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Prevention of Dementia Through Physical Exercise and Cognitive Training: A Narrative Review

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ABSTRACT

Background: Dementia reduces the ability to live independently, thus deteriorating the patient's quality of life and caregivers' mental health. Consequently, dementia indirectly affects economic and social growth. Dementia is also a major contributor to death worldwide. There is no effective treatment for dementia, but preventing physical and cognitive inactivity among the elderly could help. Studies show that the risk of dementia increases in the elderly with mild cognitive impairment (MCI).
Methods: This review set out to compare the effects of physical exercise (PE) and cognitive training (CT) on cognitive performance among the elderly with MCI, by examining the evidence from published literature between 2013-2023. Four major electronic databases were used to search the relevant studies, resulting in 2782 articles. A total of fourteen articles were included in the review.
Results: The findings showed that interventions with naturally combined cognitive and physical training not only improved cognitive performance, but also prevented the elderly from stress and fatigue. Integrating physical exercise and cognitive training interventions with the best combination method is crucial to ensure participant adherence. Therefore, the intervention can be incorporated effectively into healthcare policies and programs to support cognitive health in aging populations.
Conclusion: Future studies should also explore the optimal duration of training sessions to maximise cognitive benefits and ensure participant adherence and motivation.

Keywords: Physical exercise; Cognitive training; Mild cognitive impairment; Elderly; Dementia

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INTRODUCTION

Word Health Organization (WHO) defines dementia as a clinical disorder in which cognitive function and functional capability deteriorate progressively beyond what might be expected from normal ageing (1). The cognitive impairment includes memory, thinking, judgement, language and orientation. People with dementia usually experience mood, emotional control, behaviour, and motivation changes (1). WHO found that 60-70% of dementia cases owing to Alzheimer's disease (1). Further, an analysis of the Global Burden Study in 2019 forecasted that the cases of dementia will rise to 152.8 million in 2050, compared to only 57.4 million in 2019 (2). Approximately a trillion US dollars are invested yearly for dementia treatment at the global level, and it is estimated to double by 2030 (3). In Malaysia, the statistics of dementia sufferers are predicted to be 261,000 by 2030 and will further increase to 590,000 by 2050 (4). The mean cost of dementia treatment reported in 2017 was RM 12,806 per episode of care during hospitalization (5). 62.78% of the total cost was from ward services, 10.25% from the pharmacy and 7.64% from the Intensive Care Unit (5). This significant impact of medical costs on the economic sector highlights the need for public health planning efforts to address the dementia issue.

Dementia is a significant contributory factor to the disability among elderly aged 80 in Malaysia (6). A study found that the capability to carry out instrumental activities of daily living (IADL), such as doing house chores, using the telephone, and preparing meals and laundry, is correlated with memory and executive function (7). These subdomains of cognitive function also significantly predicted performance in the ability to buy things, use transport, and manage money and medication (7). Therefore, people with dementia who are cognitively impaired may have problems performing IADL independently, thus leading to negative impacts on caregivers' physical, psychological and quality of life (8). The caregivers are called 'informal carers', who must act like 24-hour live-in nurses to their dependent parents, husbands or wives (3). They spend about 5 hours per day (9) and 82 billion hours per year providing care for their loved ones (3). 71% of these hours are supplied by women (3). This situation can be overwhelming and cause great stress to the caregivers. Ganapathy et al. (10) demonstrated that the quality of life in dementia caregivers was significantly poorer than caregivers of people without dementia. If dementia is left untreated, it has the potential to be a serious impediment to social and economic development (9).

Mild cognitive impairment (MCI) is a transition state between normal ageing and dementia (11). Some studies have shown that the conversion rate among elderly with MCI to dementia is about 10% to 15% every year (12–14), increasing to 80-90% after about six years (12,15). The rate is considered very high compared to the 1-2% rate per year among the general population (16). Nonetheless, few studies supported that MCI can be reverted to normal cognitive functioning at subsequent follow-up with a 30%-50% conversion rate (17,18). There has been an increasing amount of literature on non-pharmacological approaches. For example, physical exercise (PE) and cognitive interventions (CT) have been widely implemented to reduce the risk of dementia among the elderly with MCI. Much of the early work in the field was undertaken on a single approach, either PE or CT interventions. Then, more recent attention has focused on combining PE and CT interventions to explore their synergetic effects on cognitive performance.

