Systematic Review

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Effectiveness of Technology-Assisted Nurse-Led Cognitive Interventions on Cognitive Function in Older Adults with Mild Cognitive Impairment: A Systematic Review and Meta-Analysis

Pakamas Pimtara, R.N., M.S.[1], Rungnapha Khiewchaum, R.N., A.P.N, Ph.D.[1], Yosapon Leaungsomnapa, R.N. M.S, Ph.D.[1], Rebecca Susan Graves, M.L.S.[2], Patrapon Bhatarasakoon, R.N., A.P.N., Ph.D., FAAN[3]

[1]Department of Adult and Gerontological Nursing, Faculty of Nursing, Phrapokklao Nursing College, Phraborommarajchanok Institute, Ministry of Public Health, Mueang, Chanthaburi 22000, Thailand.

[2]Otto Lottes Health Sciences Library, University of Missouri, Columbia 65211, United States of America.

[3]Department of Psychiatric Nursing, Faculty of Nursing, Chiang Mai University, Chiang Mai 50200, Thailand.

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Abstract:

Objective: This systematic review and meta-analysis examined the effectiveness of technology-assisted nurse-led cognitive (TNC) in improving cognitive function among older adults with mild cognitive impairment (MCI).

Material and Methods: A systematic search for randomized controlled trials (RCTs) was performed across five electronic databases (PsycINFO, PubMed, Scopus, CINAHL, and ProQuest) from inception to December 31, 2024. Primary outcomes included cognitive outcomes of older adults with MCI. The Cochrane Risk of Bias Assessment Tool 1 (ROB1) was used. Standardized mean differences (SMDs) with 95.0% confidence intervals (CIs) were synthesized using RevMan version 5.40 to calculate pooled effect sizes.

Results: Eight eligible studies comprising 2,574 participants were included. The findings demonstrated that TNC interventions led to modest improvements in cognitive function compared to standard care (SMD=0.23, 95.0% CI (0.06, 0.40), p-value=0.01). Subgroup analyses revealed that combined TNC interventions showed greater efficacy (SMD=0.31, 95.0% CI (0.09, 0.54), p-value=0.01). In contrast, single TNC interventions did not yield any significant effect (SMD=0.32, 95.0% CI (-0.05, 0.70), p-value=0.09). In terms of cognitive outcomes, the Mini-Mental State Examination (MMSE) and the Montreal Cognitive Assessment (MoCA) in both studied subgroups showed no significant difference.

Contact: Rungnapha Khiewchaum, R.N., A.P.N, Ph.D.
Department of Adult and Gerontological Nursing, Faculty of Nursing,
Phrapokklao Nursing College, Phraborommarajchanok Institute,
Ministry of Public Health, Mueang, Chanthaburi 22000, Thailand.
E-mail: rungnapha@pnc.ac.th

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Conclusion: These results highlight the potential of combined TNC interventions to promote cognitive function among older adults with MCI. However, further combined TNC studies are essential to examine the effectiveness of these interventions in improving cognitive outcomes among older adults with MCI.

Keywords: cognitive function, meta-analysis, mild cognitive impairment, nurse-led, older adults

Introduction

The global burden of dementia is expected to reach 65.7 million cases by 2030, which will impact the socio-economic system[1]. Mild cognitive impairment (MCI) represents an intermediary phase between normal cognitive aging and early dementia[2]. Additionally, older adults with MCI are characterized by declines in language abilities, spatial and temporal reasoning, memory, and frontal lobe functions, similar to Alzheimer's dementia type, a progressive decline (e.g., loss of memory, attention, executive function, language, and visuospatial skills)[3]. As a result, older adults with MCI face daily difficulties because their cognitive skills are not sufficient to perform daily activities, leading to a reduction in their quality of life[4]. Moreover, older adults with low cognitive abilities rely on caregivers for daily assistance, and thus, caregivers encounter physiological and psychological burdens[5]. Consequently, older adults with MCI and their caregivers have increased healthcare utilization. Therefore, improving the cognitive skills of older adults with MCI is a pressing health concern[6].

Current cognitive interventions in older adults with MCI were developed using various approaches to increase the effectiveness of interventions, such as interventionists (e.g., physicians, psychiatrists, nurses, or psychologists) and multidisciplinary delivery[7]. Moreover, there are a variety of intervention characteristics: types of cognitive interventions, such as a single intervention (e.g., education or psychological strategies) or combined interventions (e.g., psychoeducational or psychosocial interventions) tailored to promote cognitive conditions among older adults with MCI[8-9]. While metaverse technologies in healthcare have significantly increased roles, these traditional cognitive interventions have been increasingly replaced by technology-assisted approaches (e.g., smartphone, computer, virtual reality, robotic, or artificial intelligence approaches)[10-13]. Technology-assisted cognitive interventions have demonstrated more effective outcomes in improving cognitive functions[14]. Interestingly, nursing cognitive interventions with a technology therapy (e.g., virtual-reality strategy, game-based intervention, or robotic training) were increasingly employed to reinforce the cognitive abilities of older adults with MCI. Also, these technology-assisted nurse-led cognitive (TNC) interventions with technological strategies demonstrated that interventions incorporating technological approaches need to be used to enhance patients with MCI, and technology-assisted interventions may improve positive cognitive outcomes, and thus, initiate the remote delivery of suitable interventions for people with MCI[15].

