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Systematic Review

# Physical and cognitive-based training in healthy older adults: Evidence from a systematic review and meta-analysis

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**Abstract**

**Introduction:** Several studies have shown that cognitive training interventions and regular physical activity are popular intervention in dementia prevention guidelines. The purpose of this study was to examine the effectiveness of physical and mental training on cognitive outcomes in, older adults.

**Methods:** For this systematic review and meta-analysis, randomized clinical trials (RCTs) published between 2000 and 6 February 2023 were extracted from several electronic databases, including, ProQuest, PubMed, Scopus, Embase, and Web of Science.

**Results:** The meta-analysis included 36 studies. The results indicated that the pooled MD for cognition was 0.49 (95% CI = 0.28 to 0.70, $I^2$ = 79.3%, *P* = 0.0001) and both physical and mental training have a "large to larger" effect on Episode memory (pooled MD: 1.98; 95% CI = 1.20 to 2.77, $I^2$ = 92%, *P* = 0.001). Also, as a result, the trainings had a "small to larger" impact on the executive function of older adults (pooled MD: 0.64; 95% CI = 0.26 to 1.02, I2 = 86.2%, *P* = 0.0001).

**Conclusion:** Our controversial results indicated that the non-pharmacological physical-mental training improves executive function which that can affect the ability of elders, while did not support the improvement of attention, processing speed, and verbal memory.

**Keyword:** Aged, Cognition, Exercise, Memory

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## Introduction

Older adults may experience cognitive impairment negatively and directly may impact their self-care, autonomy, health condition, and successful aging.[1] Normal aging is related to daily functional memory complications, as demonstrated by challenges in learning unprecedented names, remembering events that happened the pasts day, and finding a particular word in discussion.[2] The most important age-related changes are related to cognitive tasks that require fast processing of data, including executive function and working memory.[3] A hallmark of cognitive aging is age-related changes in executive function which is associated with major declines in executive function, including reasoning, set-shifting, working memory, and inhibition.[4-6] Executive functions are an important part of our day-to-day life, which can affect some everyday functions, like allowing focused attention, engaging in resolving issues successfully, and planning for the future.[4] Memory is perhaps the first cognitive function to give several patterns of decrease in some aspects, such as episodic memory.[7]

The progressive trend of cognitive impairment among the older population increased the importance of prevention of cognitive impairment through providing efficient guidelines and strategies. Additionally, there is an increasing body of evidence pointing to preventing or reducing the rate of cognitive impairment by using variant strategies e.g., behavioral training,[8] mind-body exercise,[9] and neurofeedback training.[10,11]

Neuroimaging also indicated the beneficial effect of mental and physical training on cognitive health. brain-derived neurotropic factor (BDNF) may triggers metabolic, plasticity, learning, and memory processes, plays an important role in excitation of molecular machinery by physical activity. A variety of mechanisms such as regeneration after neuronal injury and prevention of neuronal degeneration are undertaken by BDNF in addition to maintaining and promoting the growth of neurons from neuronal degeneration.

Moreover, the brain plasticity of the mental training has been seen in various procedure, such as cerebral blood flow, grey matter structure and, with matter integrity and energy metabolism. For example Engvig[12] used an intensive memory training program in order to enhance memory skill. Results also revealed memory training may induce short-term structural changes in the structural grey matter and participants' memory. Scientists come to the conclusion that the different type of physical/mental activity, intensity and duration may be a specify factor in the change in serum concentration of BDNF and regional white matter integrity, and subsequently enhance memory and cognition. Therefore, identifying effective trainings in aging research is critical and necessary.

Additionally, up to the present time, there are some reviews that systematically described trainings in older adults but the number of articles that have examined the different components of cognition is rare, and so in most studies, the effect of mental and physical trainings had not been examined.

The research on physical and mental training over the last 23 years is summarized here to respond; to what types of trainings have been used to affect cognitive outcomes including total cognition, memory, episodic memory, verbal memory, attention, selective attention, sustained attention, executive function, inhibition, mental flexibility, working memory, reasoning, in healthy older adults? This is a fundamental query in the growing field of geriatric health, and the findings should be useful in establishing guidelines and recommendations for health-promoting programs for older adults.

## Methods

In this systematic review and meta-analysis, randomized clinical trials (RCTs) published between 2000 and February 6, 2023 were extracted from several electronic databases, including, ProQuest, PubMed, Scopus, Embase, and Web of Science. The study was limited to published papers in the English language that assessed the effects of trainings on cognition function. Those studies that were created to examine the impact of all trainings, excluding medicines, nutritional, advising, and driving training on improving cognition function, were included in this review. The study subjects were healthy older adults who had at least 55 years old.

### *The search strategy*

To warrant the completeness of the included studies, we used Medical Subject Headings (MeSH) and free text words on the 5th online databases (ProQuest, Web of Science, PubMed, Scopus, and Embase) on papers published between 2000 and February 6, 2023. for relevant literature, the following keyword were used: Age, Older, Elder, Movement, Walking, Sports, Yoga, Activity, Exercise, Strengthening, Resistance, Pilates, Tai chi chuan, Brain training, Mental trainings, Executive Function, Attention, Cognition, Memory, Executive, Inhibit, Interference control, Cognition, Memory, Shifting, Mental flexibility, Updating, Planning, Switching, Fluency (see Supplementary file 1).in addition , manual searches were used to identify the additional studies that had not been identified in the initial search. This meta-analysis was done according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline[8] (se Supplementary file 2).

### *Study Selection Criteria*

Two authors (F.A. and A.A.T) separately screened the selected studies; the selection was made based on the screening of titles/abstracts. Next, the full texts of the remaining papers were evaluated. Eligibility disagreements were reconciled by initial reviewers and, if necessary, by a third reviewer (Z.J).

### *Study quality assessment and risk of bias*

The methodology quality of the included studies was independently assessed by two reviewers (F.A and A.A.T), and the third reviewer (Z.J) resolved any discrepancy through the Cochrane Collaboration tool[9] which consisted of six areas. Next, each area was labeled as either low, unclear, or high potential of bias. Additionally, two reviewers evaluated the methodological quality of the contained studies in a separate manner.

### Publication bias

The funnel plot of the included papers displayed no document for publication bias. The Egger test results were not considerable for publication bias ($P > 0.05$) (se Supplementary file 3).

### *Statistical analysis*

The mean differences (MDs) and standard deviation (SD) were computed using Stata software (Sv16). The standardized mean difference is to divide the mean difference by the SD and would compare the studies. All the studies report quantitative data and a weighted mean difference at a 95% confidence interval. Heterogeneity was estimated using statistics I-square:$I^2$ and the significance criterion was $I^2 > 50\%$. The Summary statistics reported were computed using random effects models based on unexplained heterogeneity between the studies. The chi-square test for heterogeneity was used to determine whether of distribution of results was consistent with the assumption that inter-experimental differences were attributable to chance variation alone. The statistical significance level was 0.05. The publication bias has been tested through funnel plots and the Egger regression test.

## Results

We identified 680 publications and of the total 407 papers recorded, 35 papers have been included in the meta-analysis (Figure 1).

### *Characteristics of the studies*

The studies were categorized into 12 groups including cognitive function, executive function, set-shifting, inhibition, reasoning, working memory, attention, selective attention, memory, delay memory, episodic memory, and verbal memory. All the participants ranged from 55 to more than 80 years of age. Research's sample sizes in the studies were between 14 to 487 participants (Table 1).