Even though there are prior reviews that have explored the effectiveness of PE and CT, however, to our knowledge, those reviews are heterogeneous in their sample characteristics where they included studies that mixed people with dementia, Alzheimer's, and Parkinson's disease, while some included healthy subjects. Studies that focus on the elderly with MCI are lacking in previous literature. Further, Untari et al. (14) highlighted the crucial components of effective training, i.e., duration, frequency, intervention and type still need to be determined. Thus, this paper reviewed the studies that are relevant to the effectiveness of PE and CT to improve the cognitive performance of the elderly with MCI. This review also aimed to gain a better understanding of the training effects based on duration and frequency.

METHOD

Design and Search Strategy

Relevant articles were sought online through four electronic databases such as Scopus, PUBMED, ScienceDirect, and EBSCO. This search strategy was carried out via several databases by using keyword terms: ("elderly" OR "older adult") ("physical exercise" OR "physical activity") AND ("cognitive training" OR "memory training") AND ("elderly" OR "older adult") AND ("mild cognitive impairment" or "MCI").

Inclusion and Exclusion Criteria

The following inclusion criteria are implemented: (a) experimental studies (randomized controlled trial (RCT) or quasi-experimental), (b) PE and CT (performed either single or simultaneously or sequentially), and (c) cognitive function as an outcome variable. Meanwhile, the exclusion criteria include (1) articles that involved healthy subjects or other than MCI; (2) conference papers and dissertations; (3) non-English papers; and (4) studies published as only abstracts and without full text **(Figure 1).**

Reporting of The Findings

From the selected papers, the following information was extracted: name of the author; year of publication; country, study design; study sample; type of intervention; duration and frequency of the training and results (cognitive performance) **(Table 1).**

RESULTS

The search process resulted in the identification of 2782 articles from the database. The duplicates and any paper that failed to meet the inclusion criteria were removed. Fourteen papers were finalized to be included in this review. The included studies consisted of eleven randomized controlled trials (11,19–28) and three quasi-experimental studies (29–31). All the studies included participants with MCI. The interventions were conducted in Croatia (22), Spain (19,20), China (23,25,28,31), South Korea (11,24,27,29,30), Slovakia (21) and Thailand (26).

There are four studies included PE (11,19,20,22) and four studies conducted CT (23,25,27,29). Another three studies combined cognitive-physical exercise intervention with widely varying intervention components (21,24,30). One study combined PE and CT using a sequential design (21), in which the interventions were provided in separate sessions. Examples of sequential training include walking over obstacles, followed by computerized cognitive training (CCT). Two studies (24,30) used a simultaneous design, such as exercising using an elastic band exercise while counting numbers.

The remaining three studies conducted mind-body exercises such as tai chi and dance (20,27,31). Intervention duration ranged from 6 weeks to 6 months, while the frequency of interventions ranged from one to five sessions per week. Only one study reported that the intervention was conducted every two weeks (26). For each session, the duration ranged from 30 minutes to 160 minutes. **Table 1** depicts the details description of the selected studies.

