REVIEW ARTICLE

# Promoting Cognitive Resilience through Exercise in Aging: Understanding the Mechanisms and Crafting Tailored Exercise Programs for Older Adults - A Critical Review

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## Abstract

The benefits of regular physical activity and exercise are increasingly seen as key to enhancing the brain health of the elderly. Despite this growing awareness, specific guidelines for physical activities designed to improve cognitive functions are yet to be established, and the precise mechanisms that underlie cognitive benefits from such stimulation remain unclear. This review will explore current studies on how exercise and physical activities impact cognitive abilities in individuals without cognitive deficits. We aim to pinpoint the reasons behind these benefits and offer recommendations for exercise routines that could improve cognitive functions. Attention is given to three main biological mechanisms believed to drive the cognitive improvements associated with exercise: promoting neuroplasticity and growth factors, reducing inflammation biomarkers, and regulating the hypothalamic-pituitary-adrenal axis. The concluding section details factors that enhance cognitive function in the elderly, such as the nature of exercise, its frequency and type, intensity and session length, and total workout duration.

### *Keywords*

*Brain-Derived Neurotrophic Factor, Cognition, Exercise, Physical Activity.*

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## Introduction

In 2017, 962 million individuals aged 60 and up were anticipated to increase globally, reaching roughly 2.1 billion by 2050[1]. With an increasing number of elderly persons suffering from chronic illnesses[2], memory impairment expresses itself in issues with memory, language, or cognition, as well as activities necessary for daily living[3]. This could be due to dementia or vascular disease. Today, 35.6 million individuals worldwide have dementia. By 2030, this figure might rise to 75.6 million, making dementia one of the most pressing public health concerns[4]. MCI (mild cognitive impairment) encompasses any amount of impairment between normal cognition and progressive dementia. According to research, 60-66% of people with MCI will develop cognitive impairment at some point in their lifetimes, making attempts to reduce or stop this progression critical for both quality of life and healthcare costs[5]. Stopping Alzheimer's disease, one of the most common types of dementia, for only one year might save around US 113 billion by 2030[6]. Physical activity has proven beneficial in boosting the well-being of older brains. However, few guidelines attempt to improve cognitive abilities through physical activity; their processes are unknown. As a result, this work examines existing studies on the effects of physical activity and exercise on cognitive performance[7-8]. In this review, the potential mechanisms contributing to the advantages of exercise were explored along with workouts that could improve cognitive function for adults over 50 who are not experiencing cognitive decline. Furthermore, the three primary biological mechanisms thought to be responsible for the improved cognitive function that exercise induces in older adults were highlighted as follows: (i) increased neuroplasticity and growth factors, (ii) suppression of pro-inflammatory biomarker production, and (iii) regulation of the hypothalamic-pituitary-adrenal (HPA) axis. Exercise can improve cognition in various ways, promoting all the parameters in older individuals.

### *Types of Exercise*

Exercise is any planned, systematic, and repetitive physical activity aimed at improving or maintaining fitness[9]. There are several categories of exercises:

- Aerobic or endurance exercises are continuous and rhythmic physical activities that increase heart rate and breathing[10].
- Resistance exercises, often called strength or weight training, use resistance to contract muscles, improving strength, anaerobic endurance, and skeletal muscle growth[11].
- Yoga is a well-known practice involving physical postures, breathing techniques, and meditation. It emphasizes flexibility, strength, and mental well-being[11].
- Tai Chi is a Chinese martial art involving slow, fluid movements and coordinated breathing to improve flexibility, balance, and stress relief[12].

## *Effects of Physical Activity on the Growth of Brain-Derived Neural Elements and Neuroplasticity*

Physical exercise has a significant impact on brain-derived neural elements and neuroplasticity development. Studies show a brain loss in grey and white matter, particularly in the prefrontal and hippocampus cortex[13]. A two-year study using magnetic resonance imaging revealed that people without dementia can nevertheless have hippocampal atrophy, which can be shown in annual examinations. Those with Alzheimer's disease see greater volume reduction[14]. Further analysis demonstrates that ageing is connected with decreased blood and plasma levels and lower concentrations of brain-derived neural factor (BDNF), which is critical for the synergy between exercise, health, and fitness, as evaluated by enzyme-linked immunosorbent assay[15].