### *Methodological quality versus risk of bias assessment*

A high risk of selection bias due to the absence of allocation concealment (n = 1), performance bias (n = 1), and other sources of bias (n = 2) was shown. Reporting bias (n = 26), attrition bias (n = 22), and a lack of randomization method (n = 21) was unclear for the majority of the included studies (Supplementary file 4).

### *Effects of trainings on cognition (meta-analysis finding)*

The pooled MD for cognition was 0.49 (95% CI = 0.28 to 0.70, $I^2$ = 79.3%, $P$ = 0.0001) (Figure 2A). As a result, trainings had a small to larger effect on the executive function (pooled MD: 0.64 (95% CI = 0.26 to 1.02, $I^2$ = 86.2%, $P$ = 0.0001) (Figure 2B). In addition, trainings showed small to medium effect on set shifting (pooled MD: 0.37 (95% CI = 0.18 to 0.56, $I^2$ = 79.3%, $P$ = 0.0001) (Figure 2C). But trainings had not to effect on inhibitions (Figure 2D). The heterogeneity among studies also was high.

According to Figure 3, trainings were effective in reasoning (pooled MD: 0.40; 95% CI = 0.23 to 0.562, $I^2$ = 21.1%, $P$ = 0.224) (Figure 3A) and working memory of older adults (pooled MD: 0.25; 95% CI = 0.07 to 0.44, $I^2$ = 53.2%, $P$ = 0.0002; Figure 3B). But trainings showed no effect on attention (Figure 3C) and Selective Attention (Concentration, Figure 3D).

Figure 4 indicates that trainings had a small to large effect on Memory (pooled MD: 0.64; 95% CI = 0.25 to 1.04, $I^2$ = 87%, $P$ = 0.001) (Figure 4A); Delay memory (pooled MD: 1.18; 95% CI = 0.35 to 2.00, $I^2$ = 91.4%, $P$ = 0.001) (Figure 4B); and larger effect on Episode

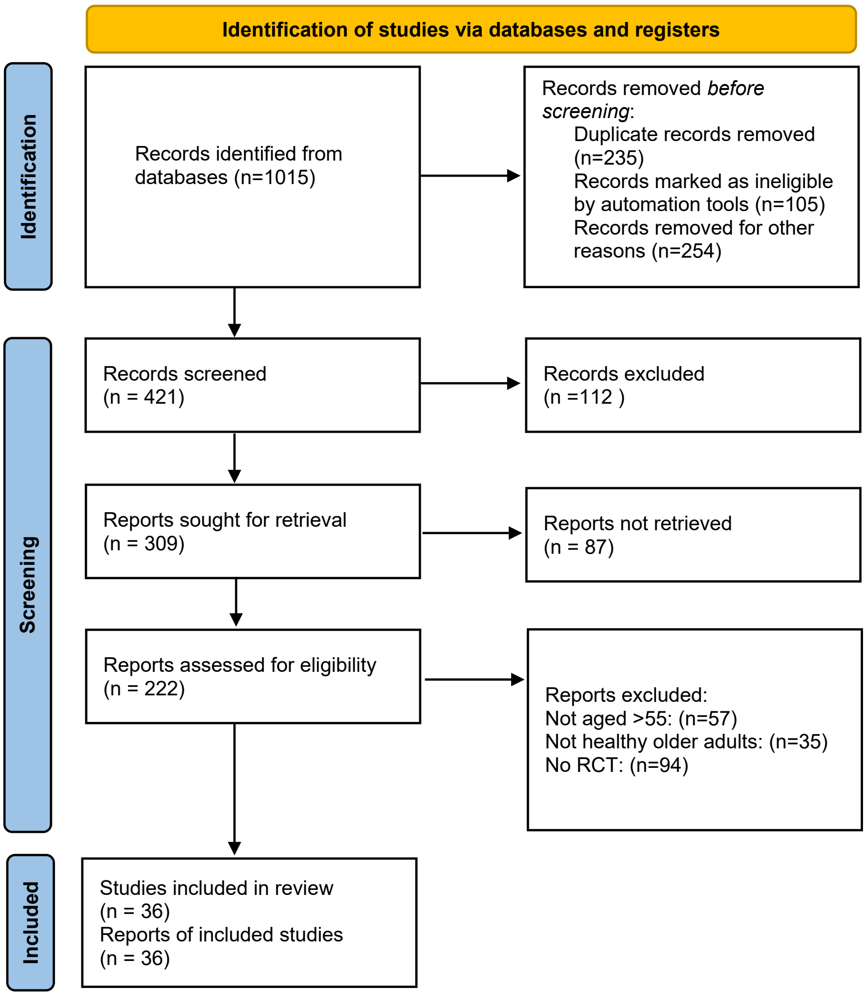


**Figure 1.** Prisma fallow diagram detailing the search strategy

**Table 1.** Main characteristics of the included studies in the meta-analysis

| First author and country | Participants | Trainings | Period of time(min) | Scales | Outcomes (significant training effect) |
|---|---|---|---|---|---|
| Yusof; Malaysia[10] | - Training group: N: 23, Age: 67.6 ± 4.5<br>- Control group: N: 20, Age: 65.8 ± 3.6 | Computerized software | 1080 | Montreal cognitive assessment | Delayed memory, cognition |
| Nouchi; Japan[11] | - Cognitive training: N: 27, Age: 71.67 ± 3.62<br>- Active control group: N: 28, Age: 73.11 ± 3.90 | Cognitive training games | 600-840 | The MMSE, The JART, Cd and SS, D-CAT, ST and rST, DS-F and DS-B, LM | Inhibition |
| Roheger; Germany[13] | - Structured cognitive training program (NEUROvitalis) group: N: 35, Age: 66.61 ± 9.30<br>- Unstructured cognitive training program Mentally Fit (active control): N: 35, Age: 69.72 ± 8.31<br>- Passive control: N: 35, Age: 63.88 ± 10.89 | NEUROvitalis program, the mentally fit program | 1080 | Dementia Detection immediate recall/delayed recall, brief test of attention, TMT A-B | Verbal short-term memory |
| Okamoto; Japan[14] | - Training group: N: 22, Age: 72 ± 1<br>- Control group: N: 24, Age: 73 ± 1 | Interval walking training | 1800 | TMT A-B | - |
| Yeo; Singapore[15] | - Training group: N: 109, Age: 66.2 ± 4.74<br>- Control group: N: 118, Age: 65.8 ± 4.65 | The brain-computer interface | 1080 | RBANS | - |
| Simon; USA and Sweden[16] | - Training group: N: 41, Age: 72.4 ± 5.6<br>- Control group: N: 41, Age: 73.7 ± 6.5 | The cogmed training system | 1000 | TMT-A, DS, COWAT | Working memory, phonemic fluency |
| Chiu; Taiwan[17] | - Training group: N: 31, Age: 72.03 ± 4.85<br>- Control group: N: 31, Age: 72.32 ± 5.50 | Executive function training | 720 | WCST, DS-F | WCST, DS-F |
| Vaportzis; UK[18] | - Training group: N: 22, Age: 68.4 ± 3.5<br>- Control group: N: 21, Age: 69.8 ± 3.0 | Cognitive activities by tablet | 1200 | The cognitive battery | - |
| Gill; UK[19] | - exercise + dual- task: N: 23, Age: 72.6 ± 7.4<br>- exercise only: N: 21, Age: 74.5 ± 7.0 | A group- based exercise program with a dual-task training program<br>A group- based exercise program alone | 3120- 5850 | TMT A-B, animal naming test, DSST, COWAT, AVLT | Cognitive function |
| Desjardins-Crépeau; Canada[20] | - Mixed aerobic/resistance training<br>DT training group: N: 22, Age: 72.7 ± 7.4<br>Computer lessons: N: 16, Age: 70.9 ± 7.4<br>- Stretching and toning exercises<br>DT training program training: N: 20, Age: 73.2 ± 6.3<br>Computer lessons: N: 18, Age: 72.5 ± 7.0 | Combination aerobic and resistance training program, stretching and toning exercises, DT training program, computer lessons | 2160 | RAVLT, CWIT, TMT- A-B | Speed of processing, Inhibition abilities,<br>Task switching abilities |
| Nouchi; Japan[21] | - Training group: N: 32, Age: 72.81 ± 6.18<br>- Control group: N: 32, Age: 71.38 ± 4.92 | Learning therapy group | 1380- 2070 | Stroop test, Verbal fluency task<br>LM, FSN, DS | Executive functions, episodic memory, attention |
| Millán-Calenti; Spain[22] | - Training group: N: 80, Age: 73.45 ± 5.95<br>- Control group: N: 80, Age: 75.48 ± 6.85 | The computerized cognitive training | | MMSE | Cognition |
| Lee; Singapore[23] | - For all participants: N: 39, Age: 65.2 ± 2.8 | Card-matching memory training | n | RBANS domain index | Delayed memory, cognition |

