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Effectiveness of Digital Health and Tele-Nursing Interventions on Frailty, Cognitive Function, and Quality of Life Among Older Adults: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

Ali Khatib[1,2], Atena Sadat Hosseini [3], Robabe Rajaei Rad [4], Seyedeh Maryam Seyedi [5*]

[1] *Healthy Ageing Research Centre, Neyshabur University of Medical Sciences, Neyshabur, Iran.*
[2] *Department of Nursing, Faculty of Nursing and Midwifery, Neyshabur University of Medical Sciences, Neyshabur, Iran.*
[3] *Department of Anesthesia, Faculty of Nursing and Midwifery, Neyshabur University of Medical Sciences, Neyshabur, Iran.*
[4] *Departments of Islamic Education, Sabzevar University of Medical Sciences, Sabzevar, Iran.*
[5] *Department of Operating Room, Faculty Member of Neyshabur University of Medical Sciences, Neyshabur,Iran.*

Corresponding Author

Seyedeh Maryam Seyedi, Ph.D.

Department of Operating Room, Faculty Member of Neyshabur University of Medical Sciences, Neyshabur,Iran

✉ seyyedim1@nums.com
✆ +985143306201
0009-0009-9122-7078

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ABSTRACT

Background: Digital health and tele-nursing interventions have emerged as promising strategies to support healthy aging; however, their overall effectiveness on key geriatric outcomes remains inconclusive. The present study aimed to systematically evaluate the effects of these interventions on frailty, cognitive function, and quality of life among older adults.

Method: A systematic review and meta-analysis were conducted in accordance with established methodological guidelines. Randomized controlled trials examining digital health or tele-nursing interventions in older adults were included. Three primary outcomes were analyzed: frailty, cognitive function, and quality of life. Pooled effect sizes were calculated using random-effects models, and heterogeneity was assessed using the I^2 statistic.

Results: Twelve studies were included with a total of 2,679 participants (1,308 in intervention groups and 1,371 in control groups). Meta-analysis demonstrated that digital health interventions significantly reduced frailty (SMD = −0.355, $p < 0.001$) and improved quality of life (SMD = 1.046, $p = 0.018$). However, no statistically significant effect was observed for cognitive function (SMD = 0.126, $p = 0.366$).

Conclusion: Digital health and tele-nursing interventions appear to be effective in reducing frailty and improving quality of life among older adults, while their impact on cognitive function remains uncertain. Future research should focus on standardized, multidomain intervention designs incorporating targeted cognitive training to enhance effectiveness across all geriatric outcomes.

Introduction

Population aging has emerged as one of the most pressing public health challenges of the twenty-first century (1). Current projections indicate that the global population aged 60 years and older will increase from approximately 1 billion in 2020 to more than 2.1 billion by 2050(2). This profound demographic shift is accompanied by a substantial increase in the burden of chronic diseases, functional impairment, cognitive decline, and dependence on long-term care services (3). Accordingly, preserving functional independence, cognitive health, and quality of life among older adults has become a central priority for healthcare systems and healthy aging policies worldwide (4, 5).

Among the most consequential geriatric syndromes affecting both individual and population health is frailty (6). Frailty is a multidimensional clinical condition characterized by reduced physiological reserve and increased vulnerability

to stressors, leading to a higher risk of falls, hospitalization, disability, dependency, and mortality (7). Evidence indicates that frailty is not only associated with declining physical function but is also closely linked to cognitive deterioration and reduced quality of life (8). Longitudinal studies further suggest that increasing frailty may precede the onset of cognitive impairment and dementia by several years, highlighting its role as a significant predictor of cognitive decline in older adults (9-11).

In addition to frailty, age-related cognitive impairment represents a major threat to healthy aging. Declines in memory, attention, executive function, and processing speed can substantially compromise independence and markedly increase healthcare utilization and caregiving burden (12). Given the rising global prevalence of dementia and other cognitive disorders, the identification and implementation of effective strategies to preserve cognitive function in older adults have become a key priority for researchers, clinicians, and policymakers (13). Recent evidence suggests that multidomain interventions, including physical activity, health education, cognitive stimulation, and continuous monitoring, may help slow cognitive decline and improve functional outcomes in older populations (14-16).

In parallel with rapid technological advancement, digital health and tele-nursing have gained increasing attention as innovative approaches to delivering care for older adults (17). Digital health encompasses a wide range of technologies, including mobile health applications, remote monitoring systems, wearable devices, e-learning platforms, virtual consultations, and artificial intelligence–driven decision-support systems (18). Tele-nursing refers to the provision of nursing care, education, monitoring, and counseling through information and communication technologies (17, 19). These approaches have become particularly prominent following the COVID-19 pandemic, offering cost-effective solutions to improve access to healthcare services, reduce unnecessary hospital visits, and support self-management among older adults (20).

Accumulating evidence suggests that digital health interventions may yield meaningful improvements in health outcomes among older adults (21, 22). A systematic review and meta-analysis by Tsai et al. focusing on healthy ageing and cognitive health in older adults, reported that digital interventions significantly improved cognitive function and enhanced quality of life (23). A meta-analysis by Park et al. synthesizing evidence from eleven randomized controlled trials, demonstrated beneficial effects of digital health interventions on improving physical activity in older adults with chronic diseases living alone (24). In addition, prior telehealth studies have reported improvements in physical functioning and selected domains of quality of life among frail older adults.