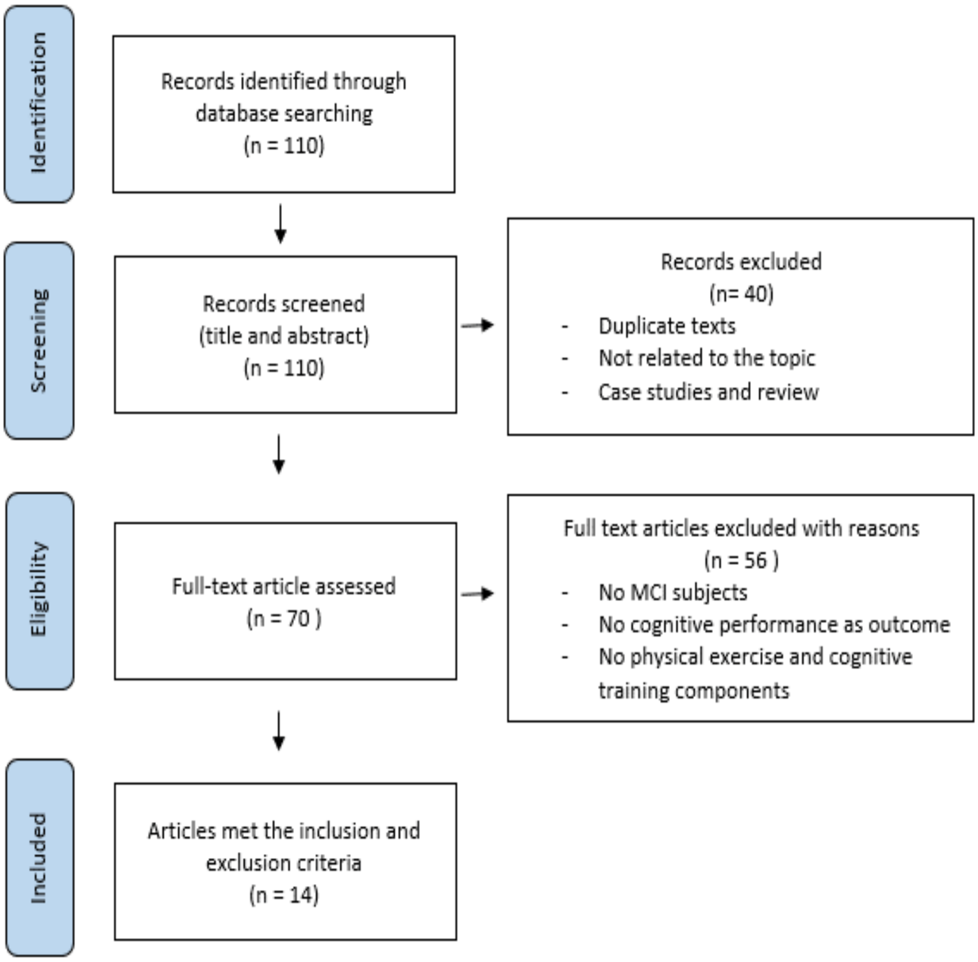
Type of Interventions and Their Effects On Cognitive Performance

Physical Exercise (PE)

A study was conducted in Europe for eight weeks to determine the effects of two types of non-aerobic training on cognitive functions in the elderly with MCI (23). The first group utilized a novel feedback-based balance and core resistance training device called HUBER, which simultaneously captured balance and strength in the MCI elderly. Another group carried out Pilates training, which focused on keeping a neutral posture and stable core in different gravity orientations. After eight weeks, both groups showed significant improvements in the overall global cognitive score, language and abstraction cognitive domains. Moreover, the HUBER group improved in executive functions and orientation domains, while the Pilates group significantly improved in the delayed recall domain (23).

Another study was done in Korea to study the effects of 12-week resistance exercise on cognitive function (11). A total of 47 MCI elderly were divided into intervention and

Figure 1: PRISMA flow diagram for search, refining, and selections process



control groups. The control group was asked to maintain their usual routine while the intervention group conducted resistance exercises for 1 hour per session with an elastic band. As a result, the digit span backwards (DB) test for working memory was significantly decreased in the control group, while cognitive function in the intervention group remained stable (11). There are some similarities between this work and a study in Spain, which compared two types of PE intervention in the same duration, which is 12 weeks (20). Cardalda et al. (20) compared strength-based (TG), and multi-callisthenics (MG) exercises in the elderly with MCI and added a comparative control group that did not perform any PE. The results showed that the TG group improved by 13.4% in MMSE score. Even though no significant changes were found in any cognitive test regarding the MG group, the results showed a tendency towards stabilizing cognitive parameters. In contrast, the control group demonstrated a deterioration in cognitive performance with 34.9% significant differences between the other two groups (21).