**Table 1.** Continued.

| First author and country | Participants | Trainings | Period of time(min) | Scales | Outcomes (significant training effect) |
|---|---|---|---|---|---|
| Kim; Korea[24] | - Traditional group: N: 24, Age: 67.7 ± 5.4<br>- Robot group: N: 24, Age: 68.0 ± 6.1<br>- Control group: N: 37, Age: 66.9 ± 4.0 | Traditional cognitive training, the robot-assisted cognitive training | | CANTAB | Executive function, cognitive, visual memory |
| Diamond; Australia[25] | - Training group: N: 36, Age: 67.33 ± 8.7<br>- Control group: N: 28, Age: 65.64 ± 8.4 | Computer-based training | | RAVLT, LM, RCFT, Phonemic and semantic verbal fluency, DS, TMT A-B | Verbal memory |
| Cavallini; Italy[26] | - Trained group: N: 16, Age 83.19 ± 7.34<br>- Control group: N: 18, Age: 87.06 ± 5.30 | Self-help memory training | 75 | Associative learning, Grocery list learning, Figure–word pairing, Text learning, Face–name learning, Object list learning, Word list learning, Everyday problems test | Memory |
| Nishiguchi; Japan[27] | - Training group: N: 24, Age: 70.6 ± 5.9<br>- Control group: N: 24, Age: 68.2 ± 6.2 | Dual-task | 1080 | MMSE, TMT | Memory, Executive functions |
| Polito; Italy[28] | - Training group: N: 38, Age: 73.8 ± 1.2<br>- Control group: N: 39, Age: 73.8 ± 1.3 | Cognitive stimulation | 1000 | MMSE, MOCA, Corsi test | MMSE, MOCA, Corsi test |
| Linde, Germany[29] | - Physical group: N: 13, Age: 65.59 ± 3.74<br>- Cognitive group: N: 15, Age: 68.28 ± 2.02<br>- Combined group: N: 11, Age: 66.56 ± 3.20<br>- Control group: N: 11, Age: 66.56 ± 3.20 | Physical activity, cognitive activity, mixed physical and cognitive activity training | 1920 | A subtest of the Leistungs-Prüf- System 50 + ,<br>D2 test of attention,<br>TMT A-B, The word list test | Concentration, cognitive speed |
| Ballesteros; Spain[30] | - Training group: N: 17, Age: 68.8 ± 5.15<br>- Control group: N: 13, Age: 69.2 ± 5.91 | Video game training | 1200 | Cross-modal oddball task, WCST,<br>Jigsaw puzzle task, Corsi, Rey-Osterrieth complex figure test | Cross-modal oddball task, WMS, SPF-IL |
| Nouchi; Japan[31] | - Training group: N: 32, Age: 66.75 ± 4.61<br>- Control group: N: 32, Age: 67.9 ± 6.7 | Combination exercise | 360 | ST and r-S, LFT, CFT, LM, FS-N,<br>DS-F and DS-B, D-CAT, Cd and SS,<br>JART | Executive functions, episodic memory |
| Lee; Singapore[32] | For all participants: N: 31, Age: 65.1 ± 2.9 | Card-matching memory training | 720 | RBANS | - |
| Teixeira; 2013 Brazil[33] | - Training group: N: 21, Age: 68.21 ± 28.4<br>- Control group: N: 20, Age: 67.9 ± 1 6.7 | Square-stepping exercise | 1920 | Modified card sorting test, MMSE,<br>Digit Span, Toulouse-Pierón | Cognitive, concentrated attention, mental flexibility |
| Shatil; USA[34] | - Cognitive training: N: 33, Age: 80 ± 5.43<br>Cognitive and physical training: N: 29, Age: 79 ± 5.49<br>No cognitive and no physical training: N: 29, Age: 81 ± 5.25<br>No cognitive and physical training: N: 31, Age: 79 ± 5.76 | The separate and combined cognitive and physical training | 1920 | The cogniFit | Working memory, long-term memory |
| Nouchi; Japan[35] | - Training group: N: 14, Age: 68.86 ± 2.07<br>- Control group: N: 14 , Age: 69.31 ± 2.82 | Brain training group, playing tetris group | 300 | MMSE, FAB, TMT-B, D-CAT, DS | Executive function |

**Table 1.** Continued.

| First author and country | Participants | Trainings | Period of time(min) | Scales | Outcomes (significant training effect) |
|---|---|---|---|---|---|
| Becerra; Mexico[36] | - Training group: N: 7, Age: 65.8 ± 2.4<br>- Control group: N: 7, Age: 67 ± 4.9 | Neurofeedback | | WAIS, NEUROPSI | Memory |
| Richmond; USA[37] | - Training group: N: 21, Age: 66<br>- Control group: N: 19, Age: 66 | Working memory | 600 | Digit span, Reading span, Raven's, test of every day attention | CVLT, everyday attention |
| Zelinski; USA[38] | - Training group: N: 242m, Age: 75.6 ± 6.6<br>- Control group: N: 245, Age: 75.0 ± 6.3 | Computerized program | 2400 | RBAN, RAVLT, Word list delayed recall, Rivermead, RBMT, DS-B | Memory, attention |
| Muscari; Italy[39] | Training group: N: 60, Age: 68.8 2.5<br>Control group: N: 60, Age: 69.6 2.8 | Endurance exercise training | 8640 | MMSE | - |
| Taylor- Piliae USA[40] | Tai Chi group: N: 37, Age: 70.6 ± 5.9<br>Western exercise: N: 39, Age: 68.5 ± 5.0<br>Control group: N: 56, Age: 68.2 ± 6.2 | Tai Chi, Western exercise | 60 min | Animal-naming test, DS | Cognition |
| Smith; 2009 USA[41] | - Training group: N: 242, Age: 75.6 ± 6.6<br>- Control group: N: 245. Age: 75.0 ± 6.3 | Computerized program | 2400 | RAVLT, Word list delayed recall, Rivermead, RBMT, DS-B | Memory, Attention |
| Uchida; 2008 Japan[42] | - Training group: N: 51, Age: 75.2 ± 3.8<br>- Control group: N: 47, Age: 75.6 ± 4. | The cognitive training | 2700 | FAB, DST | FAB, DST |
| Valentijn; Netherlands[43] | - Collective training: N: 53, Age: 69.32 ± 7.77<br>- Individual training: N: 43, Age: 68.07 ± 6.58<br>- Control group: N: 43, Age: 68.30 ± 8.03 | Memory training (collective and individual) | | VVLT, The short-story test, MMSE | Delayed recall |
| Noice; USA[44] | - Theater group: N: 44, Age: 73.02 ± 6.04<br>- Visual Arts group: N: 44, Age: 72.41 ± 6.04<br>- Control group: N: 36, Age: 75.81 ± 5.41 | The theater training, The visual arts training | 810 | Word recall task, problem-solving, listening span task | Word recall, Memory span |
| Fabre; France[45] | - Aerobic training group: N: 8, Age: 65.4 ± 2.2<br>- Mental training group: N: 8, Age: 67.5 ± 1.2<br>- Aerobic and mental training group: N: 8, Age: 64.9 ± 1.4<br>- Control group: N: 8, Age: 65.7 ± 1.5 | The separate and combined aerobic and mental training | 480 | The BEC 96 questionnaire, The Wechsler memory scale | Logical memory, Memory quotient |
| Lajeunesse; Canada[46] | - Training group: N: 12, Age: 71.96 ± 6.20<br>- Control group: N: 12, Age: 71.67 ± 6.33 | Prospective memory computer- based cognitive rehabilitation | 600-1200 | MoCA, Digit Symbol, The Symbol Cancellation Test, Digit Span, The Color- Word Interference Test | Retrospective memory |