Despite the rapidly growing body of literature, several important gaps remain. First, many previous systematic reviews have focused on single outcomes, such as physical or cognitive function, without simultaneously examining the interrelated outcomes of frailty, cognitive function, and quality of life. Second, existing reviews have often pooled heterogeneous telehealth, telemedicine, and digital health interventions without distinguishing the specific contribution of nursing-led digital care. Third, the increasing number of recently published randomized controlled trials necessitates an updated synthesis of the evidence base. Finally, the extent to which digital health and tele-nursing interventions produce consistent, sustained, and generalizable effects across multiple domains of older adults' health remains unclear, particularly given variations in intervention design, delivery, and methodological quality.

The present study addresses these limitations by providing a comprehensive synthesis of evidence from randomized controlled trials, with a specific focus on digital health and tele-nursing interventions among older adults. In addition, it simultaneously evaluates three interrelated outcomes: frailty, cognitive function, and quality of life. By offering an integrated assessment of intervention effectiveness, this review may inform the development of innovative models of geriatric care, support the implementation of evidence-based tele-nursing services, and contribute to future healthy aging policies and clinical practice. Therefore, this systematic review and meta-analysis aimed to evaluate the effectiveness of digital health and tele-nursing interventions on frailty, cognitive function, and quality of life among older adults, based on evidence from randomized controlled trials.

Methods

The present study was conducted as a systematic review and meta-analysis in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines (25). A detailed study protocol was developed a priori prior to the commencement of the literature search to reduce the risk of selection bias, reporting bias, and post hoc modifications of eligibility criteria. The research question was structured using the Population, Intervention, Comparison, and Outcomes (PICO) framework and focused on evaluating the effectiveness of digital health and tele-nursing interventions compared with usual care in older adult populations.

Research question (PICO)

The study population (P) comprised older adults (typically aged 60 years and above) residing in community settings, nursing homes, or healthcare facilities. This population included a broad range of health conditions and care needs, reflecting the heterogeneity of aging populations. The intervention (I) included digital health and tele-nursing interventions such as mobile health applications, remote monitoring systems, wearable technologies, telephonic or video-based nursing consultations, electronic health education programs, and other ICT-based healthcare delivery models. The comparator (C) consisted of usual care, standard care, or no digital/tele-nursing intervention. The primary outcomes (O) were frailty, cognitive function, and quality of life. These outcomes were selected due to their clinical relevance and their strong interrelationship in determining health status and functional independence in older adults.

Information sources and search strategy

A comprehensive systematic literature search was conducted in the following electronic databases: PubMed/MEDLINE, Embase, Scopus, and the Cochrane

Library. All eligible studies published between January 2016 and May 2026 were considered for inclusion. To ensure comprehensiveness, additional manual searches were performed by screening the reference lists of included studies and relevant systematic reviews. The search strategy was developed using a combination of controlled vocabulary (MeSH terms) and free-text keywords. Core search terms included: "digital health," "tele-nursing," "telehealth," "older adults," "frailty," "cognitive function," and "quality of life." These terms were combined using Boolean operators (AND/OR) and adapted for each database to optimize sensitivity and specificity.

The restriction to studies published within the last decade was justified by the rapid evolution of digital health technologies and tele-nursing systems during this period. In recent years, advancements in mobile health platforms, wearable devices, and remote monitoring systems have significantly improved intervention quality and accessibility. In addition, contemporary clinical practice has increasingly aligned with international guidelines issued by organizations such as the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC), particularly in relation to digital healthcare delivery and healthy aging strategies. Furthermore, the majority of high-quality randomized controlled trials in this field have been published within this timeframe, ensuring methodological relevance and consistency. Older studies were excluded due to potential heterogeneity in technology, outdated systems, and limited applicability to current clinical contexts.

Study selection

All retrieved records were imported into EndNote X8, and duplicate entries were removed prior to screening. Study selection was conducted in two stages. First, titles and abstracts were independently screened by two reviewers blinded to each other's decisions to identify potentially eligible studies. Second, full-text articles were assessed for eligibility based on predefined inclusion and exclusion criteria. Any disagreements between reviewers were resolved through discussion and consensus, and when necessary, a third senior reviewer was consulted. The study selection process was documented in accordance with PRISMA guidelines and presented using a flow diagram.

Data extraction

Data extraction was independently performed by two reviewers using a standardized and pilot-tested extraction form. Extracted data included study characteristics (author, year, country, and study design), participant characteristics (age, sample size, and sex distribution), intervention details (type, duration, and delivery mode of digital or tele-nursing interventions), comparator description, outcome measurement tools, and reported results for frailty, cognitive function, and quality of life. In cases of missing or unclear information, attempts were made to contact the original study authors for clarification. Any discrepancies in data extraction were resolved through consensus.