In Italy, a study was done to compare the cognitive effects of choreographed exercise (CG) and multimodal physical therapy (MPT) in the elderly with amnestic MCI (19). The choreography included aerobic dance, while physical therapy included strength, flexibility, balance, and gait training. The results showed that the memory domain significantly improved in the CG group compared to the MPT group. Category verbal fluency (CVF), commonly used to assess the integrity of semantic memory, improved significantly in the MPT group. This study suggests that participation in regular aerobic exercises can also improve cognitive function in the elderly with MCI (19).

Table 1: Characteristics of the studies

Author and year	Country	Study design	Study sample	Intervention	Duration and frequency of training	Results
1. Jurakic et al. (2017)	Croatia	Pilot RCT	28 elderly with MCI (average age: 72.88)	Core resistance + balance training (HUBER) & Pilates training	8 weeks. 3x/week (60mins).	HUBER group: Visuospatial/executive functions and orientation improved. Pilates group: Delayed recall domain improved.
2. Hong et al. (2018)	South Korea	RCT	47 elderly with MCI (average age: 78.33)	Resistance exercises & Control (current lifestyle)	12 weeks. 2x/week (60mins).	Exercise group: Digit span backwards (DB) test remained significant. Control group: DB test for working memory was significantly decreased.
3. Cardalda et al. (2019)	Spain	RCT	77 elderly with MCI (average age: 84.8)	Strength-based (TG), Multi-Callisthenics (MG) & Control (no exercise)	12 weeks. 2x/week (60mins).	TG group improved by 13.4% in Mini-Mental State Examination (MMSE) score, but no change was found in the MG group. 34.9% score deteriorated in the Control group.
4. Bisbe et al. (2020)	Spain	RCT	36 elderly with aMCI (average age: 72.88)	Choreography (CG): Aerobic dance & Physical Therapy (MPT): Strength, Flexibility, Balance, Gait Training,	12 weeks. 2x/week (60mins).	Choreography: Significant benefits found in memory compared to Physical Therapy, p=0.003. Physical Therapy: Verbal fluency score improved significantly, p=0.013.
5. Kim & Shim (2018)	South Korea	Quasi-experimental	48 elderly with MCI (average age: 76.33)	Cognitive therapy	12 weeks. 1x/week (90mins).	All cognitive assessments significantly improved ($p < 0.05$) except in Constructional Praxis ($p = 0.078$).
6. Peng et al. (2019)	China	RCT	140 elderly with MCI (average age: 68.99)	CT & Control (no training)	6 months. Every 2 weeks (90mins).	After 3 months, CT: 23.73% improved to normal levels. 0.00% progressed to dementia. Control group: 1.59% improved to normal levels. 1.59% progressed to dementia. After 6 months, CT: 31.48% improved to normal levels. 0.00% progressed to dementia. Control group: 1.69% improved to normal