The MMSE: Mini-Mental State Examination, The JART: Japanese version of the National Adult Reading Test, CD: Digit symbol coding, SS: Symbol search, D-CAT: Digit cancellation task, ST: Stroop task, rST: reverse Stroop task, DS-F: The digit span forward, DS-B: the digit span backward, RBANS: The Repeatable Battery for the Assessment of Neuropsychological Status, COWAT: Controlled Oral Word Association Test, TMT: The trail-making test, DSST: Digit Symbol Substitution Test, AVLT: Auditory Verbal Learning Test, CWIT: The Color-Word Interference Test, LM: The logical memory, WMS: Wechsler Memory Scale Logical Memory, CANTAB: The Cambridge Neuropsychological Test Automated Battery, RAVLT: The Rey Auditory Verbal Learning Test, WCST: The Wisconsin Card Sorting Test, RCFT: The Rey Osterrieth Complex Figure Test, LFT: The letter fluency task, CFT: The category fluency task, FS-N: First and Second names, VVLT: The Visual Verbal, RBMT: River mead Behavioral Memory Test, LNS: letter-number sequencing.

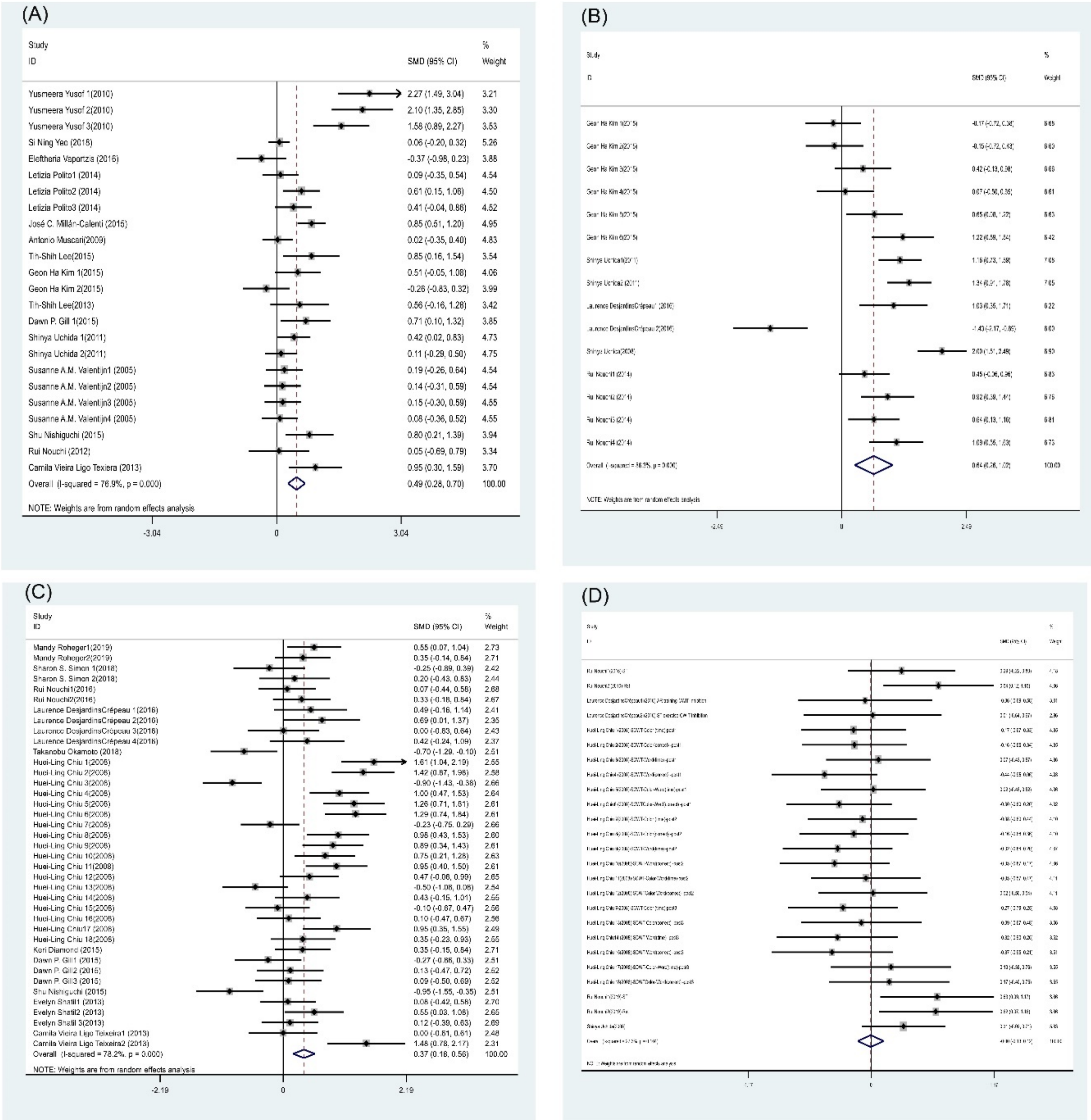


**Figure 2.** Effect of interventions on cognition (A); executive function (B); set shifting (C) and inhibition (D)

memory (pooled MD: 1.98; 95% CI = 1.20 to 2.77, $I^2 = 92\%$, $P = 0.001$) (Figure 4C) of older adults people. But with high heterogeneity and no effect on verbal memory (Figure 4D).

## Discussion

As our aim was to investigate the role of physical and mental training as a potential preventive training to improve cognitive function and its sub-domain decay in older persons and also evaluate the quality of available evidence, the analyses prepared explicit evidence that the training had a 'large' effect on the improvement of episodic memory. Also, we found that the training had a 'small to larger' effect size in cognition, executive function, reasoning, working memory, and memory.