Risk of bias assessment

The methodological quality of included studies was independently evaluated by two reviewers. Randomized controlled trials were assessed using the Cochrane Risk of Bias tool version 2 (RoB 2)(26). The RoB 2 assessment examined five key domains: bias arising from the randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result. Each domain was rated as "low risk of bias," "some concerns," or "high risk of bias" according to the standardized RoB 2 algorithm. Any disagreements between reviewers were resolved through discussion and consensus, and when necessary, consultation with a third reviewer. The results of the risk of bias assessment were incorporated into the interpretation of pooled effect estimates and were also used in sensitivity analyses to examine the robustness of the findings.

Statistical analysis, data synthesis, and certainty of evidence

All statistical analyses were conducted using STATA version 17. Standardized mean differences (SMDs) were used when appropriate. Due to anticipated clinical and methodological heterogeneity across studies, a random-effects model based on the DerSimonian and Laird method was applied for all meta-analyses. Statistical heterogeneity was assessed using Cochran's Q test and quantified using the I^2 statistic. An I^2 value greater than 50% was considered indicative of moderate to substantial heterogeneity.

Results

PRISMA Flow Description

The study selection process is presented in a PRISMA flow diagram (Figure 1), illustrating the sequential stages of identification, screening, eligibility assessment, and final inclusion. In the identification phase, a total of 679 records were retrieved from multiple electronic databases. After removal of duplicates, 466 unique records remained for title and abstract screening. During this stage, 394 studies were excluded due to irrelevance to the research question, inappropriate study design (e.g., non-RCT or observational studies), or lack of focus on digital health or tele-nursing interventions in older adults. Following the initial screening, 72 full-text articles were assessed for eligibility. Of these, 60 studies were excluded based on predefined inclusion criteria. The most common reasons for exclusion included: absence of relevant outcomes (frailty, cognitive function, or quality of life), insufficient or non-extractable quantitative data, inappropriate intervention type (not based on digital health or telehealth modalities), and study populations not meeting the target age criteria (older adults aged ≥60 years) or not clearly representing community, nursing home, or healthcare facility settings. Ultimately, twelve studies met all eligibility criteria and were included in the final analysis.

Descriptive Summary of Included Studies

Overall, 12 RCTs were included in this review (Table 1), evaluating the effects of interventions grounded in digital technologies, home-based exercise programs, virtual reality applications, cognitive–motor rehabilitation programs, and multicomponent strategies in older adult populations. These interventions were delivered across diverse settings, including home-based environments, residential care facilities, and community-based contexts. In terms of sample size, the included studies comprised 1,308 participants in the intervention groups and 1,371 in the control groups, resulting in a total sample of 2,679 older adults. Among the studies reporting sex distribution, there were 574 women in the intervention groups and 623 women in the control groups. The weighted mean age of participants was estimated at 80.6 years in the intervention groups and 80.4 years in the control groups. These figures indicate that the study population primarily consisted of very old adults with a relatively high degree of functional vulnerability.

Regarding intervention characteristics, the included trials encompassed artificial intelligence–based systems and cognitive telerehabilitation, home-based and web-based exercise interventions, virtual reality and exergaming technologies, multicomponent approaches (combining exercise, nutrition, and education), smart transitional care and digital monitoring systems, as well as eHealth platforms and online self-management programs. Intervention duration varied substantially across studies, ranging from 5–6 weeks in the shortest trials to 8–12 weeks in most studies, with some long-term interventions extending up to 12 months. Follow-up periods reached as long as 28 months in certain studies.