This review defines TNC interventions as any program or treatment specifically managed by nurses or a multidisciplinary team led by nurses using a technology approach as a central component—TNC interventions. Nurses provided more comprehensive care (e.g., clinical assessment, symptom management, health education, or tailored coaching) with technology-assisted nurses serving as the primary coordinators and decision-makers. These technology-based approaches may utilize web-based mobile applications, virtual reality platforms, robotics, and other digital tools to create and deliver health promotion

materials and provide comprehensive care to older adults with MCI[15]. Not surprisingly, technology-based interventions in nursing areas with improved cognitive outcomes for older adults have become more extensive. Existing nursing studies have demonstrated that technology-assisted cognitive training (e.g., a game-based intelligence test and remote expressive art program) delivered via smartphone, tablet, or computer can improve various cognitive functions, such as executive function, memory, attention, and coordination, in older adults with MCI and mild dementia[12,16]. Moreover, the Mini-Mental State Examination (MMSE) and the Montreal Cognitive Assessment (MoCA) are two of the most widely used cognitive screening tools for evaluating the efficacy of cognitive training for people with cognitive impairment[17].

Previous systematic reviews and meta-analyses provide strong evidence supporting the utilization of technology-assisted interventions to enhance cognitive function in older adults with MCI. One review demonstrated that mobile health applications can significantly improve cognitive function[18]. Additionally, a meta-analysis of 28 studies involving 1,489 individuals with MCI found that computerized cognitive training (CCT) delivered by multidisciplinary interventionists significantly improved verbal and working memory among older adults with MCI[19]. Similarly, another systematic meta-analysis reported that virtual reality interventions significantly enhanced attention, short-term memory, and cognitive flexibility in people with cognitive impairment[20]. However, only one previous systematic review and meta-analysis of 584 older adults with dementia from 12 eligible studies indicated that technology-assisted interventions delivered by various healthcare providers (e.g., nurses, occupational therapists, neurologists, or an exercise specialist) could improve cognitive function and decrease depressive symptoms in people with dementia compared with the usual care[15]. However, may be more effective than technology-assisted cognitive programs delivered by multidisciplinary teams due to the provision of a single accountable profession who integrates digital strategies with individualized coaching, consistent monitoring, and holistic support based on participant characteristics (e.g., age, cognitive severity, and digital literacy). Also, TNC approaches ensure timely adjustments and sustained engagement for older adults with MCI. In contrast, technology-assisted interventions tailored by multidisciplinary teams may offer differences in continuity of care, personalization, fragmented monitoring, and inconsistent feedback and adherence, leading to unreliable cognitive training.

Even though technology-based interventions delivered by multidisciplinary teams are effective, nurses are considered a crucial part of MCI care. Due to complicated cognitive challenges, nurses have played a pivotal role in providing MCI patients with educational assistance by identifying access to promoting patients' health literacy and training cognitive ability, resulting in improved cognitive functions for older adults with MCI[21]. Because nurse-led interventions promoted patients' attitudes and caregivers' positive perception of nurses, a high quality of intervention delivery, and a potentially lower healthcare expenditure, patients' health status showed positive outcomes and a higher quality of life[22].

Recently, accumulating evidence suggests that TNC interventions may incorporate individualized assessment, patient engagement, coaching, and real-time monitoring to improve cognitive outcomes among older adults with MCI, whereas general cognitive strategies may not be optimal interventions with real-time evaluation[21]. However, there were few meta-analyses of TNC interventions, and previous systematic reviews and meta-analyses only emphasized multidisciplinary delivery and general cognitive interventions. Therefore, to address the gap in prior studies, we aimed to uniquely synthesize the available evidence to examine the effectiveness of TNC interventions to improve cognitive functions among older adults with MCI. Moreover, this study provided a comprehensive understanding of nursing cognitive interventions with a technology-assisted

approach, informing clinical practice in this area. Likewise, this study revealed how to promote older adults with MCI and improve cognitive functions with TNC interventions. The technology-assisted cognitive approach was more effective than traditional cognitive interventions in increasing the cognitive outcomes of older adults with MCI and advancing nursing knowledge and practice in MCI care from hospital to community.

Material and Methods

Study design

The protocol of this study was registered with the PROSPERO International Prospective Register of Systematic Reviews (CRD42023431713), recorded by the National Institute for Health and Care Research (NIHR). The current study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol to conduct this review using the Joanna Briggs Institute (JBI) methodology for the effectiveness of systematic reviews[18].

Search strategy

The JBI three-step search strategy employed included 1) beginning with a preliminary search, 2) analyzing keywords, and 3) reviewing the reference lists of all the selected sources for eligible studies[23]. First, the search strategy was developed in consultation with an expert reference librarian (RG) to reduce the bias of narrow and limited searches[24]. In addition, the search terms were cognitive impairment, memory loss, memory decline, cognitive decline, aging, elderly, seniors, older adults, technology, telephone, smartphone, computer, smartwatch, virtual reality, video call, video chat, artificial intelligence, robotic, nurses, nursing, and nurse-led. The preliminary search was controlled using PubMed with a priori-selected search terms—keywords. Second, the search with keywords was applied, and the index terms described above were managed across PubMed, PsycINFO (Ebsco), Scopus, and the CINAHL (Ebsco) databases. ProQuest dissertations and theses, Google Scholar, a Thai thesis database: http://tdc.thailis.or.th/tdc/, and clinical trials: Clinicaltrials.gov were used to search unpublished and grey literature (e.g., dissertations and conference proceedings)[25]. The used search strategies were: ("older adults" OR "cognitive decline") AND ("virtual reality" OR "smartphone" OR "computer" OR "video call" OR video chats" OR "robotic" OR "artificial intelligence" OR "games") AND ("nurse-led" OR "nurses" OR "nursing-led"). Third, the reference lists of all selected sources of eligible studies were reviewed. A search across the five databases was performed from inception to December 31, 2024, and references cited within relevant articles and previous eligible meta-analyses were exhaustively examined. Also, database searches were conducted on January 31, 2025.