						levels. 5.08% progressed to dementia.
7. Li et al. (2019)	China	Pilot RCT	141 elderly with MCI (average age: 69.5)	CCT at patients' homes online & Control (usual care)	6 months. 3-4x/week (120-160mins).	After 6 months, MMSE improved by 0.23 SD in the CCT group and −0.5 SD in the control group. Addenbrooke's cognitive examination-revised (ACER)'s significant training effects were also found in attention and memory, symbol digit substitution test (SCWT) interference index, and shape trail test (CFT) copy.
8. Thapa et al. (2020)	South Korea	RCT	68 elderly with MCI (average age: 72.6)	VR-based cognitive & Control (educational program)	8 weeks. 3x/week (100mins).	TMT B time decreased significantly in the intervention group (p = 0.03). Executive function significantly improved, but not in MMSE and SDST.
9. Kim et al. (2021)	South Korea	Pilot quasi-experimental	9 elderly with MCI (average age: 71.33)	Fairy tales cognitive-physical dual-task training	12 weeks. 1x/week. (60-90mins).	The Montreal Cognitive Assessment (MoCA) and memory self-efficacy scores were significantly increased from baseline scores after the 12 weeks of follow-up.
10. Hagovska & Nagyova (2017)	Slovakia	RCT	80 elderly with MCI (average age: 68.22)	Experimental group (CogniPlus + physical training) & Control (physical training)	10 weeks. 2x/week. (30-60mins).	After 10 weeks, the CogniPlus group showed significant improvement in essential cognitive functions, memory, and attention, especially in fewer errors in all tests and visual-motoric coordination compared with physical training alone.
11. Park et al. (2020)	South Korea	RCT	40 elderly with MCI (average age: 75.8)	Virtual reality-based cognitive-motor rehabilitation (VRCMR) & conventional cognitive rehabilitation (CCR)	6 weeks. 5x/week. (30 mins).	The VRCMR group showed significantly better MoCA, Trail Making Test A and B (TMT-A/B), and Digit Span Test (DST)-forward scores compared to the CCR group, but not in the DST-backward score.

12. Sungkarat et al. (2017)	Thailand	RCT	66 elderly with MCI (average age: 68.3)	Tai Chi & Control (educational material)	12 weeks. 3x/week (50mins).	When adjusting for baseline scores, memory delayed recall, visuospatial ability, and executive function scores were significantly better in the Tai Chi group than the control group (P < .05). It was also found that home-based training for the elderly with multiple-domain a-MCI is feasible to implement.
13. Zhao et al. (2021)	China	Pilot quasi-experimental	107 elderly with MCI (average age: 72.29)	Square dance & Control (health education)	12 weeks. 3x/week (60 mins).	After 3 months, the results revealed a statistically significant difference in the MoCA scores of participants in the dance group before and after the intervention.
14. Zhu et al. (2018)	China	RCT	60 elderly with MCI (average age: 69.6)	Usual care + Dance routine & Control (usual care)	12 weeks. 3x/week (35 mins).	The study found that elderly with MCI who carried out a specially designed aerobic dance routine for 3 months significantly improved memory, processing speed, and cognitive function. After 6 months, the experimental group still showed a more remarkable improvement in processing speed.

Cognitive Training (CT)

A large body of work is also considering CT to improve targeted cognitive functions. A pre and post-test quasi-experimental study was conducted in Korea to study the effect of a group cognitive program on cognitive performance among the elderly with MCI (29). The intervention group received cognitive therapy for 90 minutes weekly for three months. Statistically significant improvements were found in the Verbal Fluency Test, the Modified Boston Naming Test, the Korean Version of the Mini-Mental State Examination, and the Word List Memory and Word List Delayed Recall tests ($p < 0.05$). The researcher claimed that the participants' cognitive performance changes were meaningful (29).

Furthermore, a study was to examine the efficacy of CT in 140 elderly with MCI in China (26). The subjects were divided into an intervention group involving CT and a control group with no training. The CT intervention included six months of memory, attention, and calculation training. The intervention group showed significant improvement in participants' cognitive function after three months, with some reaching normal levels (23.73%), while none progressed to dementia (0.00%). After six months, the intervention group also showed improvement, with some reaching normal levels (31.48%), while only one (1.69%) control group participant improved to normal and three (5.08%) progressed to dementia (26).

Conceptually similar work has also been carried out in China (24). A group of MCI elderly carried out CCT was compared with a control group without training. After six months of follow-up, the intervention group improved 0.23 standard deviation (SD) of MMSE, while the control group had a 0.5 SD decline. Addenbrooke's cognitive examination-revised attention, memory, Stroop colour-word test interference index, and complex figure test-copy score also favoured the training effect (24). CCT has been used widely as an alternative to traditional CT due to the evolution of information and communication technology (ICT). Only a few studies still opted for pencil-and-paper-based exercises.