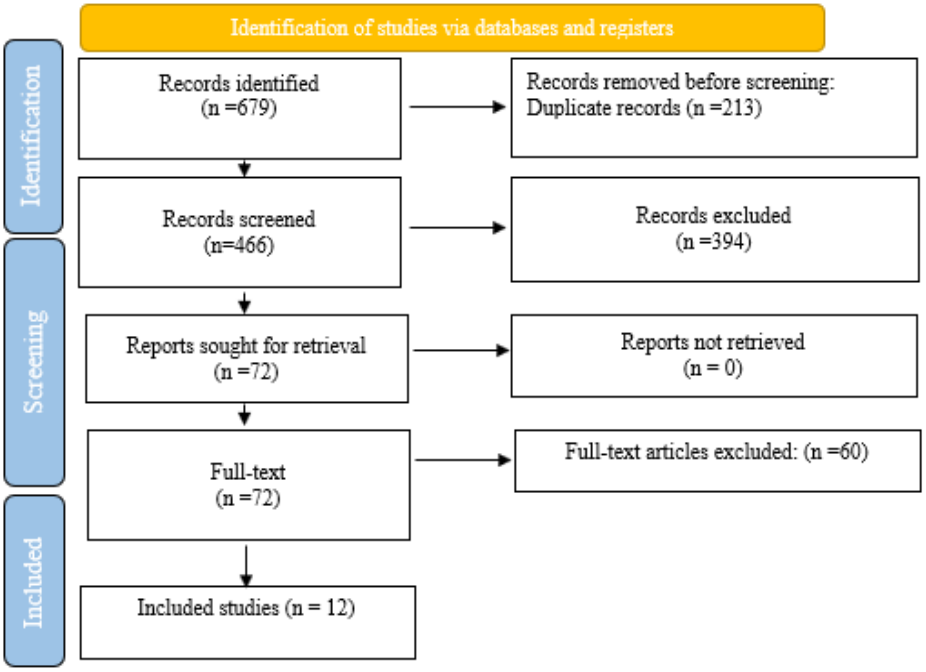


Figure 1. PRISMA 2020 Flow Diagram

Quality evaluation

Among the 12 included studies, four were rated as having a low risk of bias, seven were assessed as raising some concerns, and one study was classified as having a high risk of bias (Table 2). In the domain of the randomization process, most studies were judged to be at low risk of bias; however, several studies raised some concerns due to incomplete reporting of random sequence generation and insufficient clarity regarding allocation concealment procedures. Regarding deviations from intended interventions, the overall risk of bias was generally low. Nevertheless, a number of studies were categorized as having some concerns, primarily due to the inherent characteristics of behavioral, digital, and exercise-based interventions, in which blinding of participants and personnel was not feasible.

In the domain of missing outcome data, nearly all studies were assessed as low risk of bias, with only one study rated as high risk due to a small sample size and incomplete outcome data at follow-up. For the measurement of outcomes, most studies employed standardized and validated instruments and were therefore considered at low risk of bias. However, a small number of studies were rated as having some concerns due to the potential for measurement bias, particularly for subjective outcomes such as quality of life and cognitive performance. Finally, in the domain of selection of reported results, most studies were judged to be at low risk of bias, although a limited number of studies raised some concerns due to the absence of pre-registered protocols or insufficient reporting of prespecified analyses.

Cognitive Function

A total of six effect estimates from six studies were included in the meta-analysis examining the effect of digital health and tele-nursing interventions on cognitive function in older adults. A random-effects model using the DerSimonian–Laird method was applied. Non-significant overall effect of the intervention on cognitive function (mean difference = 0.13, 95% CI: -0.15 to 0.40; p = 0.366) (Figure 2). Heterogeneity across studies was negligible ($\tau^2 = 0.0000$, $I^2 = 0.00\%$, Q = 1.36, p = 0.928), indicating a high level of consistency among study findings.

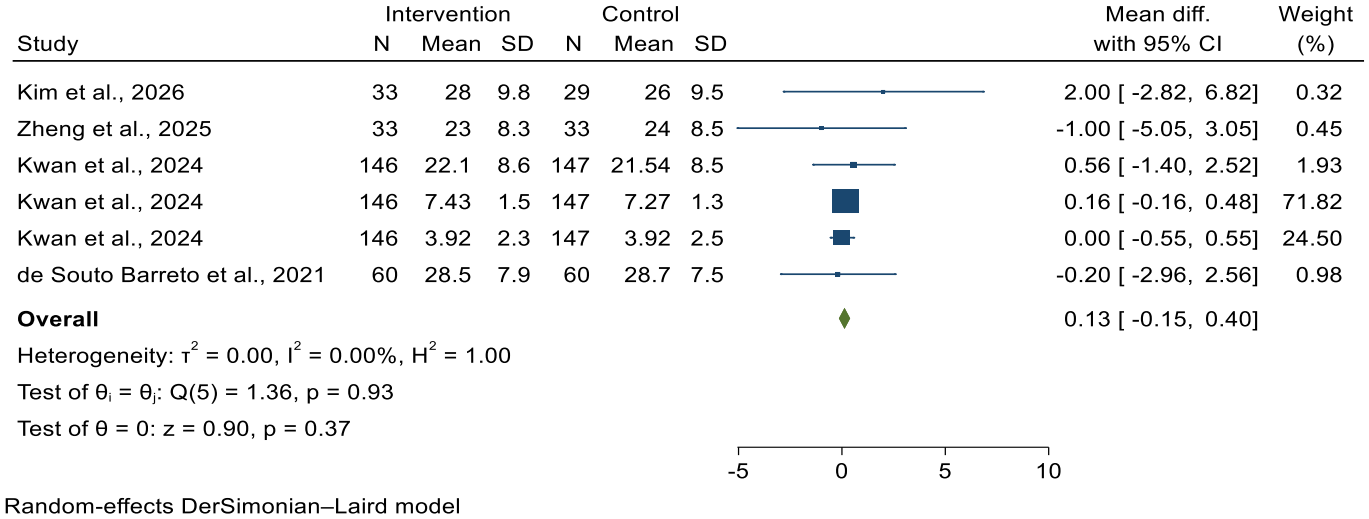
Table 1. Characteristics of Included Studies Assessing Effectiveness of Digital Health and Tele-Nursing Interventions.

