions		✓			
Education to support self-efficacy and social inclusion	✓			✓	
Training and maintenance of cognitive ability	✓				
Receiving therapy from a distance			✓		

5.5 | Ability to contribute

The fifth domain is about volunteering, working, mentoring, or providing care or support. None of the categories reflected this domain when looking at the aims and goals of the interventions.

6 | DISCUSSION

To summarize, the results provided a map of nine intervention categories. Most studies were found to be in the categories focusing on physical capacity and function, on managing the symptoms of dementia and cognitive impairment, on supporting functioning in daily life and on self-caring with a chronic disease.

6.1 | The dyadic approach in interventions using AAL-technology

Previous research indicates that dyadic interventions have a positive impact on health and well-being, not least in terms of aiding the ability to build and maintain social networks.[111,112] 14% (n = 12) of the studies assessed health outcomes for both the older person and their informal carers in accordance with a dyadic approach.[10] Interventions aimed at relieving carer burden, using various assessment measures such as the Caregiver burden inventory,[80] the Caregiver Assistive Technology Outcome measure,[69] as well as using qualitative approaches focusing on their experiences as carers.[101] In the majority of studies where informal carers were included, *their* situation or health and well-being was of subordinate interest. 86% (n = 73) of all studies in this review focused solely on the older person in the assessment of health outcomes, though 21 of these studies included informal carers to varying extents. The informal carers received alarms and provided help and support as a resource potentially replacing or alleviating professional staff.[75,77,78] Previous work confirms the viewing of informal carers as resources.[113] Cottam[114] argues that current health systems fail to recognize the role of the relationship between the informal carer and their next-of-kin, purporting that we even lack a language for this approach in public policy.

Based on this review, we argue that future AAL technology-mediated technology intervention studies could usefully consider adopting and expanding a dyadic approach, thereby promoting a reciprocal and sustainable healthy ageing for both older people and their informal carers.

6.2 | Domains of healthy ageing reflected in interventions

Overall, the WHO framework for healthy ageing[1] proved to be a useful tool for critically appraising the current state of the field. The domains "Ability to meet basic needs," "Ability to learn, grow and make decisions," "Ability to build and maintain relationships," and "Ability to be mobile," were indeed mirrored by several interventions categories.

In the category *Supervision for increased safety*, interventions were framed around safety, thus reflecting the domain "Ability to meet basic needs." However, even though monitoring and surveillance were commonly promoted as positive for safety and independence, there is a risk that these systems become a form of coercion and an unwelcome intrusion into the lives of older people.[115] Further, in this particular domain, the environment plays a crucial part in terms of poor social policies, inequality in health and social care systems, and meager politics.[1] These broader environmental factors, as described by the framework, were not given any attention in the studies. By focusing on the individual, digital health interventions tend to reduce health problems to the individual level, missing the broader social, cultural, and political dimensions of ill health.[116] It can be argued that socioeconomic factors are central to people's health and well-being. Inequality implies that not only is having enough to make ends meet important, but so too is what we have relative to others. Thus, the lower our social position, the worse our health.[117]

The domain "Ability to learn, grow and make decisions" is considered key to older people's sense of control.[1] However, this could also be viewed as an expression of how the field reflects the dominant political discourse, which emphasizes the individual's responsibility.[118] In this discourse, older people are expected to be entrepreneurial in achieving and maintaining good health, and there tends to be a focus on shifting the responsibility for care from the clinician to the patient.[116] The idea of older people in need of education and knowledge could also be a sign of ageism, whereby older people are seen as incapable and placed in an increasingly asymmetrical power relation to professionals.[119]

The domain "Ability to be mobile" was mirrored in four categories. Worth highlighting are the studies focusing on improving balance and reducing "fear of falling." The concept "fear of falling" is recognized as a health problem for older people, with consequences such as loss of health-related QoL due to cutting down or avoiding activities, decreased participation and depression.[120] The WHO[1] states that the consequences of a decline in this domain extend beyond the individual and can affect all other domains of functional ability.