These findings expand prior evidences from a meta-analysis of the single or multi-component physical and mental trainings on cognitive functions. Based on this study and previous results, all types of physical and mental training have been demonstrated to improve cognitive function of healthy aging population.[47] Our findings also extend the previous findings of the systematic review on the separate and combination of the brain and physical training benefits on improving cognitive functioning in older population,[47,48] while we found studies which claimed the opposite.[49,50] Several possible mechanisms may underlie training-induced enhancements of efficiency that are closely connected to neuroplasticity

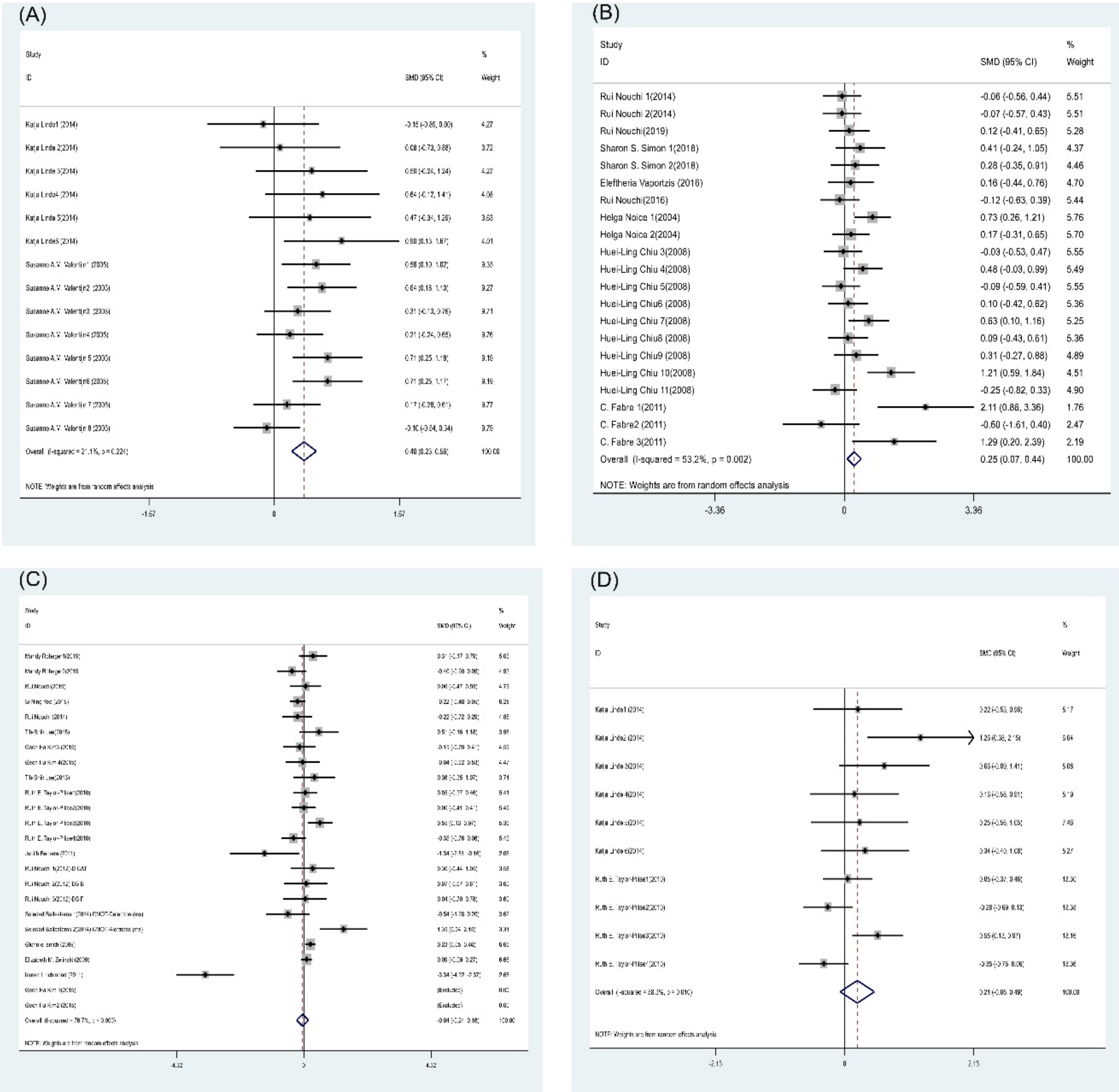


**Figure 3.** Effect of interventions on reasoning (A), working memory (B), attention (C), and selective attention (concentration) (D)

, chemical transmitter, and change in neuromodulator of central pathway, selectively increasing angiogenesis, synaptogenesis, and neurogenesis.[51] The heterogeneity of the reviewed studies makes the results be interpreted cautiously.

The current study shows a critical extension to the body of literature by examining physical activity and mental training on cognitive function and displays small to large improvements in executive function and small to medium improvement within 3 sub-domains of executive function. Similar to this review, several systematic reviews and training studies have shown an improvement in executive function through aerobic and stretch exercise training,[52] traditional mental training,[53] and cognitive-motor training.[54] This is in contrast to Shah et al[55] that did not demonstrate the post-intervention benefits of a combined mental and physical training for executive functions. Limited sample size, differences in the outcome measures, and types of training may be responsible. It may also be assumed that the type of physical activity may be more determinative than the intensity of physical activity in this sub-domain of cognitive function because the training time is equal in both studies.

In addition, the finding of this meta-analysis is comparable to those of the review in terms of the effects of aerobic exercise and combination mind-body training on working memory as another sub-domain of executive function.[56,57] Among the eight reviewed articles, most of the articles (seven out of eight) had mental training but the greatest improvement founded in Fabre et al. study by aerobic and combined mind-body trainings. In contrast, in another meta-analysis, Guo et al showed that mixed