First Author (Year)	Number of participants		Gender		Mean age or Age Range		Type of Intervention	Intervention Delivery Method	Control Condition	Intervention Duration	Primary Outcomes	Key Findings
	Intervention Group (n)	Control Group (n)	Intervention Group (M/F)	Control Group (M/F)	Intervention Group	Control Group						
Kim et al., 2026 (27)	33	29	4/29	4/25	73.8 ± 4.4 years	74.2 ± 5.3 years	AI-based Digital Cognitive Telerehabilitation	Home-based tablet PC cognitive training (Zenicog® platform) with adaptive AI algorithm and remote monitoring	No treatment/usual activities during Period 1	5 weeks (24 sessions, 30 min/session)	Cognitive Function, Quality of Life, Depression, Functional Independence, Self-efficacy	Significant improvement in global cognitive function (MMSE) compared with control ($p<0.001$). No significant improvements observed in quality of life (EQ-5D), depression, self-efficacy, or functional independence.
Rapp et al., 2026 (28)	196	189	Not separately reported	Not separately reported	~81.7 ± 5.9 years (total sample)	~80.7 ± 5.8 years (total sample)	PromeTheus programme (home-based exercise + counselling + optional group components)	Home-based physiotherapy-supervised programme + 10 home visits + phone calls	Usual care + PA/nutrition leaflet + one-time physiotherapist visit	12 months	LLFDI function, Life-Space Assessment	Significant improvement in LLFDI function (+1.38), no effect on life-space mobility; improvements in frailty status and SPPB
Eikemo et al., 2026 (29)	516	595	337/179	382/213	84.77 ± 7.74	84.36 ± 7.76	Digital communication technology (Komp video-call device)	Home-based digital device + installation + support	Usual home care + leaflet + 1 visit	~870 days (~28.5 months)	Time to move to long-term care / time living at home	No significant difference in time to institutionalization; slight ↑ risk of moving to care facility in IG (HR≈1.09–1.16, NS); ↓ short-term institutional stay days (≈17% reduction)
Üçpunar et al., 2026 (30)	30	30	13/17	14/16	75.80	75.87	Post-discharge tele-nursing education	Video consultations (3 sessions) + phone calls (3 sessions) + educational booklet	Routine in-hospital discharge education only (no follow-up)	6 weeks post-discharge	Quality of life (SF-36), Functional Independence (FIM)	Significant improvement in FIM total score in intervention group; several SF-36 domains (e.g., vitality, mental health) improved; overall better functional recovery vs control; no adverse between-group demographic differences
Zheng et al., 2025 (31)	33	33	Not reported	Not reported	80.20 ± 9.14	80.20 ± 9.14	Virtual reality-based ADL rehabilitation training	VR-based training sessions (supervised structured rehabilitation program)	Usual care / routine nursing home care	12 weeks (45 min, 2 sessions/week)	ADL performance, cognition, frailty, depression, quality of life	Significant improvement in intervention group: ADL, cognition, frailty reduction, improved QoL (mental & physical components) and reduced depression at T2; stronger effects at 12 weeks than 6 weeks
Kwan et al., 2024 (32)	146	147	36/110	28/119	75.2 ± 7.1	73.9 ± 6.6	Virtual Reality Motor-Cognitive Training (VRMCT)	VR-based supervised training in community centers (1:1 interventionist, headset + cycling + cognitive tasks)	Usual care + community center activities (waitlist control)	8 weeks (16 sessions; 2 sessions/week, 60 min each; 30 min VR exposure)	Cognitive function (MoCA), physical frailty (FFP), executive function, verbal short-term memory	Significant improvement in cognitive function (MoCA), physical frailty, and some executive function measures in intervention group vs control; no significant differences in some cognitive subdomains
Pilotto et al., 2024 (33)	30	28	18/12	12/16	81.6 ± 7.2	83.4 ± 5.4	Multicomponent transitional care (physical, cognitive, education, lifestyle + smart monitoring)	In-hospital PRO-HOME smart facility with wearable & environmental sensors + staff-guided program	Usual hospital acute ward care	During hospitalization (short stay; median LOS 2 vs 4 days) + 6-month follow-up	MPI (multidimensional frailty), SF-12 (HRQoL), adverse outcomes (hospitalization, institutionalization, death)	Reduced length of stay ($p<0.001$); improved multidimensional frailty at 6 months (MPI better in IG, $p=0.040$); no significant HRQoL differences; lower frailty trend and fewer institutionalizations in IG