This article emphasizes the importance of growth-related factors such as BDNF, IGF-1, and VEGF. These chemicals are critical in improving cognitive functions in older adults through physical activity, with BDNF and IGF-1 supporting neuron survival and growth while facilitating synaptic plasticity, which aids in the formation and fortification of synapses. VEGF is essential for ensuring activated neurons receive sufficient oxygen and nutrients to meet their metabolic requirements[15]. There is significant evidence that exercise increases growth factors in older persons. Dinoff et al.[16] did a meta-analysis of 29 studies on aerobic exercise (AE) and resistance training (RE) with 910 participants from various age groups. Regardless of the type of exercise, the findings showed an increase in BDNF levels following physical activity. Another meta-analysis of AE and RE in healthy people found that aerobic exercise significantly increased peripheral BDNF levels. In a study of older adults with mild cognitive impairment (MCI), intensive aerobic exercise dramatically increased blood levels of BDNF and IGF-1. In contrast, acute resistance exercises produced relatively moderate increases. A 2014 study of 49 sedentary women found that after 16 weeks of aerobic, resistance, and motor exercises, including twice-daily cardiovascular and resistance training, blood BDNF levels and verbal language processing speeds improved compared to those on the waitlist[17,18]. Furthermore, an RCT involving a moderate-intensity AE program for 90 older participants over a year discovered a strong association between age and blood BDNF levels, notably in persons over 65, who saw the most significant rise in BDNF following exercise[19].

Another RCT among older adults with MCI found that women improved on executive functioning tests. However, plasma BDNF levels decreased after a six-month intense aerobic training program. In contrast, the study discovered that males had greater levels of IGF-1 in their plasma and performed significantly better in executive function tests[20]. Another year-long randomized controlled trial incorporating walking and stretching exercises among healthy seniors reported no significant variations between groups in BDNF, IGF-1, and VEGF blood concentrations. On the other hand, individuals who walked had higher growth factors, which might be linked to more robust functional connectivity between their middle and para-hippocampal gyrus, as seen using functional magnetic resonance imaging[21]. To appropriately analyze the impact of exercise on growth factors in the elderly and how it links to a rise in these markers and cognitive capacities in this cohort, high-quality RCTs and meta-analyses that focus on measurement concerns are required.

## *The Effect of Exercise on Inflammation*

In the elderly, pro-inflammatory signals are activated by microglia, cytokines, and other inflammatory factors. These signals can alter blood artery permeability and endothelial cell function, contributing to neurodegeneration[22]. Ongoing or acute inflammation can produce reactive oxygen molecules, neurotoxic chemicals, and other harmful neurotoxins, all deleterious impacts on brain health[23]. Notably, the human hippocampus and basal ganglia contain more significant levels of inflammation-associated enzymes than other brain regions, rendering them more prone to inflammation-related damage[24]. Inflammatory indicators such as C-reactive protein, interleukin (IL)-6, IL-1 beta, and tumour necrosis factor-alpha tend to rise with age. This increase in inflammatory markers may be associated with diminished cognitive abilities[21]. Chronic illnesses such as atherosclerosis, type 2 diabetes, multiple sclerosis, and dementia frequently show high levels of inflammation, emphasizing its importance to health[25]. According to research, increased levels of inflammation are associated with smaller hippocampi and medial temporal lobes in older adults and people with type 2 diabetes. A study of 3,298 older adults found that after adjusting for education level, age, and cardiovascular risk factors, serum IL-6 levels were inversely associated with Mini-Mental State Examination scores, implying that increased inflammation directly impacts cognitive functions[26]. Meanwhile, a study of 331 healthy older people found that individuals with the highest levels of IL-6 and CRP were at a higher risk of cognitive impairment than their less active counterparts[27]. Positive results from 13 Randomized Controlled Trials (RCTs) show that resistance and aerobic activities can lower inflammatory markers in inactive people of all ages[28]. Furthermore, research of senior people who engaged in sixteen weeks of aerobic, neuromotor, and strength workouts found that the exercising group had significantly lower TNF and IL-6 levels and higher peripheral brain-derived neurotrophic factors than the non-exercisers[29].