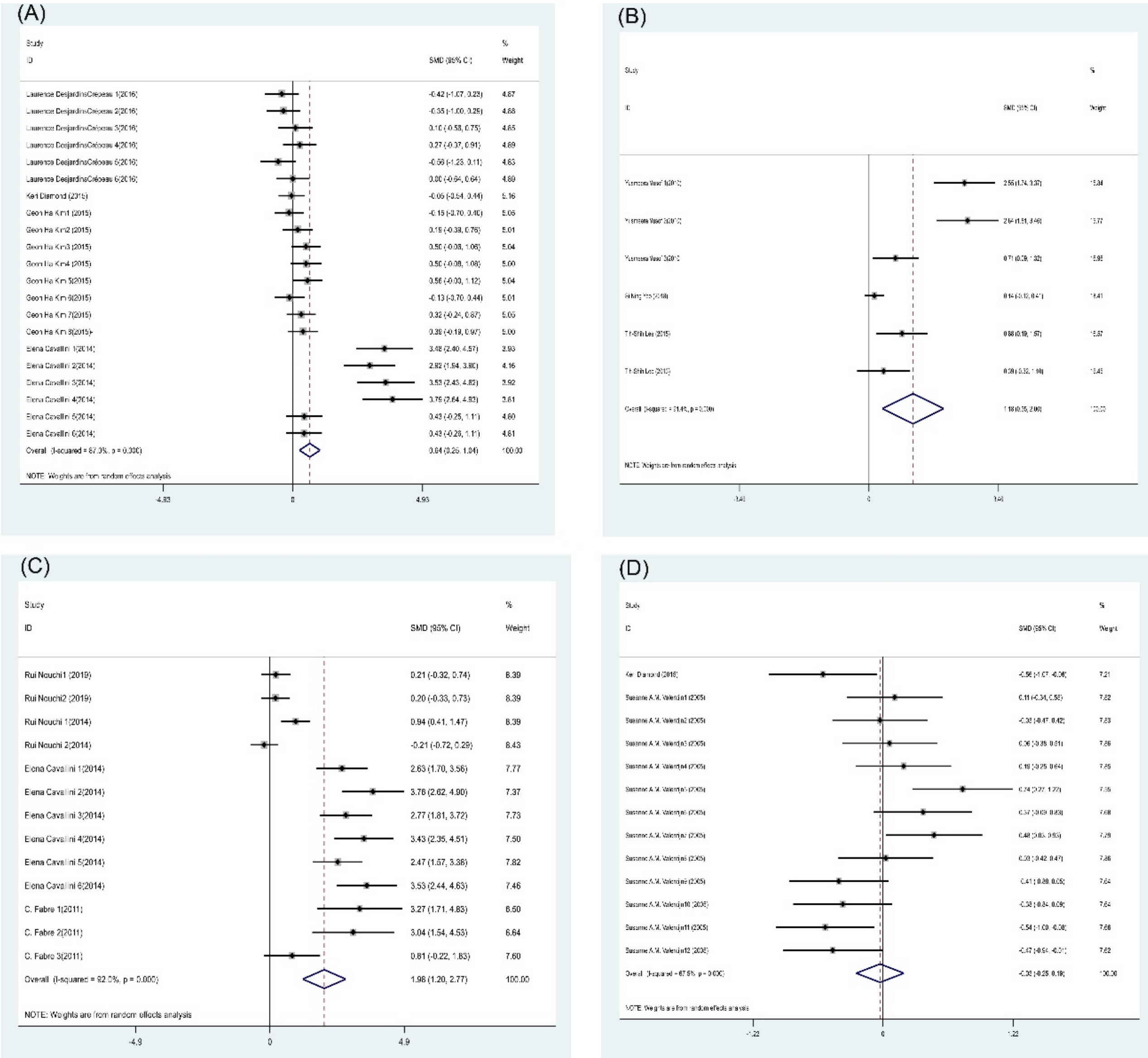


**Figure 4.** Effect of interventions on memory (A); Delay memory (B); Episode memory(C); Verbal memory (D)

training was not superior to physical or mental training alone on executive function.[58] However, it would be important to interpret in a cautious manner the results in view of the methodological heterogeneity of the studies. in fact, the effectiveness of physical trainings may depend on the nature and length of trainings. Physical activity may greatly increase neurogenesis in the frontal lobe, and mental exercise may decrease the number of neuronal cell deaths.[59]

The results of the current study did not show important benefits from physical activity training in memory function. In contrast, another review by Babaei et al. has shown that physical activity improved neurotrophic factors, mitochondrial biogenesis, and the release of some signaling molecules.[60] Neuromotor exercise e.g. yoga has been successful in enhancing all types of short and long-term memory in the elderly.[61] These insights can be used to develop future memory enhancement protocols for an aging population.

This study suggests that the separate and combined aerobic and mental training can improve episodic memory in the older population. Based on the findings of Aghjayan et al[62] and Loprinzi et al[63] aerobic exercise may enhance episodic memory. Acute and long-term physical activity has also been displayed to be linked with episodic memory function. According to our finding a systematic review led by Mendonça et al.[64] Also, physical activity influences cognitive function by spreading BDNF and promoting neuronal growth and survival.[65]

The comprehensive search strategy, measuring different components of cognition, and various pieces of training were major strengths of this review. However, the limitations of the study are mentioned. First, in this study, both physical and mental training results were analyzed in a concurrent manner. As a result, the effects of any type of training cannot be identified alone. It is suggested that each type of training be considered separately for future studies.

Second, the variation in the instruments used to measure the subdomains of cognition function can be identified as a limiting factor. Third, it is very complicated to eliminate the influence of diet, medication, and social support, on the results.

## Conclusion

Our findings in this systematic review and meta-analysis show that physical and mental training is a helpful way to improve the mental and executive function of older adults. As a result, emphasizing on physical and mental training programs may improve the quality of life of older adults and let them live more in an independent manner and consequently may guide healthcare providers to set up programs that let elders engage more in physical and mental training programs and also the combined physical and mental training programs may be assumed as a new strategy in the field of geriatric health and gerontology to emphasize on synergetic effects of physical exercise and mental training.

### Authors' Contribution

**Conceptualization:** Fatemeh Adelirad, Iman Dianat.
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### Competing Interests

The authors declare that they have no competing interests.

### Ethical Approval

This study was approved by Ethical committee Tabriz University of Medical Sciences (Ethical number: IR.TBZMED.REC.1398.829).

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### Supplementary Files

Supplementary file 1. Search strategy for ProQuest, PubMed, Scopus, Embase and Web of Science databases
Supplementary file 2. PRISMA Checklist for the meta-analysis.
Supplementary file 3. Funnel plot of interventions.
Supplementary file 4. Risk of bias assessment of studied.

### References

1. Mana J, Bezdicek O. Cognition in successful aging: systematic review and future directions. Clin Gerontol. 2022;45(3):477-85. doi: 10.1080/07317115.2020.1752346.
2. Parikh PK, Troyer AK, Maione AM, Murphy KJ. The impact of memory change on daily life in normal aging and mild cognitive impairment. Gerontologist. 2016;56(5):877-85. doi: 10.1093/geront/gnv030.
3. Murman DL. The impact of age on cognition. Semin Hear. 2015;36(3):111-21. doi: 10.1055/s-0035-1555115.
4. Ferguson HJ, Brunsdon VEA, Bradford EE. The developmental trajectories of executive function from adolescence to old age. Sci Rep. 2021;11(1):1382. doi: 10.1038/s41598-020-80866-1.
5. Salthouse TA. Effects of aging on reasoning. In: Holyoak KJ, Morrison RG, eds. The Cambridge Handbook of Thinking and Reasoning. Cambridge University Press; 2005. p. 589-605.
6. Adelirad F, Salimi MM, Dianat I, Asghari-Jafarabadi M, Chattu VK, Allahverdipour H. The relationship between cognitive status and retained activity participation among community-dwelling older adults. Eur J Investig Health Psychol Educ. 2022;12(4):400-16. doi: 10.3390/ejihpe12040029.
7. Tromp D, Dufour A, Lithfous S, Pebayle T, Després O. Episodic memory in normal aging and Alzheimer disease: insights from imaging and behavioral studies. Ageing Res Rev. 2015;24(Pt B):232-62. doi: 10.1016/j.arr.2015.08.006.
8. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med. 2009;151(4):264-9. doi: 10.7326/0003-4819-151-4-200908180-00135.
9. Higgins JP, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ. 2011;343:d5928. doi: 10.1136/bmj.d5928.
10. Yusof Y, Mukari SZS, Dzulkifli MA, Chellapan K, Ahmad K, Ishak I, et al. Efficacy of a newly developed auditory-cognitive training system on speech recognition, central auditory processing and cognitive ability among older adults with normal cognition and with neurocognitive impairment. Geriatr Gerontol Int. 2019;19(8):768-73. doi: 10.1111/ggi.13710.
11. Nouchi R, Kobayashi A, Nouchi H, Kawashima R. Newly developed TV-based cognitive training games improve car driving skills, cognitive functions, and mood in healthy older adults: evidence from a randomized controlled trial. Front Aging Neurosci. 2019;11:99. doi: 10.3389/fnagi.2019.00099.
12. Engvig A, Fjell AM, Westlye LT, Moberget T, Sundseth Ø, Larsen VA, et al. Effects of memory training on cortical thickness in the elderly. Neuroimage. 2010;52(4):1667-1676. doi:10.1016/j.neuroimage.2010.05.041.
13. Roheger M, Kessler J, Kalbe E. Structured cognitive training yields best results in healthy older adults, and their ApoE4 state and baseline cognitive level predict training benefits. Cogn Behav Neurol. 2019;32(2):76-86. doi: 10.1097/wnn.0000000000000195.
14. Okamoto T, Hashimoto Y, Kobayashi R. Effects of interval walking training compared to normal walking training on cognitive function and arterial function in older adults: a randomized controlled trial. Aging Clin Exp Res. 2019;31(10):1451-9. doi: 10.1007/s40520-018-1093-8.
15. Yeo SN, Lee TS, Sng WT, Heo MQ, Bautista D, Cheung YB, et al. Effectiveness of a personalized brain-computer interface system for cognitive training in healthy elderly: a randomized controlled trial. J Alzheimers Dis. 2018;66(1):127-38. doi: 10.3233/jad-180450.
16. Simon SS, Tusch ES, Feng NC, Håkansson K, Mohammed AH, Daffner KR. Is computerized working memory training effective in healthy older adults? Evidence from a