Tuan et al., 2024 (34)	30	30	10/20	11/19	78.83 ± 7.71	78.73 ± 6.82	Exergame-based exercise training (Ring Fit Adventure) for frailty/sarcopenia prevention	Group-based exergame training in LTCFs (supervised sessions using Ring Fit Adventure system) + standard care	Standard care only in long-term care facilities	12 weeks	Frailty (SOF index), sarcopenia indicators (ASMM, ASMMI, grip strength), physical performance (gait speed), ADL, HRQoL	Significant improvement in frailty (SOF p=0.007), muscle mass (p=0.002–0.005), grip strength (p=0.011), gait speed (large effect). No significant HRQoL differences; overall better physical function in intervention group
Osuka et al., 2023 (35)	29	29	4 M / 25 F	5 M / 24 F	77 [72–82] years	77 [74–79] years	Home-based multicomponent exercise (Radio-Taiso + nutrition program)	Home exercise (TV/DVD-based + diary + periodic instruction sessions + telephone support)	Nutrition program only	12 weeks	SPPB, SF-36 (PCS & MCS), frailty-related mobility	No significant improvement in SPPB; no PCS benefit; slight improvement in MCS in intervention group; good adherence (83.8%); safe with no intervention-related adverse events
de Souto Barreto et al., 2021 (36)	60	60	29/31	22/38	75.2 ± 5.7	73.2 ± 5.3	Web-based multidomain lifestyle intervention (cognitive training + exercise training + nutritional advice)	Tablet-based secured web platform + wearable accelerometer (Fitbit)	Minimal intervention: accelerometer + informational link only (no active training)	6 months	Cognitive function, physical function, depressive symptoms, nutritional status, HRQoL, physical activity, cognitive activities	No significant between-group differences for most outcomes. Significant improvement only in HRQoL (EQ-5D index and VAS) favoring intervention. Low adherence to exercise component; feasibility acceptable; acceptability generally positive but with usability and engagement issues.
Lin et al., 2022 (37)	8	8	2/6	2/6	86.25 ± 5.15	82.50 ± 6.55	AIoT-based ergometer exercise training with adaptive (AI decision-tree) prescription for frail elderly with cognitive decline	Ergometer + mobile app + Bluetooth sensors + web-based AI management system (supervised long-term care facility setting)	Usual care + regular physical training (1 hour/week) without AI system	12 weeks (3–5 sessions/week)	Muscle strength, physical function (TUG, SPPB, balance tests), HRQoL (EQ-5D-3L), frailty (SOF), cognition (SPMSQ), depression (GDS-5)	Significant improvement in hip flexor strength (R: p=0.014), balance tests (semi-tandem p=0.025; tandem p=0.034) in intervention group; no significant differences in HRQoL, cognition, or most functional outcomes; overall better physical performance trends in intervention group
Gustafson et al., 2021 (38)	197	193	52/145	46/147	76.3 ± 7.4	76.8 ± 7.5	eHealth intervention (ElderTree: online platform with informational, social, self-management, and motivational services)	Web-based platform + optional computer/internet support + interactive services (chat, modules, self-management tools)	Usual care (access to standard information and communication only)	12 months intervention + 6 months follow-up	Mental & physical quality of life, independence (IADL), social support, depression, falls prevention	No significant overall intervention effects on primary outcomes. Significant effects only in moderation analyses: participants with high healthcare utilization showed improved mental QoL, social support, and depression outcomes. Overall intervention not superior to control.

Table 2. Risk of bias summary

Study	Randomization process	Deviations from intended interventions	Missing outcome data	Measurement of outcome	Selection of reported result	Overall Risk of Bias
Kim et al., 2026 (27)	Low	Low	Low	Low	Low	Low
Rapp et al., 2026 (28)	Some concerns	Some concerns	Low	Low	Low	Some concerns
Eikemo et al., 2026 (29)	Some concerns	Some concerns	Low	Low	Low	Some concerns
Üçpunar et al., 2026 (30)	Low	Low	Low	Low	Low	Low
Zheng et al., 2025 (31)	Some concerns	Some concerns	Low	Low	Some concerns	Some concerns
Kwan et al., 2024 (32)	Low	Low	Low	Low	Low	Low
Pilotto et al., 2024 (33)	Some concerns	Some concerns	Low	Some concerns	Low	Some concerns
Tuan et al., 2024 (34)	Low	Low	Low	Low	Low	Low
Osuka et al., 2023 (35)	Some concerns	Some concerns	Low	Low	Low	Some concerns
de Souto Barreto et al., 2021 (36)	Low	Some concerns	Low	Low	Low	Some concerns
Lin et al., 2022 (37)	High	Some concerns	High	Some concerns	Some concerns	High
Gustafson et al., 2021 (38)	Some concerns	Some concerns	Low	Low	Some concerns	Some concerns



Frailty

A total of six studies were included in the meta-analysis examining the effect of digital health and tele-nursing interventions on frailty among older adults. A random-effects model was applied due to expected methodological and clinical heterogeneity. A statistically significant reduction in frailty in the intervention groups compared with controls (mean difference = -0.36, 95% CI: -0.49 to -0.22; $p < 0.001$) (Figure3), indicating a beneficial effect of digital health and tele-nursing interventions on frailty-related outcomes. However, substantial heterogeneity was observed across studies ($I^2 = 94.13\%$, $\tau^2 = 0.0225$, $Q = 85.20$, $p < 0.001$), suggesting considerable variability in effect sizes. This high heterogeneity indicates that the magnitude of intervention effects differed markedly between studies.

Quality of Life

The meta-analysis of seven studies revealed a statistically significant positive effect of digital health and tele-nursing interventions on quality of life in older adults (mean difference = 1.05, 95% CI: 0.180 to 1.913; $p = 0.018$) (Figure 4). Heterogeneity was low to moderate ($I^2 = 31\%$), indicating acceptable consistency across studies.