Eligibility criteria

The Population, Intervention, Comparison, Outcomes, and Study Design (PICOS) method was employed to select qualified studies. The inclusion criteria were as follows: the population (P) comprised people with MCI, aged 60 or over; the intervention (I) involved cognitive interventions using a technology approach managed by nurses; a comparator (C) was usual or standard care, referring to no intervention or passive activities or traditional paper-based cognitive training or any intervention that did not include technology-assisted interventions tailored by other professionals; the outcome (O) was cognitive function measured by cognitive tools; the studies (S) were randomized controlled trials (RCTs) of any design published in the English language. Studies that did not meet these inclusion criteria or were available as abstracts only were excluded. The reference management systems were used in all citations, and duplicated studies were removed. In addition, the reference lists of the retrieved publications were searched to identify any study that may have been lost during the database search.

Study selection

An initial search identified 3,500 potential studies across five databases. After automatically removing 29 duplicates with EndNote X9, four reviewers screened and collated the studies (N=3,471) independently in a two-step process. First, titles and abstracts were assessed by an assistant researcher (PN), then full-text articles were independently evaluated based on the PICOS criteria by two researchers (RK/PP). The discrepancies were resolved by discussion and reaching a final agreement with a third investigator (YL). The selection process is reported in the PRISMA flow diagram shown in Figure 1. Of the 3,411 studies, 3,471 were excluded because the titles of these studies did not meet the inclusion criteria. Next, 52 of 60 were excluded due to not having older adults with MCI, not being RCT studies, not being related to TNC interventions, and not having cognitive outcomes. Finally, eight eligible studies were analyzed.

Data extraction

Data extraction was conducted using a structured form developed by the researcher, which was independently piloted and evaluated before full data extraction by two researchers (RK/PP). Extracted information includes the authors (year, country, and location of the study), study design, interventions examined, intervention setting, participant demographics (i.e., sample size, number of older adults with MCI and age), types of nursing technology-assisted interventions used, the types of interventions examined in the experimental and control groups, intervention characteristics, including frequency and duration, and cognitive outcomes measured by scales.

Assessment of risk of bias and certainty of evidence

The risk of bias was evaluated for each study using the Cochrane Risk of Bias Assessment Tool 1 (ROB1) for RCT studies, assessing factors such as randomization, allocation concealment, baseline treatment similarity, blinding (et al., treatment delivery, participants, personnel, and outcome assessment), completeness of outcome data, and other biases[26]. The assessments of risk of bias were graded into three categories: high, low, and unclear risk of bias[26]. The quality assessment of RCT studies included in this review was assessed using the JBI Critical Appraisal Checklist—the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach[27]. For the assessment process, two researchers (RK/PP) independently assessed for study selection and data extraction, resolving discrepancies through discussions with a third investigator (YL) to increase the homogeneity of the data.

Statistical analysis

To compare cognitive outcomes, cognitive measurements were related to memory, language, attention, and executive functions in people with MCI– true means and standard deviations were used to calculate the standardized mean difference (SMD). A random-effects meta-analysis model was employed, with the significance threshold set at p-value<0.05. Heterogeneity was assessed using the I^2 statistic, categorized as low (<25%), moderate (25-50%), or high (>50%). For instances of significant heterogeneity (I^2>50.0%), sensitivity analyses and a random-effects model were applied. To evaluate the characteristics of TNC interventions associated with positive outcomes, we conducted an exploratory subgroup analysis using a mixed-effects model on categorical moderators: a type of intervention and measurement.All statistical analyses were conducted using Review Manager software (RevMan) version 5.40, and the Funnel Plot was used to investigate publication bias (a visual examination)[28] in the studies included in Figure 2.