Subsequent analyses have shown frequent exercisers with mild cognitive impairment (MCI) demonstrated significantly enhanced executive functioning and attention levels[30]. Aerobic exercise (AE) could trigger the release of anti-inflammatory agents that reduce the activity of pro-inflammatory cytokines in older individuals[31]. There is evidence suggesting aerobic exercise could positively affect cognitive functions. Recent studies have also found aerobic exercise helpful in lowering inflammation markers in the elderly population—a factor long known to affect cognition directly. However, the specific effects of exercise-induced changes in inflammation on cognition among seniors remain largely unexplored. As such, forthcoming studies aim to delve into these pathways to understand better how exercise influences cognition through its impact on inflammation markers[32]. While the current data underlines the potential benefits of aerobic exercise in reducing inflammation markers, future investigations are poised to elucidate the intricate interplay between exercise's effects on inflammation and cognitive functions in ageing individuals, particularly those impacted by exercise-related cognitive concerns.

## *The Transformative Power of Exercise on the Hypothalamic-Pituitary-Adrenal Axis for Boosting Cognitive Function*

Exercise also improves cognitive function by influencing the HPA axis. The Hypothalamic-Pituitary-Adrenal (HPA) axis is an essential neuroendocrine system that controls the body's stress response. It affects cognition by secreting stress chemicals, particularly cortisol33. Individuals' ability to cope with stress decreases as they age. High-stress levels can overwhelm the HPA Axis, reducing cognitive performance. Long-term stress can impair sugar tolerance as well as neuroendocrine and autonomic functions[34,35]. Furthermore, a review of 51 research studies, including over 2,486 participants from various life stages, revealed that stressful experiences strain working memory and the ability to manage thoughts[36]. According to both cross-sectional and longitudinal research, people who have stress-related chronic illnesses are 2.7% more likely to be diagnosed with Alzheimer's disease[37]. A link exists between greater cortisol levels and diminishing cognitive capacities in older people[38]. However, comprehensive research on 52 seniors found that. In contrast, elevated cortisol levels are associated with a gradual cognitive decline in those with mild cognitive impairment (MCI); this is not the case for people with normal cognitive functions[39]. Regular exercise can lower stress responses in people of all ages by modulating catecholamine and cortisol levels[37]. It also activates the HPA axis and increases tissue sensitivity to glucocorticoids, which helps to reduce muscular inflammation and cytokine production, hence reducing overall inflammation[40]. Mental and physical activities diminish activity in the sympathetic nervous system and the HPA axis[41]. A review of 25 Randomized Controlled Trials in patients with chronic illnesses found that yoga practitioners had significantly better sympathetic nervous system function and HPA axis regulation (measured by cortisol levels, heart rate, and blood pressure) than control groups. However, this review only included those over the age of 50[42].

A meta-analysis encompassing 40 studies mainly involving elderly subjects revealed that practising Tai Chi was effective in ameliorating symptoms of anxiety and depression[43]. Conversely, an observational study, which included 42 middle-aged and elderly individuals, demonstrated that mental health benefits were significantly superior to aerobic exercise alone[44]. The positive effects of body-mind coordination exercises such as Tai Chi and yoga on improving cognitive performance in seniors have also been highlighted through meta-analysis[45-46]. Additionally, an experimental study engaging over 118 seniors in an eight-week yoga program found that participants exhibited improved executive function and lower cortisol responses than those who did not participate[44]. Research indicates that leveraging the HPA axis could significantly enhance cognitive functions. However, the effectiveness of the HPA Axis as a facilitator for cognitive improvement in older adults still needs to be examined[47]. Engaging in mind-body exercises has shown promise in boosting cognitive abilities in seniors by mitigating anxiety and reinstating balance within the parasympathetic nervous system, among additional mechanisms. Therefore, there is a pressing need for randomized controlled trials (RCTs) and a meta-analysis of the acquired data to verify the relationship between mental exercises, HPA axis imbalances, cognition in the elderly, and the efficacy of this particular treatment approach.