The domain "Ability to build and maintain relationships" was only mirrored in three categories, suggesting that the field, to a large extent, fails to address issues of social exclusion. The importance of relationships and connections for health are well established in the framework[1] as well as in the literature, see for instance Cottam[114] and Carstensen et al.[121]

The domain "The ability to contribute" was not mirrored at all, suggesting a gap in the research field. Previous research shows that older people are involved in voluntary work, but opportunities may be conditioned due to age-related negative perceptions within the organizations.[122] There is, though, a risk that viewing older people's engagement in voluntary work only as investment in their health and not based on their sense of citizenship may diminish their contribution to society.[119]

The intervention categories in this review are largely in agreement with those described by Robbins et al.,[17] which we referred to

in the introduction. However, while Robbins et al[17] used the concept of "active ageing" and digital elements as an inclusion criterion, this review explored the field more broadly using the WHO[1] framework as an interpretative theoretical lens. We thereby offer a basis for a critical discussion of where the current emphasis lies in the field of interventions using AAL-technology for older people and their informal carers, and where it might look in the future to meet the goals of healthy ageing.

We acknowledge that the WHO's five domains do not offer measures or criteria for healthy ageing "per se." According to the Global Strategy and Action Plan on Ageing and Health (2017), there is a need to improve evaluation and measurement so as to better understand and act on healthy ageing.[123] Bosch-Farre et al,[124] for instance, suggest a model for measuring the prevalence of active and healthy ageing. However, this aspect lies outside the primary aim and scope of this review.

6.3 | Study strengths and limitations

Our results should be viewed against several study strengths and limitations. Searching the topic was problematic due to a large number of terms for technology employed by researchers. The searches were restricted to articles reporting health outcomes, thus excluding purely technical reports and technology evaluations. Updated searches, including grey literature, might produce another picture, and this needs to be taken into account when assessing the validity of the results.

In the search process, several articles were excluded as they had mixed samples of younger and older participants without differentiating results. One possible reason for such mixed samples is that many studies were diagnosis-specific rather than focusing on age. It is, therefore, possible that the mapping of intervention categories was subsequently affected.

When adopting a dual focus on both the older person and the informal carer, there is arguably a risk of less sharpness in the analysis. However, we would argue that informal carers of older people remain marginalized in health and social care as well as in AAL technology-mediated research. The WHO[1] framework clearly highlights the importance of promoting the rights of both older people and their informal carers. This review has identified and discussed aspects of the role of informal carers within the context of a dyadic approach that might, with a single focus on older people, have remained largely invisible to health science research. Finally, this study is unique in how it uses the framework to highlight which WHO domains of healthy ageing are interpretively present in the current field.

7 | CONCLUSIONS AND IMPLICATIONS FOR RESEARCH, POLICY, AND PRACTICE

Our scoping review found that the WHO[1] framework is indeed mirrored to varying extents within the empirical literature included here. Further, findings indicate that the interventions tended to focus on an increased level of individual responsibility and also to operate at the level of the individual. These findings are relevant for policymakers when developing technology-mediated health strategies. These findings can also be useful for health and social care professionals attempting to navigate through a growing field of interventions concerned with health promotion for older people using technology-mediated interventions. We suggest that future research should devote greater attention to interventions addressing broader environmental factors for both older people and their informal carers, such as affordable access to safe outdoor environments, culture, healthy foods, and supporting networks and, finally, that it should adopt a dyadic approach to technology-mediated health research.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization: Maria Nilsson, Stefan Andersson, Elizabeth Hanson, Lennart Magnusson
Data curation: Maria Nilsson, Stefan Andersson, Elizabeth Hanson
Formal analysis: Maria Nilsson, Stefan Andersson, Lennart Magnusson, & Elizabeth Hansson
Methodology: Maria Nilsson, Stefan Andersson, & Elizabeth Hanson
Supervision: Stefan Andersson, Lennart Magnusson, & Elizabeth Hansson
Validation: Maria Nilsson, Stefan Andersson, & Elizabeth Hanson
Visualization: Maria Nilsson & Stefan Andersson
Writing - original draft preparation: Maria Nilsson & Stefan Andersson, Elizabeth Hanson
Writing - review and editing: Maria Nilsson, Stefan Andersson, Lennart Magnusson, & Elizabeth Hansson

All authors have read and approved the final version of the manuscript.

Maria Nilsson, as the corresponding author, confirms having full access to all of the data and takes complete responsibility for the integrity of the data and the accuracy of the data analysis.

TRANSPARENCY STATEMENT

The lead author, Maria Nilsson, affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

DATA AVAILABILITY STATEMENT

The authors confirm that all the data reported in this manuscript are derived from public domain sources, including PubMed, CINAHL, Web of Science, PsychInfo, and Scopus.

ORCID

Maria Y. Nilsson https://orcid.org/0000-0003-1601-5533

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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