In Korea, other techniques using virtual reality (VR) games were used as CT (28). The study found that Trail Making Test B time decreased significantly in the intervention group compared to the control group, which improved working memory. Small but insignificant positive changes were also observed in the MMSE and symbol digit substitution test (SDST). The results indicated that although the global cognitive function did not change significantly, significant improvement in executive function was observed after eight weeks of VR game intervention (28). However, most studies do not attempt to differentiate between the feasibility of conventional and modern approaches. It is vital to investigate the feasibility because some of the elderly might not be familiar with the advanced technology.

Synergistic Effects of Combined Training

Despite all these positive effects of single PE and CT on cognitive performance, few studies (22,25,30) have attempted to compare the effects between combined intervention and single intervention. Hagovska & Nagyova (21) conducted a randomized controlled trial to study the transfer of skills from CT and PE to activities of daily living in the elderly with MCI. The control and intervention groups received PE as a foundation to which CT (CogniPlus) was added in the intervention group. The study found that the intervention group, which included CT (CogniPlus), showed significant improvement in cognitive functions, memory, and attention after ten weeks, particularly in reducing errors and improving visual-motoric coordination, and transferring these improvements to daily living activities compared to PE alone (22).

Further, a quasi-experimental study by Kim et al. confirmed that cognitive-physical dual-task training based on fairy tales significantly increased global cognitive function scores and memory self-efficacy after three months compared to the control group (30). Park et al. (24) compared two groups of MCI elderly in a virtual reality-based cognitive-motor rehabilitation (VRCMR) and conventional cognitive rehabilitation (CCR) setting. The VRCMR group used MOTOcog, a computer recognition program which requires some movement, while the CCR group used traditional cognitive rehabilitation methods like puzzles, woodblocks, and card play. The study results suggested that VRCMR improved cognitive function, including memory and attention, in the elderly with MCI more than CCR. However, the researcher suggested that if the CCR is combined with PE, it brings comparable benefits to cognitive function as VRCMR (25).

The Potential of Other Cognitively Engaging Exercises in Improving Cognitive Performance

In a randomized controlled study of Tai Chi, it was demonstrated that elderly with MCI in Thailand who attended Tai Chi programs improved memory delayed recall after 12 weeks (32). The intervention was held for three weeks at the community center. Then, the participants were asked to practice Tai Chi at home three times per week for 12 weeks. Besides improving memory, the study also revealed that it is feasible to implement home-based training for the elderly with MCI. Moreover, the effects of nurse-led square dancing on the elderly with MCI were studied (31). The control group received health education, while the intervention group performed square dance thrice per week for 60 minutes per session. After three months, the results revealed a statistically significant difference in the global cognitive function scores of participants in the dance group before and after the intervention (31). In addition, elderly with MCI who carried out a specially designed aerobic dance routine for three months significantly improved global cognitive function, memory, and processing speed (20). After six months, the intervention group showed a more remarkable improvement in processing speed (20).

DISCUSSION

Overall, there seems to be evidence that the most pronounced effects appear to arise from exercise that combines PE and CT compared to

PE or CT alone. According to Park et al. (24), the combined interventions are efficacious for promoting cognitive alongside physical health in the elderly and, therefore, should be preferred over the implementation of single-domain training on MCI patients. Some researchers suggested that superior cognitive benefits may be gained from the naturally or simultaneously combined PE and CT, for example, dance and tai-chi (32,33). The cognitive benefits of tai chi have been proven in past research (26), while the cognitive benefits of dance were found in three studies (28,31,34). Additionally, there is a previous study suggested that naturally or simultaneously combined training may positively affect training enjoyment (35). For example, the dance intervention is enjoyable and would promote high adherence among the elderly (28,34). It was stated that " fun " elements are considered the most vital factor in boosting motivation and engagement among the elderly (36). Compared with sequential or separated training, previous study found that the sequential design generally requires high-frequency training as the training may induce stress and fatigue reactions that counteract training effects (35). This is exemplified in the work undertaken by previous study (35). Participants were required to complete 30 minutes of balance training, followed by 30 minutes of cognitive sub-programs.