### *Recommendations for Enhancing Cognitive Function in Elderly Individuals*

Moderate-intensity exercise affects brain functions and cognitive capacities, including memory, attention, and executive control. The ACSM Guidelines (2009) recommend a minimum of 150 minutes of moderate aerobic activity per week (30 minutes, five days a week) or 60 minutes of severe aerobic exercise (20 minutes, three days a week). Over time, participating in resistance training programs has resulted in gains in cognitive function, particularly executive skills[48]. The American College of Sports Medicine recommends that older persons incorporate resistance workouts targeting the major muscle groups into their weekly regimens twice.

Much of the research on the cognitive benefits of exercise has primarily focused on aerobic or strength training programs. Comparatively, there needs to be more investigation into the effects of multicomponent exercise regimes. Tai Chi represents such a multicomponent exercise that may enhance the link between physical activity and cognitive function in elderly populations. Nonetheless, the current body of evidence remains sparse, necessitating further studies to dissect the exercise specifics and their effectiveness on different cognitive domains[50]. Beyond its physical aspects, Tai Chi encompasses activities that engage multiple cognitive functions. Results from a study that measured cognitive functions against reported participation in Tai Chi and aerobic exercises revealed that seniors engaging in both exercise types exhibited superior memory performance compared to their counterparts who were involved in only one type of exercise or none at all[51]. While the bulk of research has focused on aerobic endurance (AE), growing evidence supports resistance exercises (RE) and mind-body practices, such as Tai Chi or yoga, in boosting cognitive performance in older adults. Studies have even reported enhanced outcomes from a combination of these exercises. A meta-analysis conducted by Colcombe and Kramer, which reviewed 18 randomized controlled trials among inactive older participants, concluded that integrating RE with AE yielded more significant cognitive benefits than engaging in AE alone or avoiding exercise altogether[49].

Barha and their team reported similar outcomes in their meta-analysis on healthy adults engaging in two different exercise modalities. Both modalities enhanced overall cognitive performance and episodic memory more than resistance exercise (RE) alone[45]. Future studies could delve into the cognitive effects of various exercise forms on older individuals, such as eccentric and concentric movements of lower and upper limbs, exercises both on land and in water, repetitive exercising that includes aquatic exercises, resistance exercises, plyometric workouts, and exercises aimed at improving motor skills like balance, agility, and proprioceptive training. In a related study, Northey and colleagues reviewed 36 RCTs through meta-analysis. They found that moderate to vigorous exercise, irrespective of the type, significantly benefitted cognitive performance in older adults, though the effects were modest[51].

## Conclusion

This review assesses the body of research focused on the impact of physical activity on cognitive abilities, highlighting the fundamental biological mechanisms that may be involved. Studies have illustrated that engaging in physical activities, particularly those that incorporate multiple modes and involve mental engagement, can improve cognitive functions in the elderly. However, the evidence has notable limitations, such as a limited number of studies exploring factors that might influence cognitive outcomes in older adults and a call for more rigorous research in this domain. Further studies are needed to understand better the specific details regarding exercise regimens, types of activities, and the most beneficial environments for supporting cognitive health in this demographic.