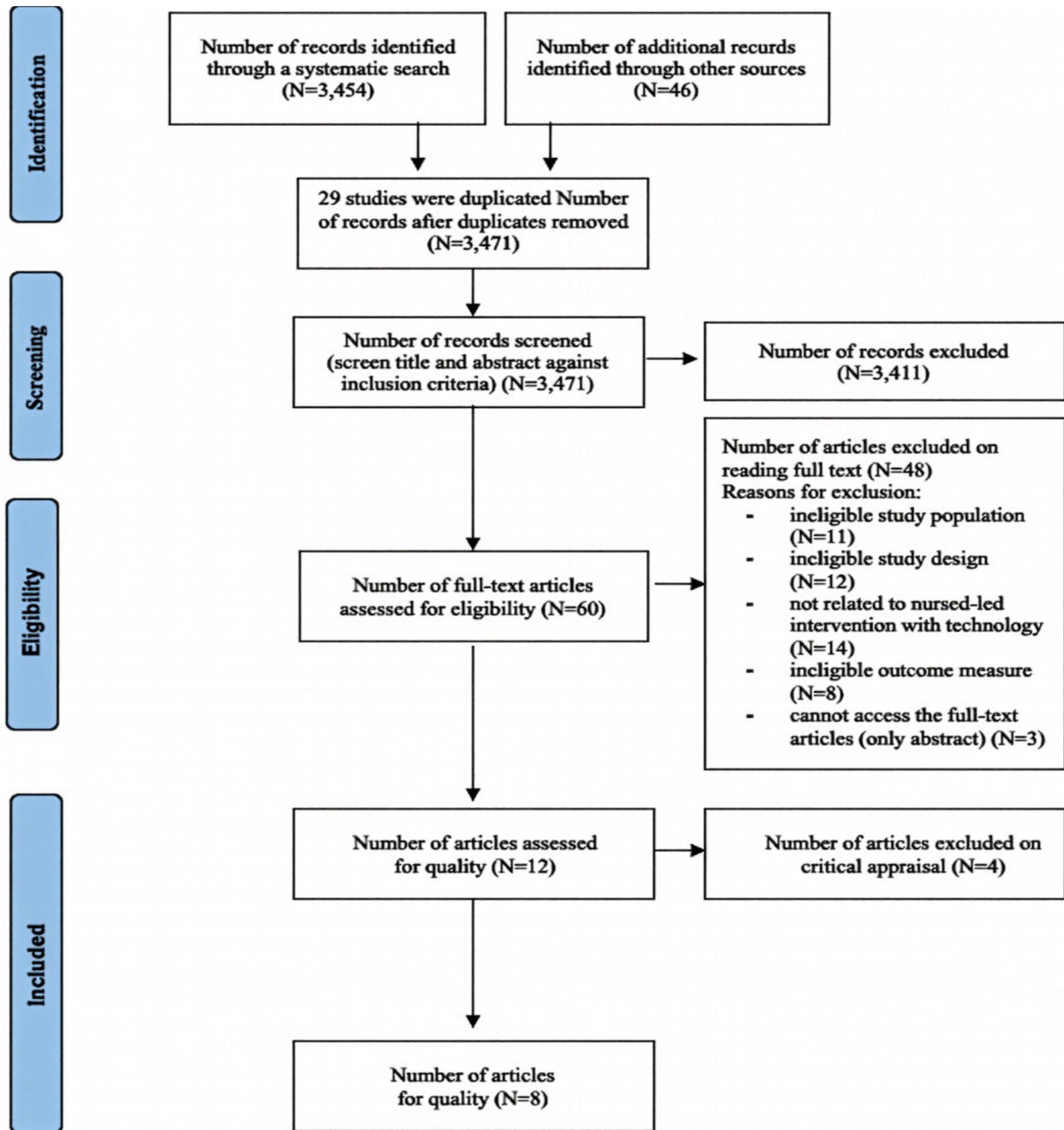


Figure 1 PRISMA flow chart of study selection

Results

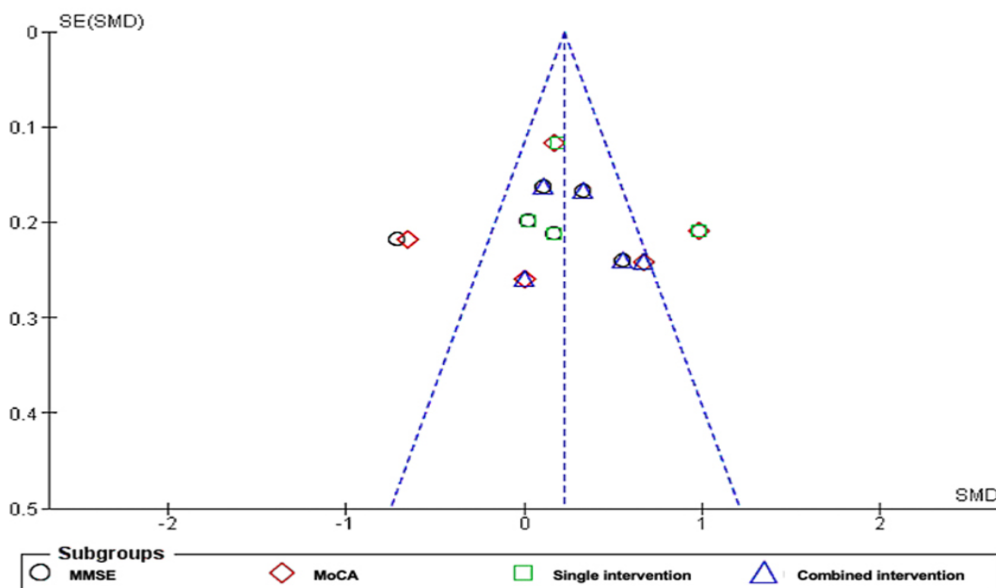
Study characteristics

All the included studies were published in English between 1989 and 2024. Out of 3,471 screened studies, eight were included in the review[10-12,16,29-32]. Three studies were conducted in China, two in Taiwan, and one study each in Italy, South Korea, and Hong Kong. The sample sizes in the eight TNC intervention studies ranged from 62 to 300 participants, totaling 1,289, with mean ages ranging from 65.75 to 83.50 years. All technology-assisted cognitive interventions were delivered by nurses and implemented in various settings, including memory clinics, neurology clinics, community centers for older adults, hospitals, and dementia centers. Intervention methods included tablets, smartphones, virtual reality, synchronous video training, robot-assisted cognitive training (RACT), game-based intelligence tests, and CCT support. In contrast, the control group received the usual therapy (e.g., listening to audiobooks, reading newspapers, and classic paper-and-pencil cognitive training). The TNC intervention programs were administered once or twice per week over 2 to 52 weeks, with session durations ranging from 0.5 to 16 hours. The follow-up period varied from immediately post-intervention to 12 months after the intervention (Table 1).

Risk of bias and rob 1 evaluations

The included studies were assessed for risk of bias. The issues were the lack of blinding regarding treatment allocation among participants, interventionists, and assessors, as well as poor treatment concealment. Based on the ROB1 approach, eight studies were categorized as follows: five (62.50%) as low risk [10-12,16,32] and three (37.50%) as high risk[29-31].

Although this study had a small number of eligible studies for each type of TNC intervention, we tried to reduce the publication bias by thoroughly examining the relevant



SMD=standardized mean difference, MMSE=mini-mental state examination, MoCA=montreal cognitive assessment

Figure 2 Funnel plot of selected studies.