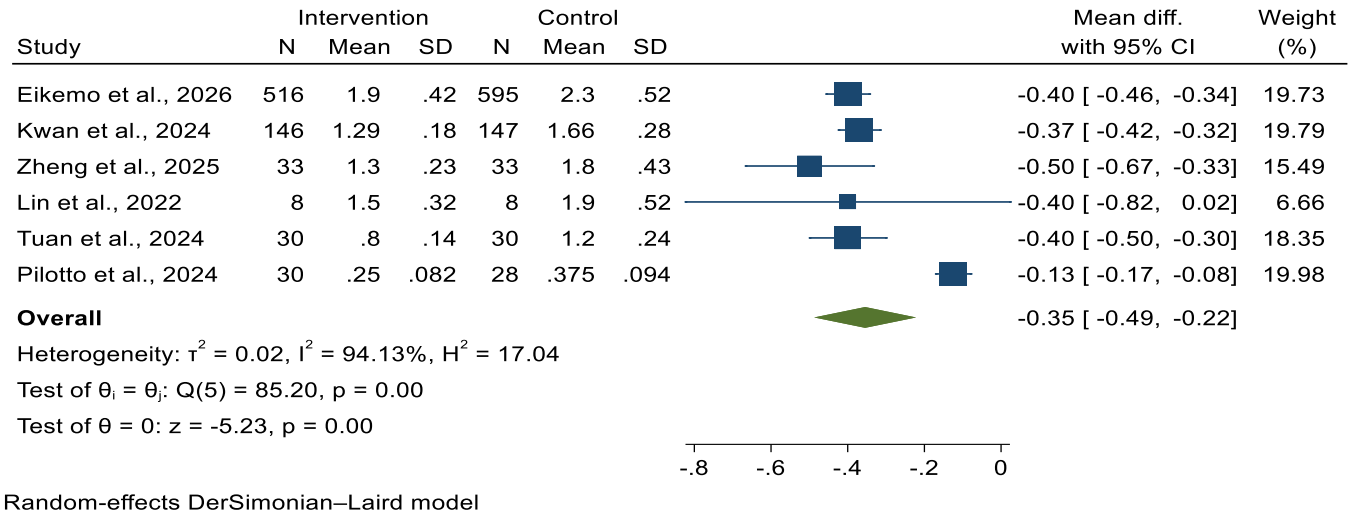


Figure 3. Forest Plot showed the effect of Digital Health and Tele-Nursing Interventions on Frailty in Older Adults

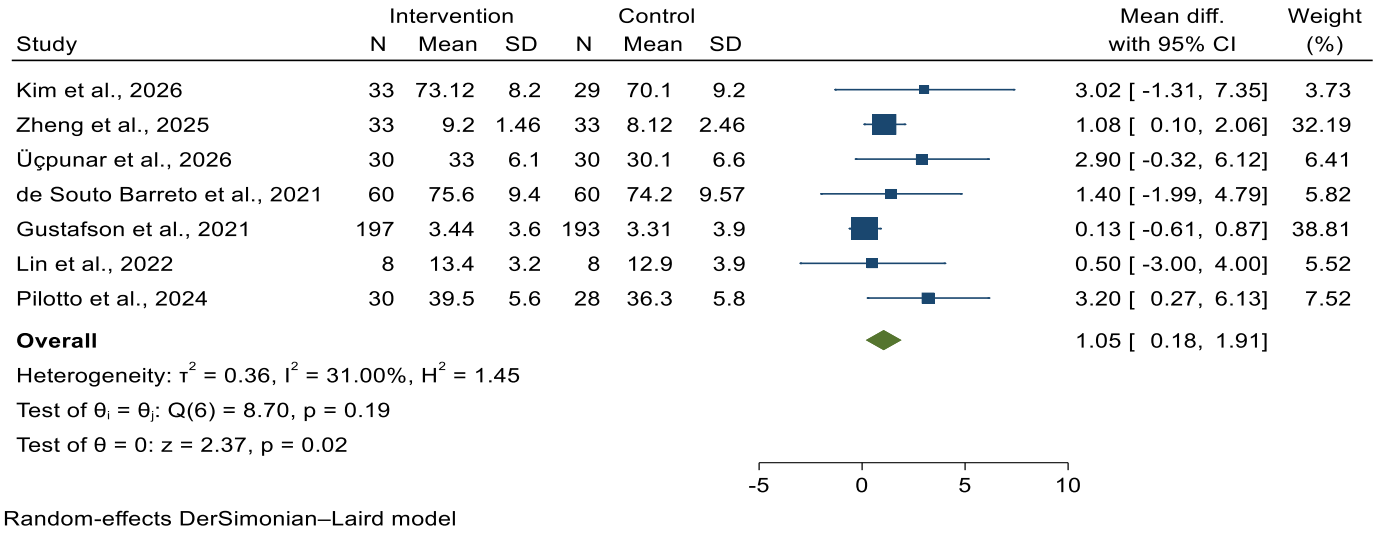


Figure 4. Forest Plot showed the effect of Digital Health and Tele-Nursing Interventions on Cognitive Function

Discussion

In this systematic review and meta-analysis, we evaluated the effects of digital health and tele-nursing interventions on three key outcomes: frailty, cognitive function, and quality of life among older adults. Overall, the findings demonstrated differential effects across outcomes, with significant improvements observed in frailty reduction and quality of life, whereas no statistically significant overall effect was identified for cognitive function.

The pooled analysis indicated that digital health interventions significantly reduced frailty in older adults (SMD = −0.355, $p < 0.001$), although substantial heterogeneity was present ($I^2 = 94.13\%$). This suggests that, despite considerable variability in intervention modalities and implementation contexts, the direction of effect was generally consistent across studies, favoring improvements in frailty status. In contrast, quality of life showed a statistically significant improvement (SMD = 1.046, $p = 0.018$) with moderate heterogeneity ($I^2 = 31\%$), indicating relatively stable effects across studies.