multi-site, randomized controlled trial. J Alzheimers Dis. 2018;65(3):931-49. doi: 10.3233/jad-180455.
17. Chiu HL, Chan PT, Kao CC, Chu H, Chang PC, Hsiao SS, et al. Effectiveness of executive function training on mental set shifting, working memory and inhibition in healthy older adults: a double-blind randomized controlled trials. J Adv Nurs. 2018;74(5):1099-113. doi: 10.1111/jan.13519.
18. Vaportzis E, Martin M, Gow AJ. A tablet for healthy ageing: the effect of a tablet computer training intervention on cognitive abilities in older adults. Am J Geriatr Psychiatry. 2017;25(8):841-51. doi: 10.1016/j.jagp.2016.11.015.
19. Gill DP, Gregory MA, Zou G, Liu-Ambrose T, Shigematsu R, Hachinski V, et al. The healthy mind, healthy mobility trial: a novel exercise program for older adults. Med Sci Sports Exerc. 2016;48(2):297-306. doi: 10.1249/mss.0000000000000758.
20. Desjardins-Crépeau L, Berryman N, Fraser SA, Vu TT, Kergoat MJ, Li KZ, et al. Effects of combined physical and cognitive training on fitness and neuropsychological outcomes in healthy older adults. Clin Interv Aging. 2016;11:1287-99. doi: 10.2147/cia.s115711.
21. Nouchi R, Taki Y, Takeuchi H, Nozawa T, Sekiguchi A, Kawashima R. Reading aloud and solving simple arithmetic calculation intervention (learning therapy) improves inhibition, verbal episodic memory, focus attention and processing speed in healthy elderly people: evidence from a randomized controlled trial. Front Hum Neurosci. 2016;10:217. doi: 10.3389/fnhum.2016.00217.
22. Millán-Calenti JC, Lorenzo T, Núñez-Naveira L, Buján A, Rodríguez-Villamil JL, Maseda A. Efficacy of a computerized cognitive training application on cognition and depressive symptomatology in a group of healthy older adults: a randomized controlled trial. Arch Gerontol Geriatr. 2015;61(3):337-43. doi: 10.1016/j.archger.2015.08.015.
23. Lee TS, Quek SY, Goh SJ, Phillips R, Guan C, Cheung YB, et al. A pilot randomized controlled trial using EEG-based brain-computer interface training for a Chinese-speaking group of healthy elderly. Clin Interv Aging. 2015;10:217-27. doi: 10.2147/cia.s73955.
24. Kim GH, Jeon S, Im K, Kwon H, Lee BH, Kim GY, et al. Structural brain changes after traditional and robot-assisted multi-domain cognitive training in community-dwelling healthy elderly. PLoS One. 2015;10(4):e0123251. doi: 10.1371/journal.pone.0123251.
25. Diamond K, Mowszowski L, Cockayne N, Norrie L, Paradise M, Hermens DF, et al. Randomized controlled trial of a healthy brain ageing cognitive training program: effects on memory, mood, and sleep. J Alzheimers Dis. 2015;44(4):1181-91. doi: 10.3233/jad-142061.
26. Cavallini E, Bottiroli S, Capotosto E, De Beni R, Pavan G, Vecchi T, et al. Self-help memory training for healthy older adults in a residential care center: specific and transfer effects on performance and beliefs. Int J Geriatr Psychiatry. 2015;30(8):870-80. doi: 10.1002/gps.4230.
27. Nishiguchi S, Yamada M, Tanigawa T, Sekiyama K, Kawagoe T, Suzuki M, et al. A 12-week physical and cognitive exercise program can improve cognitive function and neural efficiency in community-dwelling older adults: a randomized controlled trial. J Am Geriatr Soc. 2015;63(7):1355-63. doi: 10.14989/doctor.k19642.
28. Polito L, Abbondanza S, Vaccaro R, Valle E, Davin A, Degrate A, et al. Cognitive stimulation in cognitively impaired individuals and cognitively healthy individuals with a family history of dementia: short-term results from the "Allena-Mente" randomized controlled trial. Int J Geriatr Psychiatry. 2015;30(6):631-8. doi: 10.1002/gps.4194.
29. Linde K, Alfermann D. Single versus combined cognitive and physical activity effects on fluid cognitive abilities of healthy older adults: a 4-month randomized controlled trial with follow-up. J Aging Phys Act. 2014;22(3):302-13. doi: 10.1123/japa.2012-0149.
30. Ballesteros S, Prieto A, Mayas J, Toril P, Pita C, Ponce de León L, et al. Brain training with non-action video games enhances aspects of cognition in older adults: a randomized controlled trial. Front Aging Neurosci. 2014;6:277. doi: 10.3389/fnagi.2014.00277.
31. Nouchi R, Taki Y, Takeuchi H, Sekiguchi A, Hashizume H, Nozawa T, et al. Four weeks of combination exercise training improved executive functions, episodic memory, and processing speed in healthy elderly people: evidence from a randomized controlled trial. Age (Dordr). 2014;36(2):787-99. doi: 10.1007/s11357-013-9588-x.
32. Lee TS, Goh SJ, Quek SY, Phillips R, Guan C, Cheung YB, et al. A brain-computer interface based cognitive training system for healthy elderly: a randomized control pilot study for usability and preliminary efficacy. PLoS One. 2013;8(11):e79419. doi: 10.1371/journal.pone.0079419.
33. Teixeira CV, Gobbi S, Pereira JR, Vital TM, Hernandéz SS, Shigematsu R, et al. Effects of square-stepping exercise on cognitive functions of older people. Psychogeriatrics. 2013;13(3):148-56. doi: 10.1111/psyg.12017.
34. Shatil E. Does combined cognitive training and physical activity training enhance cognitive abilities more than either alone? A four-condition randomized controlled trial among healthy older adults. Front Aging Neurosci. 2013;5:8. doi: 10.3389/fnagi.2013.00008.
35. Nouchi R, Taki Y, Takeuchi H, Hashizume H, Nozawa T, Sekiguchi A, et al. Beneficial effects of short-term combination exercise training on diverse cognitive functions in healthy older people: study protocol for a randomized controlled trial. Trials. 2012;13:200. doi: 10.1186/1745-6215-13-200.
36. Becerra J, Fernández T, Roca-Stappung M, Díaz-Comas L, Galán L, Bosch J, et al. Neurofeedback in healthy elderly human subjects with electroencephalographic risk for cognitive disorder. J Alzheimers Dis. 2012;28(2):357-67. doi: 10.3233/jad-2011-111055.
37. Richmond LL, Morrison AB, Chein JM, Olson IR. Working memory training and transfer in older adults. Psychol Aging. 2011;26(4):813-22. doi: 10.1037/a0023631.
38. Zelinski EM, Spina LM, Yaffe K, Ruff R, Kennison RF, Mahncke HW, et al. Improvement in memory with plasticity-based adaptive cognitive training: results of the 3-month follow-up. J Am Geriatr Soc. 2011;59(2):258-65. doi: 10.1111/j.1532-5415.2010.03277.x.
39. Muscari A, Giannoni C, Pierpaoli L, Berzigotti A, Maietta P, Foschi E, et al. Chronic endurance exercise training prevents aging-related cognitive decline in healthy older adults: a randomized controlled trial. Int J Geriatr Psychiatry. 2010;25(10):1055-64. doi: 10.1002/gps.2462.
40. Taylor-Piliae RE, Newell KA, Cherin R, Lee MJ, King AC, Haskell WL. Effects of Tai Chi and Western exercise on physical and cognitive functioning in healthy community-dwelling older adults. J Aging Phys Act. 2010;18(3):261-79. doi: 10.1123/japa.18.3.261.
41. Smith GE, Housen P, Yaffe K, Ruff R, Kennison RF, Mahncke HW, et al. A cognitive training program based on principles of brain plasticity: results from the Improvement in Memory with Plasticity-based Adaptive Cognitive Training (IMPACT) study. J Am Geriatr Soc. 2009;57(4):594-603. doi: 10.1111/j.1532-5415.2008.02167.x.
42. Uchida S, Kawashima R. Reading and solving arithmetic problems improves cognitive functions of normal aged people: a randomized controlled study. Age (Dordr).