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## References

1. Yoshino N, Kim CJ, Sirivunnabood P. Aging population and its impacts on fiscal sustainability. Ageing Societies. 2019 Mar 15.
2. Chiaranai C, Chularee S, Srithongluang S. Older people with chronic illness. Geriatric Nursing. 2018 Sep 1;39(5):513-20.
3. Cipriani G, Danti S, Picchi L, Nuti A, Fiorino MD. Daily functioning and dementia. Dementia & neuropsychologia. 2020 Jun 12;14:93-102.
4. Shirai K, Iso H. Dementia. Social Determinants of Health in Non-communicable Diseases: Case Studies from Japan. 2020:105-23.
5. Bivona G, Iemmolo M, Ghersi G. Cerebrospinal and Blood Biomarkers in Alzheimer's Disease: Did Mild Cognitive Impairment Definition Affect Their Clinical Usefulness? International Journal of Molecular Sciences. 2023 Nov 29;24(23):16908.
6. Alzheimer's Association. 2018 Alzheimer's disease facts and figures. Alzheimer's & Dementia. 2018 Mar 1;14(3):367-429.
7. Li J, Herold F, Ludyga S, Yu Q, Zhang X, Zou L. The acute effects of physical exercise breaks on cognitive function during prolonged sitting: The first quantitative evidence. Complementary Therapies in Clinical Practice. 2022 Aug 1;48:101594.
8. Harris TC, De Rooij R, Kuhl E. The shrinking brain: cerebral atrophy following traumatic brain injury. Annals of biomedical engineering. 2019 Sep 15;47:1941-59.
9. Chang YK, Nien YH, Tsai CL, Etnier JL. Physical activity and cognition in older adults: the potential of Tai Chi Chuan. *J Aging Phys Act.* 2010;18(4):451–472.
10. Walsh JN, Manor B, Hausdorff J, Novak V, Lipsitz L, Gow B, Macklin EA, Peng CK, Wayne PM. Impact of short-and long-term tai chi mind-body exercise training on cognitive function in healthy adults: results from a hybrid observational study and randomized trial. Global advances in health and medicine. 2015 Jul;4(4):38-48.

11. Qiu Y, Fernández-García B, Lehmann HI, Li G, Kroemer G, López-Otín C, Xiao J. Exercise sustains the hallmarks of health—Journal of sport and health science. 2023 Jan 1;12(1):8-35.
12. Yang GY, Sabag A, Hao WL, Zhang LN, Jia MX, Dai N, Zhang H, Ayati Z, Cheng YJ, Zhang CH, Zhang XW. Tai Chi for health and well-being: A bibliometric analysis of published clinical studies between 2010 and 2020. Complementary therapies in medicine. 2021 Aug 1;60:102748.
13. Uysal G, Ozturk M. Hippocampal atrophy based Alzheimer's disease diagnosis via machine learning methods. Journal of Neuroscience Methods. 2020 May 1;337:108669. .
14. Jaberi S, Fahnestock M. Mechanisms of the Beneficial Effects of Exercise on Brain-Derived Neurotrophic Factor Expression in Alzheimer's Disease. Biomolecules. 2023 Oct 26;13(11):1577.
15. Zhou B, Wang Z, Zhu L, Huang G, Li B, Chen C, Huang J, Ma F, Liu TC. Effects of different physical activities on brain-derived neurotrophic factor: A systematic review and Bayesian network meta-analysis. Frontiers in Aging Neuroscience. 2022 Aug 26;14:981002.
16. Dinoff A, Herrmann N, Swardfager W, Liu CS, Sherman C, Chan S, Lanctot KL. The effect of exercise training on resting concentrations of peripheral brain-derived neurotrophic factor (BDNF): a meta-analysis. PloS one. 2016 Sep 22;11(9):e0163037.
17. Quigley A, MacKay-Lyons M, Eskes G. Effects of Exercise on cognitive performance in older adults: a narrative review of the evidence, possible biological mechanisms, and recommendations for exercise prescription. Journal of aging research. 2020 May 14, 2020.
18. Górna S, Domaszewska K. The effect of endurance training on serum BDNF levels in the chronic Post-Stroke Phase: Current evidence and qualitative systematic review. Journal of Clinical Medicine. 2022 Jun 20;11(12):3556.
19. Anderson-Hanley C, Barcelos NM, Zimmerman EA, Gillen RW, Dunnam M, Cohen BD, Yerokhin V, Miller KE, Hayes DJ, Arciero PJ, Maloney M. The aerobic and cognitive exercise study (ACES) for community-dwelling older adults with or at-risk for mild cognitive impairment (MCI): neuropsychological, neurobiological and neuroimaging outcomes of a randomized clinical trial. Frontiers in ageing neuroscience. 2018 May 4;10:76.
20. Liu Y, Yan T, Chu JM, Chen Y, Dunnett S, Ho YS, Wong GT, Chang RC. The beneficial effects of physical Exercise in the brain and related pathophysiological mechanisms in neurodegenerative diseases. Laboratory Investigation. 2019 Jul 1;99(7):943-57.
21. Harris TC, De Rooij R, Kuhl E. The shrinking brain: cerebral atrophy following traumatic brain injury. Annals of biomedical engineering. 2019 Sep 15;47:1941-59.
22. Teleanu DM, Niculescu AG, Lungu II, Radu CI, Vladâcenco O, Roza E, Costăchescu B, Grumezescu AM, Teleanu RI. An overview of oxidative stress, neuroinflammation, and neurodegenerative diseases. International journal of molecular sciences. 2022 May 25;23(11):5938.
23. Skaper SD, Facci L, Zusso M, Giusti P. An inflammation-centric view of neurological disease: beyond the neuron. Frontiers in cellular neuroscience. 2018 Mar 21;12:72.