Table 1 Summary of systematic review

Author	Countries/ Setting	Type of technology-assisted materials	Sample size	Participant characteristics	Intervention characteristics			Cognitive outcome measures	Results
					Frequency/ duration	Intervention length (week)	Follow-up Length (week)		
Bevilacqua et al., 2023	Italy / Neurology unit and the Alzheimer's evaluation unit (memory clinic)	The tablet Compann (tablet's interface)	62	1) Mean age (S.D.) year: Ex group 75.8 (8.1) Co group 74.2 (8.1) 2) Gender, n (%) Male 30 (48.39%) Female 32 (51.61%)	2 times/day	12	0	MoCA	The MoCA scores showed no significant differences between the intervention and control groups (p-value=0.381).
Jeong et al., 2016	Taiwan/ Neurology clinic	An audio-visual interactive input interface device and a special training course application (APP) on a smartphone or tablet	300	For group-based cognitive intervention (GCI) 1) Mean age (S.D.) year 70.8 (6.9) 2) Gender, n (%) Male 21 (29.6%) Female 50 (70.4%) For home-based cognitive intervention (HCI) 1) Mean age (S.D.) year 68.5 (8.5) 2) Gender, n (%) Male 27 (35.1%) Female 50 (64.9%) For Control group 1) Mean age (S.D.) year: 71.6 (6.5) 2) Gender, n (%) Male 35 (46.1%) Female 41 (53.9%)	90-min sessions twice weekly	12	24	MMSE	GCI and HCI participants had no significant improvement from baseline to the 6-month follow-up (p-value=0.39 and 0.60 respectively).
Kwan et al., 2024	Hong Kong/ Older adult community centers	Virtual reality (VR)	293	1) Mean age (S.D.) year: Ex group 75.2 (7.1) Co group 73.9 (6.6) 2) Gender, n (%) Male 64 (21.8%) Female 229 (78.2%)	8 consecutive Weeks, two 1-hour sessions each week (30 minutes for VR devices)	2	9	MoCA	VR was effective in promoting global cognitive function (interaction effect: p-value=0.03).

Table 1 (countined)

Author	Countries/ Setting	Type of technology-assisted materials	Sample size	Participant characteristics	Intervention characteristics			Cognitive outcome measures	Results
					Frequency/ duration	Intervention length (week)	Follow-up Length (week)		
Lu & Mao, 2021	China/Hospital	Telephone call	90	1) Mean age (S.D.) year: Ex group 71.4 (8.3) Co group 70.9 (8.5) 2) Gender, n (%) Male 71 (67.78%) Female 229 (32.22%)	2.5 hours	52	52	MMSE MoCA	After the intervention, the MMSE and MoCA scores were increased in both groups (p-value<0.01), with a more significant increase observed in the control group than in the experimental group (p-value<0.01).
Luo et al., 2023	China/ Fujian Provincial Hospital	The visual art creation involved synchronous video teaching of art-themed activities.	73	For remote expressive arts program (rEAP) 1) Median age (range) year: 71.5 (66.0-75.0) 2) Gender, n (%) Male 10 (26%) Female 28 (74%) For health education (HE) 1) Median age (range) year: 71.0 (65.0-75.0) 2) Gender, n (%) Male 15 (43%) Female 20 (57%)	30-60 minutes	12	0	MMSE MoCA	The rEAP group's MMSE scores before the intervention and after the intervention were higher than those of the HE group, and the difference was statistically significant (p-value=0.035). The rEAP group's MoCA scores before the intervention and after the intervention were higher than those of the HE group, and the difference was statistically significant (p=0.012).
Park et al., 2021	South Korea/ S-City Dementia Center	Robot-assisted cognitive training (RACT)	90	1) Mean age (S.D.) year: Ex group 75.5 (5.9) Co group 75.6 (6.6) 2) Gender, n (%) Male 25 (27.78%) Female 65 (72.22%)	16 hours	6	6	MMSE	RACT participants had significantly greater post-intervention improvement in cognitive function (t=4.707, p-value<0.001) Memory (t=-2.282, p-value=0.007) Executive function (t=4.610, p-value<0.001)

Table 1 (countined)

Author	Countries/ Setting	Type of technology-assisted materials	Sample size	Participant characteristics	Intervention characteristics			Cognitive outcome measures	Results
					Frequency/ duration	Intervention length (week)	Follow-up Length (week)		
Sung et al., 2023	Taiwan/ Community care center	The game-based intelligence test	72	1) Mean age (S.D.) year: Ex group 83.5 (6.36) Co group 81.0. (6.41) 2) Gender, n (%) Male 17 (23.6%) Female 55 (76.4%)	30 minutes	8	52	MMSE	The effects of multi-domain cognitive function training on cognitive function (β=1.51; 95% CI=0.40-2.63; p-value=0.008), working memory (β=-1.93; 95% CI -3.33, -0.54; p-value=0.007), selective attention (β=-27.8; 95% CI=-47.1, -8.48; p-value=0.005), and coordination (β=1.61; 95% CI=0.25, 2.96; p-value=0.020) were maintained for one year. There were no significant improvements in attention outcomes (visual-spatial and divided attention) after training.
Wen et al., 2024	China/ Memory clinic	CCT support	118	1) Mean age (S.D.) year: Ex group 66.78 (8.3) Co group 65.75 (9.4) 2) Gender, n (%) Male 70 (59.32%) Female (40.68%)	30 minutes	12	12	MMSE	The experimental group's MMSE scores at T2 (post-intervention) and T3 (3-month follow-up) showed no statistical difference compared to the control group (p-value=0.08).
								MoCA	The MoCA scores of the experimental group at T2 (post-intervention) and T3 (3-month follow-up) were higher than those of the control group, and the difference was statistically significant (p-value<0.001).

S.D.=standard deviation, Ex group=experimental group, Co group=control group, MMSE=mini-mental state examination, MoCA=montreal cognitive assessment, CCT=.computerized cognitive training, APP=application

published studies and grey literature: theses, dissertations, and conference proceedings[25]. A detailed appraisal of the study methodology quality is reported in Table 2. No significant publication bias was observed, as indicated by the symmetry in the funnel plot—a visual examination in Figure 2.