The previous studies also highlight that high frequency, duration and length of the training are not required. Such elements should be considered when prescribing exercise as a routine for the elderly with MCI to benefit cognitive performance. In this review, four studies (21,22,24,27) conducted the intervention less than 12 weeks were found to be effective in improving cognitive performance same as studies that were conducted in a longer period. In terms of duration, the presented studies were conducted the sessions ranged from 30 minutes to 160 minutes. Previous study found that short (≤ 45 min) and medium-duration (> 45 to ≤60 min) sessions had significant effect sizes compared to studies with longer durations (> 60 min), with effect sizes being smaller for the highest frequency of delivery (32). This study also revealed that longer sessions had no statistically significant effect sizes (32).

The findings are similar to a study which reported that interventions with the lowest volumes (40-45 min per week) presented better results on cognitive function in elderly with cognitive impairment (33). The effectiveness of the short-duration technique has been exemplified in a previous report which conducted a specially designed aerobic dance for 30 minutes per session (28). Even though the participants had discontinued the routine after 6 months, the intervention group still showed a more remarkable improvement in cognitive performance. High doses (frequent intervention, extended intervention, and long session duration) are not necessary for greater efficacy (32). Although there was no significant difference in effect size between intervention sessions delivered once a week, twice a week, or three or more times a week, effect sizes were on average smaller at the highest frequency of delivery (32).

CONCLUSION

PE and CT have been widely studied as risk-reduction strategies for dementia. Both single and combined modes of intervention delivered either simultaneously or sequentially showed positive effects on cognitive performance, particularly among the elderly with MCI. Based on our review, we speculated that a short duration of training (30 minutes) is enough to generate positive outcomes instead of a longer duration, as it may cause fatigue in the elderly population. Previous studies also suggested that the naturally or simultaneously combined intervention such as dance should be implemented compared to sequential training owing to less frequency, and it gives an enjoyable experience. These elements are important to be further explored to ensure the elderly consistently participate in the program, thus gaining the desired outcome.

RECOMMENDATIONS AND IMPLICATIONS

Despite being focused solely on the cognitive performance outcomes, more research is required to explore any challenges in recruiting participants so that the research studies will be conducted effectively with a larger sample size, thus increasing the accuracy of the statistical data. Several interesting aspects may be explored in future studies including the sustained cognitive benefits. Long-term studies can help determine whether the positive effects of combined physical exercise and cognitive training interventions on cognitive performance are sustained over time. Understanding the long-term cognitive benefits is crucial for establishing the effectiveness and practical relevance of these interventions in managing MCI.

Furthermore, future studies should investigate the optimal frequency and duration of training sessions to maximize cognitive benefits while ensuring participant adherence and motivation. For example, if the frequency of training sessions is too high or the duration of each session is too long, participants may experience fatigue or become demotivated, leading to lower adherence and reduced cognitive benefits. On the other hand, if the frequency and duration of training sessions are too low, participants may not receive enough cognitive stimulation to generate significant cognitive benefits.

Our results emphasize the importance of incorporating intervention with the best combination method into routine practice. Future studies can build upon these findings to enhance our understanding of effective interventions for cognitive health in the elderly population. This could lead to the development of guidelines and recommendations for implementing such interventions in clinical settings. Therefore, policymakers and healthcare organizations may consider integrating physical exercise and cognitive training interventions into healthcare policies and programs aimed at supporting cognitive health in aging populations.

CONFLICT OF INTEREST

There is no conflict of interest to be declared.

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AUTHOR CONTRIBUTIONS

NAR: revised the manuscript critically with intellectual contents and approved the final version of the manuscript.
ZAMZ: drafted the manuscript and contributed to the concept development and design of the review article through data collection, analysis and data interpretation for the article.

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