24. Furman D, Campisi J, Verdin E, Carrera-Bastos P, Targ S, Franceschi C, Ferrucci L, Gilroy DW, Fasano A, Miller GW, Miller AH. Chronic inflammation in the aetiology of disease across the life span. Nature medicine. 2019 Dec;25(12):1822-32.
25. Bettcher BM, Wilheim R, Rigby T, Green R, Miller JW, Racine CA, Yaffe K, Miller BL, Kramer JH. C-reactive protein is related to memory and medial temporal brain volume in older adults—brain, behaviour, and immunity. 2012 Jan 1;26(1):103-8.
26. Boccardi V, Baroni M, Cecchetti R, Scamosci M, Bastiani P, Mecocci P. Serum interleukin-6 levels are higher in older subjects with Alzheimer's dementia. Geriatric Care. 2021 Feb 19;7(1).
27. Cronin O, Keohane DM, Molloy MG, Shanahan F. The effect of exercise interventions on inflammatory biomarkers in healthy, physically inactive subjects: a systematic review. QJM: An International Journal of Medicine. 2017 Oct 1;110(10):629-37.
28. Manuela Crispim Nascimento C, Rodrigues Pereira J, Pires de Andrade L, Garuffi M, Leme Talib L, Vicente Forlenza O, Maria Cancela J, Regina Cominetti M, Stella F. Physical Exercise in MCI elderly promotes reduction of pro-inflammatory cytokines and improvements on cognition and BDNF peripheral levels. Current Alzheimer Research. 2014 Oct 1;11(8):799-805.
29. Tsuk S, Netz Y, Dunsky A, Zeev A, Carasso R, Dwolatzky T, Salem R, Behar S, Rotstein A. The acute effect of Exercise on executive function and attention: resistance versus aerobic Exercise. Advances in cognitive psychology. 2019;15(3):208.
30. Angulo J, El Assar M, Álvarez-Bustos A, Rodríguez-Mañas L. Physical activity and Exercise: Strategies to manage frailty. Redox biology. 2020 Aug 1;35:101513.
31. Stamou MI, Colling C, Dichtel LE. Adrenal ageing and its effects on the stress response and immunosenescence. Maturitas. 2023 Feb 1;168:13-9.
32. Shields GS, Sazma MA, Yonelinas AP. The effects of acute stress on core executive functions: A meta-analysis and comparison with cortisol. Neuroscience & Biobehavioral Reviews. 2016 Sep 1;68:651-68.
33. Wilson RS, Arnold SE, Schneider JA, Kelly JF, Tang Y, Bennett DA. Chronic psychological distress and risk of Alzheimer’s disease in old age. Neuroepidemiology. 2006 Oct 27;27(3):143-53.
34. Ouanes S, Popp J. High cortisol and the risk of dementia and Alzheimer's disease: a literature review. Frontiers in ageing neuroscience. 2019 Mar 1;11:43.
35. Tortosa-Martínez J, Manchado C, Cortell-Tormo JM, Chulvi-Medrano I. Exercise, the diurnal cortisol cycle and cognitive impairment in older adults. Neurobiology of stress. 2018 Nov 1;9:40-7.
36. JAWWAD G, ANJUM AF, RASUL A, ARSHAD S, IFTIKHAR M, RIZVI A, LALIQUE T. Role of Exercise in modulating neuroendocrine response to psychological stress. Age (years). 2021;30:6.
37. Ross A, Thomas S. The health benefits of yoga and Exercise: a review of comparison studies. The journal of alternative and complementary medicine. 2010 Jan 1;16(1):3-12.
38. Corazza DI, Sebastião É, Pedroso RV, Andreatto CA, de Melo Coelho FG, Gobbi S, Teodorov E, Santos-Galduróz RF. Influence of chronic Exercise on serum cortisol levels in older adults. European Review of Aging and Physical Activity. 2014 Apr;11(1):25-34.