Meta-analysis

The meta-analysis results are summarized before and after removing the outlier in Table 3 and illustrated after removing the outlier in the forest plot (Figure 3). The overall effect size for the eight studies, including an outlier, was SMD=0.04 (95.0% CI: -0.21-0.29), with very high heterogeneity (I^2=89.0%). In terms of a heterogeneous study, one study was removed as the outlier[12] because of a significant difference in the intervention characteristics (e.g., type, duration, and length of the intervention). To consider the heterogeneity, a leave-one-out forest plot was used to provide a sensitivity analysis and to justify exclusion transparently. After removing the outlier, the overall effect size increased to SMD=0.23 (95.0% CI: 0.06-0.40), with considerably high heterogeneity (I^2=76.0%). Because of various TNC interventions, the random effect model was utilized for the subgroup analyses. Subgroup analyses revealed that single technology-assisted TNC interventions (e.g., a technological approach) (n=4) yielded an effect size of SMD=0.32 (95.0% CI: -0.05-0.70) with high heterogeneity (I^2=78.0%), whereas combined TNC interventions (e.g., combining educational intervention with technology) (n=5) showed an effect size of SMD=0.31 (95.0% CI: 0.09-0.54) with low heterogeneity (I^2=36.0%). Likewise, the random effect model was used for subgroup analyses because the MMSE and MoCA were employed in various TNC interventions. When considering cognitive assessment tools, studies using the MMSE outcomes (n=6) showed an effect size of SMD=0.08 (95.0% CI: -0.24-0.39), with high heterogeneity (I^2=75.0%), while those using the MoCA (n=5) demonstrated an effect size of SMD=0.23 (95.0% CI: -0.28-0.74) with high heterogeneity (I^2= 88.0%). Notably, the overall effect of TNC interventions without the

Table 2 Summary of the risk of bias for RCTs

Study ID	The Cochrane Collaboration's tool for assessing risk of bias for RCT studies: Low/High/Unclear risk of bias							
	1	2	3	4	5	6	7	8
Bevilacqua et al., 2023	L	U	U	U	L	L	L	H
Jeong et al., 2016	L	H	L	H	L	L	L	H
Kwan et al., 2024	L	L	U	L	L	L	L	L
Lu & Mao, 2021	L	U	U	U	L	L	L	H
Luo et al., 2023	L	L	L	L	L	L	L	L
Park, Jung, & Lee, 2021	L	L	U	L	L	U	L	L
Sung et al., 2023	L	L	U	L	L	L	L	L
Wen et al., 2024	U	L	U	L	L	L	L	L

L=low risk of bias, H=high risk of bias, and U=unclear risk of bias, 1. Random sequence generation (selection bias), 2. Allocation concealment (selection bias), 3 Blinding of participants and personnel (performance bias), 4. Blinding of outcome assessment (detection bias), 5. Incomplete outcomes (attrition bias), 6. Selective reporting (reporting bias), 7. Other bias, 8. Authors' judgment

Table 3 Summary results of the meta–analysis and subgroup analysis for before and after removing the outlier

Meta–analyses	Subgroup categorization	Number of studies (number of interventions)	Number of subjects	SMD	95% CI (SMD)	Z	df	p–value	I^2
Overall analysis	Before removing the outlier								
	All TNC intervention vs. Usual control	8 (22)	2,574	0.04	(0.06–0.40)	0.31	21	0.76	89
	After removing the outlier All TNC intervention vs. Usual control	7 (20)	2,430	0.23	(0.06–0.40)	2.61	19	0.009	76
Subgroup analysis: TNC Interventions	Before removing the outlier								
	Single intervention	4 (4)	619	0.32	(–0.05–0.70)	1.68	3	0.09	78
	Combined intervention	6 (6)	578	–0.05	(–0.68–0.58)	0.16	5	0.87	92
	After removing the outlier	4 (4)	619	0.32	(–0.05–0.70)	1.68	3	0.09	78
	Single intervention	5 (5)	506	0.31	(0.09–0.54)	2.71	4	0.009	36
	Combined intervention								
Subgroup analysis: Cognitive outcomes	Before removing the outlier								
	MMSE	6 (7)	743	–0.21	(–0.73–0.31)	0.08	6	0.43	91
	MoCA	5 (5)	634	0.23	(–0.28–0.74)	0.89	4	0.37	88
	After removing the outlier								
	MMSE	5 (6)	671	0.08	(–0.24–0.39)	0.48	5	0.37	75
	MoCA	5 (5)	634	0.23	(–0.28–0.74)	0.89	4	0.37	88

SMD=standardized mean differences, MMSE=mini–mental state examination, MoCA=montreal cognitive assessment, TNC=technology–assisted nurse–led cognitive, 95% CI=95% confidence interval, Z=Z–scroe, I^2=I–squared