2008;30(1):21-9. doi: 10.1007/s11357-007-9044-x.

43. Valentijn SA, van Hooren SA, Bosma H, Touw DM, Jolles J, van Boxtel MP, et al. The effect of two types of memory training on subjective and objective memory performance in healthy individuals aged 55 years and older: a randomized controlled trial. Patient Educ Couns. 2005;57(1):106-14. doi: 10.1016/j.pec.2004.05.002.
44. Noice H, Noice T, Staines G. A short-term intervention to enhance cognitive and affective functioning in older adults. J Aging Health. 2004;16(4):562-85. doi: 10.1177/0898264304265819.
45. Fabre C, Chamari K, Mucci P, Massé-Biron J, Préfaut C. Improvement of cognitive function by mental and/or individualized aerobic training in healthy elderly subjects. Int J Sports Med. 2002;23(6):415-21. doi: 10.1055/s-2002-33735.
46. Lajeunesse A, Potvin MJ, Labelle V, Chasles MJ, Kergoat MJ, Villalpando JM, et al. Effectiveness of a visual imagery training program to improve prospective memory in older adults with and without mild cognitive impairment: a randomized controlled study. Neuropsychol Rehabil. 2022;32(7):1576-604. doi: 10.1080/09602011.2021.1919529.
47. García-Hermoso A, Ramirez-Vélez R, Sáez de Asteasu ML, Martínez-Velilla N, Zambom-Ferraresi F, Valenzuela PL, et al. Safety and effectiveness of long-term exercise interventions in older adults: a systematic review and meta-analysis of randomized controlled trials. Sports Med. 2020;50(6):1095-106. doi: 10.1007/s40279-020-01259-y .
48. Zhang H, Huntley J, Bhome R, Holmes B, Cahill J, Gould RL, et al. Effect of computerised cognitive training on cognitive outcomes in mild cognitive impairment: a systematic review and meta-analysis. BMJ Open. 2019;9(8):e027062. doi: 10.1136/bmjopen-2018-027062.
49. Schmitter-Edgecombe M, Dyck DG. Cognitive rehabilitation multi-family group intervention for individuals with mild cognitive impairment and their care-partners. J Int Neuropsychol Soc. 2014;20(9):897-908. doi: 10.1017/s1355617714000782.
50. Zotcheva E, Håberg AK, Wisløff U, Salvesen Ø, Selbæk G, Stensvold D, et al. Effects of 5 years aerobic exercise on cognition in older adults: the generation 100 study: a randomized controlled trial. Sports Med. 2022;52(7):1689-99. doi: 10.1007/s40279-021-01608-5.
51. Gligoroska JP, Manchevska S. The effect of physical activity on cognition - physiological mechanisms. Mater Sociomed. 2012;24(3):198-202. doi: 10.5455/msm.2012.24.198-202.
52. Chen FT, Etnier JL, Chan KH, Chiu PK, Hung TM, Chang YK. Effects of exercise training interventions on executive function in older adults: a systematic review and meta-analysis. Sports Med. 2020;50(8):1451-67. doi: 10.1007/s40279-020-01292-x.
53. Chambon C, Alescio-Lautier B. Improved executive functioning in healthy older adults after multifactorial cognitive training targeting controlled processes. J Syst Integr Neurosci. 2019;6:1-9. doi: 10.15761/jsin.1000218.
54. Wollesen B, Wildbredt A, van Schooten KS, Lim ML, Delbaere K. The effects of cognitive-motor training interventions on executive functions in older people: a systematic review and meta-analysis. Eur Rev Aging Phys Act. 2020;17:9. doi: 10.1186/s11556-020-00240-y.
55. Shah T, Verdile G, Sohrabi H, Campbell A, Putland E, Cheetham C, et al. A combination of physical activity and computerized brain training improves verbal memory and increases cerebral glucose metabolism in the elderly. Transl Psychiatry. 2014;4(12):e487. doi: 10.1038/tp.2014.122.
56. Zhidong C, Wang X, Yin J, Song D, Chen Z. Effects of physical exercise on working memory in older adults: a systematic and meta-analytic review. Eur Rev Aging Phys Act. 2021;18(1):18. doi: 10.1186/s11556-021-00272-y.
57. Sun MJ, Yu DD, Lin DM, Lu SD. Effect of shadow boxing on the physical quality of middle-aged and old women. Chin J Clin Rehabil. 2005;9(32):188-9.
58. Guo W, Zang M, Klich S, Kawczyński A, Smoter M, Wang B. Effect of combined physical and cognitive interventions on executive functions in older adults: a meta-analysis of outcomes. Int J Environ Res Public Health. 2020;17(17):6166. doi: 10.3390/ijerph17176166.
59. Curlik DM 2nd, Shors TJ. Training your brain: do mental and physical (MAP) training enhance cognition through the process of neurogenesis in the hippocampus? Neuropharmacology. 2013;64(1):506-14. doi: 10.1016/j.neuropharm.2012.07.027.
60. Babaei P, Bolouki Azari H. Exercise training improves memory performance in older adults: a narrative review of evidence and possible mechanisms. Front Hum Neurosci. 2021;15:771553. doi: 10.3389/fnhum.2021.771553.
61. da Silva Santos T, Rocha SV, Vasconcelos LR, de Queiroz BM, de Oliveira SC, Coutinho AP. The effect of physical exercise on the memory of elderly-an intervention study. Motriz. 2019;25(4):e10190020. doi: 10.1590/s1980-6574201900040020.
62. Aghjayan SL, Bournias T, Kang C, Zhou X, Stillman CM, Donofry SD, et al. Aerobic exercise improves episodic memory in late adulthood: a systematic review and meta-analysis. Commun Med (Lond). 2022;2:15. doi: 10.1038/s43856-022-00079-7.
63. Loprinzi PD, Moore D, Loenneke JP. Does aerobic and resistance exercise influence episodic memory through unique mechanisms? Brain Sci. 2020;10(12):913. doi: 10.3390/brainsci10120913.
64. Murawska-Ciałowicz E, Wiatr M, Ciałowicz M, Gomes de Assis G, Borowicz W, Rocha-Rodrigues S, et al. BDNF impact on biological markers of depression-role of physical exercise and training. Int J Environ Res Public Health. 2021;18(14):7553. doi: 10.3390/ijerph18147553.
65. Loprinzi PD. Does brain-derived neurotrophic factor mediate the effects of exercise on memory? Phys Sportsmed. 2019;47(4):395-405. doi: 10.1080/00913847.2019.1610255.