39. Wang C, Bannuru R, Ramel J, Kupelnick B, Scott T, Schmid CH. Tai Chi on psychological well-being: systematic review and meta-analysis. BMC complementary and alternative medicine. 2010 Dec;10(1):1-6.
40. Siddarth D, Siddarth P, Lavretsky H. An observational study of the health benefits of yoga or tai chi compared with aerobic Exercise in community-dwelling middle-aged and older adults. The American journal of geriatric psychiatry. 2014 Mar 1;22(3):272-3.
41. Sanders LM, Hortobagyi T, la Bastide-van Gemert S, van der Zee EA, van Heuvelen MJ. Dose-response relationship between Exercise and cognitive function in older adults with and without cognitive impairment: a systematic review and meta-analysis. PloS one. 2019 Jan 10;14(1):e0210036.
42. Smith PJ, Blumenthal JA, Hoffman BM, Cooper H, Strauman TA, Welsh-Bohmer K, Browndyke JN, Sherwood A. Aerobic exercise and neurocognitive performance: a meta-analytic review of randomized controlled trials. Psychosomatic medicine. 2010 Apr;72(3):239.
43. Wayne PM, Walsh JN, Taylor-Piliae RE, Wells RE, Papp KV, Donovan NJ, Yeh GY. Effect of Tai Chi on cognitive performance in older adults: Systematic review and meta-analysis. Journal of the American Geriatrics Society. 2014 Jan;62(1):25-39.
44. Gothe NP, Keswani RK, McAuley E. Yoga practice improves executive function by attenuating stress levels. Biological psychology. 2016 Dec 1;121:109-16.
45. Barha CK, Davis JC, Falck RS, Nagamatsu LS, Liu-Ambrose T. Sex differences in exercise efficacy to improve cognition: a systematic review and meta-analysis of randomized controlled trials in older humans. Frontiers in neuroendocrinology. 2017 Jul 1;46:71-85.
46. Wu C, Yi Q, Zheng X, Cui S, Chen B, Lu L, Tang C. Effects of mind-body exercises on cognitive function in older adults: A meta-analysis. Journal of the American Geriatrics Society. 2019 Apr;67(4):749-58.
47. Zhang Y, Li C, Zou L, Liu X, Song W. The effects of mind-body Exercise on cognitive performance in elderly: a systematic review and meta-analysis. International Journal of Environmental Research and Public Health. 2018 Dec;15(12):2791.
48. Sáez de Asteasu ML, Martínez-Velilla N, Zambom-Ferraresi F, Casas-Herrero Á, Cadore EL, Galbete A, Izquierdo M. Assessing the impact of physical Exercise on cognitive function in older medical patients during acute hospitalization: Secondary analysis of a randomized trial. PLoS medicine. 2019 Jul 5;16(7):e1002852.
49. Colcombe S, Kramer AF. Fitness effects on the cognitive function of older adults: a meta-analytic study. Psychological science. 2003 Mar;14(2):125-30.
50. Wang Y, Tian J, Yang Q. Tai Chi exercise improves working memory capacity and emotion regulation ability. Frontiers in Psychology. 2023 Feb 17;14:1047544.
51. Northey JM, Cherbuin N, Pumpa KL, Smee DJ, Rattray B. Exercise interventions for cognitive function in adults older than 50: a systematic review with meta-analysis. British journal of sports medicine. 2018 Feb 1;52(3):154-60.

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All the authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.