Regarding cognitive function, although some individual studies reported beneficial effects, the overall pooled estimate was not statistically significant (SMD = 0.126, $p = 0.366$; $I^2 = 0\%$). This finding suggests that the impact of digital interventions on cognition may be contingent upon specific intervention characteristics, including intensity, duration, and the inclusion of structured cognitive training components. The findings of the present study are broadly consistent with previous systematic reviews and meta-analyses. Liang et al. reported that digital health interventions improve frailty (SMD = −0.42), cognitive function (SMD = 0.12), and quality of life (SMD = 0.30) among older adults(39). In the present study, the beneficial effects on frailty and quality of life were similarly confirmed; however, no significant effect on cognitive function was observed, which contrasts with the findings reported by Liang et al. (39).

Similarly, De Souto Barreto et al. 2021(36) found modest but statistically significant improvements in quality of life following multidomain digital interventions, while effects on cognition and physical function were heterogeneous. These findings are consistent with those of the present study, particularly regarding the modest yet significant improvement in quality of life.

With respect to frailty, the results of this study are aligned with previous meta-analyses such as Liang et al. (39) and Yi et al. (40), which demonstrated that exercise-based and digitally supported rehabilitation interventions can significantly reduce frailty severity and improve physical function. This suggests that the physical domains of frailty may be more responsive to digital health interventions compared with other domains. In contrast, the absence of a significant effect on cognitive function in the present study is inconsistent with some previous findings, including those of Liang et al. (39). This discrepancy may be attributed to differences in intervention composition. In many of the included studies, the primary emphasis was on physical activity promotion or health monitoring, whereas specific cognitive training components were limited. Conversely, studies reporting significant cognitive benefits typically incorporated structured cognitive training or dual-task interventions combining cognitive and motor training.

Regarding quality of life, the present findings are consistent with those reported by Gustafson et al. (38) and Pilotto et al. (33), both of which demonstrated that multicomponent digital interventions can improve quality of life, particularly in domains related to mental health and social functioning.

The substantial heterogeneity observed in frailty outcomes ($I^2 = 94.13\%$) reflects marked variability in intervention type, intensity, duration, and participant characteristics across studies. Nevertheless, the consistent direction of effect across most studies suggests a robust overall beneficial impact of digital health interventions on frailty reduction. From a clinical perspective, these findings indicate that digital health interventions are most effective when implemented as multidimensional programs integrating digital monitoring, structured physical exercise, and behavioral support. This aligns with contemporary frailty management frameworks that emphasize multimodal intervention strategies.

The observed improvements in frailty and quality of life may be explained by several potential mechanisms. Digital health interventions may enhance adherence to exercise programs, promote self-management behaviors, and facilitate access to rehabilitation services, thereby increasing physical activity levels and mitigating functional decline. Additionally, reductions in physical inactivity, improved social engagement, and an enhanced sense of control over health may collectively contribute to improvements in quality of life. The absence of a significant cognitive effect may be attributable to insufficient cognitive stimulation intensity in many of the included interventions, as clinically meaningful cognitive improvements in older adults generally require targeted and sustained cognitive training.

This study has several limitations. First, substantial heterogeneity in some outcomes, particularly frailty, may have reduced the precision of the pooled estimates. Second, the considerable heterogeneity in intervention types and outcome measurement tools limited direct comparability across studies. Third, incomplete reporting of intervention details and randomization procedures in some studies may have affected the overall quality of evidence. Finally, the relatively small number of studies included in the cognitive function analysis limited statistical power.

Future research should focus on the development and evaluation of standardized intervention protocols, the incorporation of combined cognitive–physical–digital strategies, and extended follow-up periods to assess long-term effects. Furthermore, network meta-analyses may be useful in identifying the most effective components of digital health interventions for older adults.

Conclusion

The findings of this systematic review and meta-analysis provide evidence that digital health and tele-nursing interventions have a meaningful but outcome-specific impact on health status among older adults. Overall, these

interventions were associated with a significant reduction in frailty and an improvement in quality of life, indicating their potential clinical value in supporting healthy aging and functional independence in later life. In contrast, no significant pooled effect was observed for cognitive function, suggesting that current digital intervention models may be insufficient in isolation to produce measurable cognitive benefits.

In conclusion, digital health and tele-nursing interventions represent a promising and scalable approach to addressing key geriatric health challenges, particularly frailty and quality of life, but their cognitive benefits remain limited and require further investigation through well-designed, high-quality randomized controlled trials.

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Ethical Approval

The present study is a systematic review and meta-analysis based solely on data obtained from previously published articles. No human subjects were directly involved, and no individual-level identifiable data were collected or accessed by the authors. The review was conducted in accordance with established methodological and ethical standards for evidence synthesis and secondary research. All sources were appropriately acknowledged, and all citations, paraphrases, and direct quotations were accurately attributed to their original authors in accordance with accepted standards of publication ethics and academic integrity.

Conflict of Interests

The authors declare that they have no competing interests.

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