Study or Subgroup	Nurse led intervention Mean	SD	Total	Usual care Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI	Risk of Bias A B C D E F G
1.1.1 MMSE									
Jeong et al., 2016-A	25.6	1.8	71	25	1.8	76	5.5%	0.33 [0.01, 0.66]	+ − + − + + +
Jeong et al., 2016-B	25.2	2	77	25	1.8	76	5.5%	0.10 [-0.21, 0.42]	+ − + − + + +
Lu & Mao, 2021 -A	23.05	3.2	45	25.23	2.8	45	4.8%	-0.72 [-1.15, -0.29]	+ ? ? ? + + +
Luo et al., 2023-A	27.9	1.8	38	26.7	2.5	35	4.5%	0.55 [0.08, 1.02]	+ + + + + + +
Park et al., 2021	26.6	3.3	45	26	4.1	45	4.9%	0.16 [-0.25, 0.57]	+ + ? + + ? +
Wen et al., 2024-A	23.22	3.831	37	23.15	4.061	81	5.0%	0.02 [-0.37, 0.41]	? + ? + + + +
Subtotal (95% CI)			**313**			**358**	**30.2%**	**0.08 [-0.24, 0.39]**	
Heterogeneity: Tau² = 0.11; Chi² = 19.84, df = 5 (P = 0.001); I² = 75%									
Test for overall effect: Z = 0.48 (P = 0.63)									
1.1.2 MoCA									
Bevilacqua et al., 2023	25.1	2.5	33	25.1	1.9	27	4.2%	0.00 [-0.51, 0.51]	+ ? ? ? + + +
Kwan et al, 2024	22.1	3.2987	146	21.54	3.6252	147	6.1%	0.16 [-0.07, 0.39]	+ + ? + + + +
Lu & Mao, 2021-B	24.08	2.89	45	26.05	3.05	45	4.8%	-0.66 [-1.08, -0.23]	+ ? ? ? + + +
Luo et al., 2023-B	24.8	2.7	38	22.9	2.9	35	4.5%	0.67 [0.20, 1.14]	+ + + + + + +
Wen et al., 2024-B	21.95	3.064	37	18.14	4.203	81	4.9%	0.97 [0.57, 1.38]	? + ? + + + +
Subtotal (95% CI)			**299**			**335**	**24.5%**	**0.23 [-0.28, 0.74]**	
Heterogeneity: Tau² = 0.29; Chi² = 33.94, df = 4 (P < 0.00001); I² = 88%									
Test for overall effect: Z = 0.89 (P = 0.37)									
1.1.3 Sigle intervention									
Kwan et al, 2024	22.1	3.2987	146	21.54	2.7765	147	6.1%	0.18 [-0.05, 0.41]	+ + ? + + + +
Park et al., 2021	26.6	3.3	45	26	4.1	45	4.9%	0.16 [-0.25, 0.57]	+ + ? + + ? +
Wen et al., 2024-A	23.22	3.831	37	23.15	4.062	81	5.0%	0.02 [-0.37, 0.41]	? + ? + + + +
Wen et al., 2024-B	21.95	3.064	37	18.14	4.203	81	4.9%	0.97 [0.57, 1.38]	? + ? + + + +
Subtotal (95% CI)			**265**			**354**	**20.9%**	**0.32 [-0.05, 0.70]**	
Heterogeneity: Tau² = 0.11; Chi² = 13.83, df = 3 (P = 0.003); I² = 78%									
Test for overall effect: Z = 1.68 (P = 0.09)									
1.1.4 Combined intervention									
Bevilacqua et al., 2023	25.1	2.5	33	25.1	1.9	27	4.2%	0.00 [-0.51, 0.51]	+ ? ? ? + + +
Jeong et al., 2016-A	25.6	1.8	71	25	1.8	76	5.5%	0.33 [0.01, 0.66]	+ − + − + + +
Jeong et al., 2016-B	25.2	2	77	25	1.8	76	5.5%	0.10 [-0.21, 0.42]	+ − + − + + +
Luo et al., 2023-A	27.9	1.8	38	26.7	2.5	35	4.5%	0.55 [0.08, 1.02]	+ + + + + + +
Luo et al., 2023-B	24.8	2.7	38	22.9	2.9	35	4.5%	0.67 [0.20, 1.14]	+ + + + + + +
Subtotal (95% CI)			**257**			**249**	**24.3%**	**0.31 [0.09, 0.54]**	
Heterogeneity: Tau² = 0.02; Chi² = 6.29, df = 4 (P = 0.18); I² = 36%									
Test for overall effect: Z = 2.71 (P = 0.007)									
Total (95% CI)			**1134**			**1296**	**100.0%**	**0.23 [0.06, 0.40]**	
Heterogeneity: Tau² = 0.11; Chi² = 77.85, df = 19 (P < 0.00001); I² = 76%									
Test for overall effect: Z = 2.61 (P = 0.009)									
Test for subgroup differences: Chi² = 1.65, df = 3 (P = 0.65), I² = 0%									

-2 -1 0 1 2
Usual care] Nurse led intervention

Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Figure 3 Forest plots of subgroup analysis after excluding heterogeneous studies

outlier was statistically significant (Z=2.61, p-value=0.01), whereas the effect with the outlier was not statistically significant (Z=0.31, p-value=0.08).

Subgroup analyses

Because of the variety of types of TNC interventions with technology approaches, such as single TNC interventions (e.g., virtual reality therapy, robotic approach, or computer cognitive training)[10-11,32] and combined TNC interventions (e.g., psychoeducational intervention with specific training course application on smartphones or tablets)[16,29-31], the potential moderators of this study were identified a priori based on theoretical frameworks and evidence from prior systematic reviews (e.g., intervention characteristics and delivery format). Therefore, only two variables with sufficient data across the primary studies were analyzed: the type of intervention (single intervention vs combined intervention) and cognitive tools (MMSE vs MoCA). Subgroup analysis indicated that combined TNC interventions significantly improved cognitive function among older adults with MCI (Z=2.71, p-value=0.01). However, single interventions did not reach any significance of improvement (Z=1.68, p-value=0.09). In addition, analyses of TNC interventions without the outlier using MMSE and MoCA did not reach statistical significance (Z=0.48, p-value=0.63 and Z=0.89, p-value=0.37, respectively).

Discussion

This systematic review and meta-analysis evaluated the efficacy of TNC interventions in improving cognitive function among older adults with MCI. Even though the effect sizes of this study were small and accompanied by substantial heterogeneity across the studies, the findings demonstrated that TCN interventions may be related to improvements in cognitive outcomes. Nurses using technology strategies can effectively educate older adults with cognitive impairment because technology may foster communication between users (patients, caregivers, and nurses)[33]. Additionally, nurses using technology support can promote cognitive function and positive behavior change for older adults with MCI, leading to an increase in people's QoL[34].

Moreover, our pooled analysis aligned with prior research, indicating that technology-assisted interventions improve cognitive outcomes (e.g., memory, language, attention, or executive functions) in older adults with MCI[15]. The analysis revealed a modest overall effect size with significant heterogeneity across studies. Although our findings suggest that TNC interventions confer cognitive benefits compared to standard care, they may not be representative of technology-assisted cognitive interventions because of 1) the small overall effect size (SMD=0.23) and 2) confidence intervals crossing zero in some subgroups, leading to the high heterogeneity of this study.

In terms of intervention characteristics, two distinct intervention modalities emerged: single technology-based interventions and combined technology-based interventions. Single-technology approaches—employing mobile applications, virtual reality, and robotic rehabilitation—demonstrated improvements in memory, attention, and problem-solving skills[10-11,32]. Notably, some studies reported delayed cognitive decline after approximately six months of intervention, yet the lack of personalization inherent in these approaches may constrain their broader applicability[12,32].

In contrast, combined TNC interventions, which integrate physical, educational, cognitive, and social elements, offer a more comprehensive strategy for mitigating cognitive decline. Evidence from multidomain intervention studies, such as cognitive-based games and exercise training, suggests that combined approaches are more effective in slowing cognitive impairment progression[35-36]. Nonetheless, standardizing the combined interventions remains challenging, and future research should aim to determine the optimal balance between intervention components and patient characteristics.

For a type of cognitive measurement, assessing cognitive outcomes in this population is further complicated using diverse neuropsychological instruments. Patients with cognitive impairment are screened by using Petersen's criteria: 1) not demented, 2) memory complaint, 3) preserved general cognitive function, 4) intact activities of daily life, and 5) impaired memory for age and education[37]. However, the diagnosis of patients with MCI needs to use Petersen's criteria and cognitive tools to identify and accurately diagnose patients with MCI early. The MMSE has traditionally been the most widely used screening tool for orientation, memory, attention, language, and visuospatial skills, and a cutoff score of 24 is reported for normal cognition[38]. However, its diagnostic sensitivity is limited, particularly among older adults, individuals at the extremes of age, and those with lower educational attainment[39]. The MoCA has developed with superior sensitivity and diagnosis to detect subtle cognitive deficits in MCI[40], with the added advantage of education-based score adjustments. However, it is difficult to say that MoCA is more effective than MMSE because MoCA includes abstraction, trail-making, and verbal fluency tasks that may be more sensitive to the education level of older adults with MCI. Therefore, MMSE may offer strong reliability, but it may poorly detect subtle executive and visuospatial deficits, whereas MoCA includes higher-order tasks and shows better sensitivity to MCI, while with slightly lower specificity in low-education groups.

The findings reported that almost all TCN interventions were conducted in Asian countries, and we considered that the cultural influences may substantially shape and potentially impact the development of TCN interventions for older adults with MCI, such as intervention characteristics (e.g., type, format, dose, and delivery) and outcomes[10]. The health beliefs of aging populations in Asian societies are concerned about applying digital training to reduce cognitive challenges among older adults with MCI[13]. Significantly, respect for older adults and family-centered caregiving form how older adults with MCI access and adhere to new technologies or strategies with feasible and sustainable support. As a result, the number of TCN interventions of the Asian region is expected to increase, addressing cognitive outcomes among older adults with MCI. For risk of bias, three studies of this review showed a high risk of bias, such as performance bias, detection bias, and poor allocation concealment, leading to a reduction in the internal validity of the study[23]. Consequently, the effect size of this review may increase the overestimation or underestimation of the treatment effect as well.

In summary, while TNC interventions promise to improve cognitive function in older adults with MCI, the current evidence is constrained by methodological heterogeneity and small sample sizes. Future rigorously designed RCTs should control for education levels, digital literacy, or intervention dose, and combined approaches, using sensitive, more standardized cognitive assessment tools to clarify their long-term efficacy and clinical utility.

Strengths and limitations

This review demonstrated that the effectiveness of technology-assisted cognitive interventions delivered by nurses can improve cognitive impairment in older adults with MCI. In particular, nurse-led combined interventions using technology strategies improved cognition in people with MCI more effectively than nurse-led single interventions. However, the limitations of this study include the small number of eligible studies with heterogeneity, particularly in the subgroup analyses. Second, this systematic review and meta-analysis included only English-language studies published in peer-reviewed journals, which may have restricted the diversity of the included studies. Third, most of the available TNC studies were conducted in Asian countries, while only one study was conducted in a Western country. Therefore, the findings lack diversity in population characteristics, potentially limiting generalizability regarding which groups might benefit most from the interventions.

Conclusion

TNC interventions should be implemented to improve cognitive function in older adults with MCI. Findings from this review suggest that TNC interventions should be delivered as a combined intervention, while TNC interventions using MMSE and MoCA showed no significant difference. Future nursing interventions using a technology-assisted approach should consider intervention characteristics (e.g., type, dosage, and length of interventions) and use cognitive assessment tools to ensure optimal delivery and a more reliable evaluation of cognitive performance in this population. Even though TNC interventions demonstrate potential for improving cognitive outcomes, applying TNC interventions into routine practice may require the careful consideration of feasibility and sustainability, including limited digital literacy among older adults with MCI, inconsistency in team training, and expenditure of hardware and software devices as well.

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Author's contribution statement

All authors contributed significantly, including 1) PP contributed to the study's conception and design, data acquisition, and data analysis, and wrote the first draft of the manuscript; 2) RK contributed to the study's conception and design, data acquisition, and data analysis, revised the final draft, and gave final approval of the version before submission; 3) YL contributed to conducting data analysis; 4) RG contributed to conducting search strategies; and 5) PB contributed to editing the final draft.

Conflict of interest

There are no conflicts of interest in connection with this article.

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